



# **T LEVEL**

*Technical Qualification in Science  
(Level 3)*

## **Specification**

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# Contents

<b>1</b>	<b>Introducing the Qualification</b>	<b>1</b>
	T Level Programme	1
	Understanding the Specification and Administrative Guide	1
	What is the Technical Qualification (TQ)?	1
	Technical Qualification and Outline Content	2
	Employer and Provider Panels	2
	Qualification Purpose	2
	Student Profile and Progression	3
<b>2</b>	<b>Qualification Summary and Structure</b>	<b>4</b>
	Summary	4
	Assessment Structure	6
	1. Core component	6
	2. Occupational Specialism component	6
	What does the qualification cover?	7
<b>3</b>	<b>Core Component</b>	<b>8</b>
	Content	12
	Scheme of assessment – Core component	48
	Core examinations	48
	Core Examination Assessment Objectives	52
	Employer Set Project	53
	Employer Set Project Assessment Objectives	54
	Resources for the delivery of the Core component content	55
<b>4</b>	<b>Occupational Specialisms</b>	<b>58</b>
	1. Laboratory Sciences	58
	Performance Outcome 1: Design and execute scientific tasks using scientific knowledge	58

Performance Outcome 2: Perform scientific techniques to collect experimental data adhering to regulatory and safety requirements	70
Performance Outcome 3: Review, interpret and present experimental data	92
Performance Outcome 4: Continuously review scientific tasks, suggesting and implementing improvements	97
Scheme of Assessment	107
Resources for the delivery of Occupational Specialism: Laboratory Sciences	109
<b>2. Food Sciences</b>	<b>110</b>
Content Summary	110
Performance Outcome 1: Perform appropriate activities to support the food supply chain complying with regulatory requirements	110
Performance Outcome 2: Develop new food and food related products to support the food supply chain	149
Performance Outcome 3: Identify and resolve issues in the food supply chain	162
Performance Outcome 4: Collect, analyse and interpret food production data	166
Scheme of Assessment	169
Resources for the delivery of Occupational Specialism: Supporting Food Sciences	171
<b>5 Command word taxonomy list</b>	<b>172</b>
Command word taxonomy list	172
<b>6 General Competency Frameworks for T Levels</b>	<b>174</b>
English, maths and digital competencies	174
General English competencies	174
General maths competencies	174
General digital competencies	176

# 1 Introducing the Qualification

## T Level Programme

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T Levels are two-year, Level 3 study programmes that follow the study of GCSEs and Technical Awards and offer an alternative to A Levels and Apprenticeships.

T Levels combine classroom theory, practical learning and a minimum 315 hours of industry placement with an employer. The work placement ensures students have real experience of the workplace.

Students also need to work towards the attainment of a minimum standard of English and maths, either GCSE grade 4 or above, or Level 2 Functional Skills.

T Level programmes are developed in collaboration with employers so that the content meets the needs of industry and prepares students for work. T Levels provide the knowledge and experience needed to progress to highly skilled employment, an apprenticeship or higher-level study, including university.

## Understanding the Specification and Administrative Guide

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This specification should be read in conjunction with the Administrative Guide for Delivery and Assessment. The specification contains all the information you need to teach the technical qualification including content and assessment details. The Admin Guide contains the information and references you need to register as a provider, register students and administer their results. It also contains grading information and information on resources.

## What is the Technical Qualification (TQ)?

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The *T Level Technical Qualification in Science* is the main classroom-based element of the T Level. Students will learn using a curriculum that has been shaped by industry experts.

During the two-year programme, students will acquire the core knowledge that underpins each industry, and they will develop occupationally specific skills that will allow them to enter skilled employment within a specific occupation.

# Technical Qualification and Outline Content

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The Outline Content for the *T Level Technical Qualification in Science* has been produced by T Level panels of employers, professional bodies and Providers. It is based on the Apprenticeship Standards.

Pearson has used the Outline Content to form the basis of the Technical Qualification specification. This includes:

- elaboration of the Outline Content to produce a specification that gives Providers an accurate interpretation of what needs to be taught and assessed
- enabling students to achieve threshold competence in relation to the Occupational Specialist components
- the integration of English, maths and digital competencies.

## Employer and Provider Panels

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Pearson engaged with employer and Provider panels throughout the development of the Technical Qualification.

Our engagement with experts during the development of the qualification ensures:

- the content gives students quality preparation to help them progress
- assessments are realistic and assess the knowledge and skills that are important to employers
- the technical qualification meets the needs of Providers.

Pearson is grateful to all university and further education lecturers, teachers, employers, professional body representatives and other individuals who have generously shared their time and expertise to help us develop these new qualifications.

## Qualification Purpose

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This Technical Qualification is for T Level students who are undertaking the *T Level in Science*. It is intended for students who want to progress to a career in the science sector.

The purpose of the *T Level Technical Qualification in Science* (Level 3) is to ensure students have the knowledge and skills needed to progress into highly skilled employment, an Apprenticeship or higher-level study, including university, within the specialist areas of Laboratory Science and Food Science.

At the end of the Technical Qualification, students are expected to demonstrate threshold competence, which means that they have gained the core knowledge and skills related to science and are well placed to develop full occupational competence with additional development and support once in employment in the science sector.

## Student Profile and Progression

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Students undertaking this Technical Qualification will be 16–19 years old and in full-time education.

The typical student has:

- a clear idea about the industry sector in which they wish to pursue a career.
- an idea of the type of job role they would like to explore as a career.

This Technical Qualification aligns to the Level 3 Apprenticeships in Laboratory Science, Laboratory technician/Skills England and Food industry technologist – Food development specialist, Food industry technologist – Food development specialist/Skills England or Food industry technologist – Food quality specialist, Food industry technologist – Food quality specialist/Skills England.

Job roles could include:

- Laboratory Research Scientist
- Biomedical Scientist
- Medical Laboratory Assistant
- Food Safety Analyst.

Alternatively, students could progress to a Level 5 Technician Scientist Apprenticeship depending on their skills or experience.

Where students may not have access to an Apprenticeship or would prefer a more academic route, they could progress to a relevant Higher National Certificate (HNC) or Higher National Diploma (HND) programmes or degree programmes such as Biomedical Science, Applied Science, Food Science/Nutrition, Agricultural Science or Environmental Science.

Students must check the entry requirements for each degree programme with the relevant higher education provider.

## 2 Qualification Summary and Structure

### Summary

Qualification title	T Level Technical Qualification in Science (Level 3)
Qualification number (QN)	610/7439/1
First teaching	September 2026
Total Guided Learning Hours (GLH)	1180 hours (520 hours core)
Total Qualification Time (TQT)	1700 hours (850 hours core)
Occupational Specialism(s)	<ul style="list-style-type: none"> <li>Laboratory Sciences (660GLH, 850TQT)</li> <li>Food Sciences (730GLH, 850TQT)</li> </ul>
Components and weighting	Core Paper 1 = 18.3% of core Core Paper 2 = 23.4% of core Core Paper 3 = 18.3% of core Core ESP = 40% of core Core Component = 50% of total Occupational specialism= 50% of total
Grading information	Core and Employer Set Project (ESP) components are graded A*–E or Unclassified. The Occupational Specialism (OS) components are graded Pass, Merit, Distinction or Unclassified. The overall grading is on a scale of Pass, Merit, Distinction, Distinction* or Unclassified.

<b>Qualification title</b>	<b>T Level Technical Qualification in Science (Level 3)</b>
Entry requirements	<p>There are no formal prior learning requirements. It is the Provider's responsibility to ensure students recruited have a reasonable expectation of success.</p> <p>Students are most likely to succeed if they have qualifications at Level 2 (for example, five GCSEs at grade 4 and above including English and maths or a vocational Tech Award pass at Level 2).</p> <p>Students may demonstrate the ability to succeed in various ways. For example, they may have relevant work experience or may have shown specific aptitude through diagnostic tests or other non-educational experience.</p>
Assessment	<ul style="list-style-type: none"> <li>• The core and ESP components are externally set and marked by Pearson.</li> <li>• The OS components are set by Pearson. These are marked by Pearson apart from practical Task 4.</li> </ul>

# Assessment Structure

The *T Level Technical Qualification in Science* has two mandatory components.

## 1. Core component

This component covers the underpinning knowledge, concepts and skills that support threshold competence in the Science industry.

The content for the Core component is provided in *Section 3*.

Assessment component	Assessment method	Duration	Marks	Weighting	Availability
Core Paper 1	Written examination	1 hour 20 minutes	55	18.3%	Summer/Autumn
Core Paper 2	Written examination	1 hour 45 minutes	70	23.4%	Summer/Autumn
Core Paper 3	Written examination	1 hour 20 minutes	55	18.3%	Summer/Autumn
Employer Set Project	Externally set project	14 hours 30 minutes	108	40%	Summer/Autumn

## 2. Occupational Specialism component

There are two Occupational Specialist components in this Technical Qualification.

These components cover the Occupational Specialist knowledge and skills required to demonstrate threshold competence for the specialism. The Occupational Specialism is assessed by a skills-related project that synoptically assesses the performance outcome skills and associated underpinning knowledge.

The content for the Occupational Specialist component is provided in *Section 4*.

Assessment component	Assessment method	Duration	Marks	Weighting	Availability
OS 1: Laboratory Sciences	Externally set project	22 hours	180	100%	March–May
OS 2: Food Sciences	Externally set project	24 hours 30 minutes	298	100%	March–May

# What does the qualification cover?

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Students learn about the following topics:

Core Biology concepts:

- Cells and tissues
- Biological molecules (carbohydrates, lipids and proteins)
- Enzyme and protein structure
- DNA and RNA
- Cell cycle
- Exchange, transport mechanisms and ecosystems
- Cellular respiration
- Pathogens (causative agents)
- Immunology.

Core Chemistry concepts:

- Materials and chemical properties
- Rates of reaction and energy changes
- Kinetic changes – rates of chemical reactions
- Acids/bases and chemical change
- Chemical analysis of substances
- Formulae and equations.

Core Physics concepts:

- Particles and radiation
- Electricity
- Magnetism and electromagnetism
- Waves
- Gas laws
- Pressure/fluid/viscosity
- Units and quantities.

The science sector (synoptic):

- Working in the science sector
- Good scientific practice.

# 3 Core Component

The content of the Core component has mapped the core skills to where there are opportunities to develop them. The competencies and skills are not expected to be developed at every point where they are mapped, but using this guidance tutors will embed them into teaching to prepare students for the assessments in the Core component.

The core skills are assessed through the Employer Set Project. The core skills for this Core component are as follows:

## **Core Skill 1 (CS1) – Project management**

### **Independently produce a well-structured and evidence-informed project plan.**

For this skill, students will:

- State the aim or hypothesis, identify variables, outline the method and equipment, provide a risk assessment and detail the data collection and quantitative analysis.
- List required resources, including equipment, materials, workspace and their availability, and adjust the plan to accommodate any limitations.
- Write a step-by-step method and detailed data plan incorporating quality checks such as repeated trials, control samples, verification that all equipment is functioning correctly, and the types of numerical data to be gathered (e.g., measurements, titration results, calibration-curve readings).
- Preparation of a risk assessment and definition of safety measures, demonstrating how health and safety protocols will be maintained throughout the process.

## **Core Skill 2 (CS2) – Researching**

### **Conduct a review of the selected science literature/sources and produce an evidence-informed literature report.**

For this skill, students will:

- Review appropriate sources on the chosen topic; evaluate each for relevance and reliability (consider the author's credentials, publications and potential biases), as well as, accuracy, data quality, peer review, statements; maintain clear, organised and structured notes throughout.
- Identify and evaluate the value of different types of information sources (including broadsheet newspapers, tabloid newspapers, academic journals, magazines, electronic library (e-library) and case studies) when researching and interpreting scientific information.
- Compare the perspectives of different sources; highlight areas of agreement, disagreement and any gaps; explain your reasoning for including or excluding each source.
- Communicate information effectively interpreting findings and draw evidence-based conclusions, incorporating scientific or technical terminology.

- Apply a single referencing style consistently for both in-text citations and the reference list, and ensure all notes, figures and data are properly linked to their original sources.

### **Core Skill 3 (CS3) – Working with others**

**Identify their role in relation to the wider team and meet their responsibilities by ensuring that the project is compliant with relevant requirements.**

For this skill, students will:

- Assign roles for practical tasks (e.g., lead, recorder, timekeeper, safety officer), agreeing on a shared method with checkpoints.
- Follow PPE requirements and risk controls; confirm everyone understands before starting; use a 'stop and check' if uncertain and report any hazards to the tutor.
- Peer-check all setups and calculations; calibrate and zero instruments collaboratively; standardise units, file names and data tables and maintain consistent numerical records.
- Distribute tasks fairly using a rota; swap roles if someone is overloaded; provide clear, respectful feedback; resolve minor issues promptly or escalate when necessary.
- Handle, label, store and dispose of materials collaboratively following the agreed SOP; doublecheck critical steps with two people signing or verifying.
- Reflect on teamwork by summarising role allocation, communication strategies, impact on accuracy and efficiency, challenges or successes, and improvements for future group work, while making experimental notes.

### **Core Skill 4 (CS4) – Creativity and innovation**

**Make creative, innovative improvements to scientific practice, processes and outcomes.**

For this skill students will:

- **Plan:** Identify an improvement area, suggest small, safe tweaks or tools (e.g., labels, templates, checklists), and prepare a simple contingency plan for likely changes.
- **Do:** Test the change with a small pilot, record results and communicate with others.
- **Check:** Compare outcomes with the original process, apply success criteria, and analyse results.
- **Act:** Decide as a team whether to adopt or document changes and set next steps.

## **Core Skill 5 (CS5) – Problem solving**

### **Solve a problem within a science context.**

For this skill, students will:

- Recognise and define problems clearly, using scientific context and evidence.
- Record results accurately in appropriate formats, such as tables, charts, digital tools or spreadsheets.
- Applying appropriate scientific and mathematical methods, including statistical techniques such as averages and standard deviation, and undertaking calculations relevant to experimental data.
- Analysing outcomes against success criteria, identifying strengths, weaknesses and anomalies in quantitative results.
- Suggest refinements or alternative approaches to improve reliability or effectiveness.

## **Core Skill (CS6) – Communication**

### **Provide results and recommendations (written and verbal) to customers/clients.**

For this skill, students will:

- Present results and recommendations in the required format (e.g., report, slides, poster) with a clear structure, plain language and correct terminology.
- Use clear visuals (tables, charts, diagrams) with labels and units; tailor the message to the audience; state limits and next steps; answer questions clearly.
- Use digital tools to enhance the presentation: include clear visuals (tables, charts, diagrams) with labels and units, tailor the message to the audience, state limits and next steps, and answer questions clearly.
- Deliver, clear and engaging presentation using appropriate technical and non-technical language for the audience; demonstrate effective tone of voice and body language, communicating a coherent message showing how the ideas meet the project brief, and responding appropriately to questions.

## **Core Skill 7 (CS7) – Reflective Evaluation**

**Provide results and recommendations (written and verbal) to customers/clients.**

For this skill, students will:

- Critically evaluate a literature report by accessing information coverage, source reliability and relevance, applying correct academic referencing, and using appropriate scientific language and terminology.
- Reflect on their work to make improvements. Apply relevant success criteria to check interpretation of evidence, judged what worked and why, and suggest clear improvements.
- Use simple tools: collect and analyse data carefully, use a reflection model (What? So what? Now what?) and make SMART improvement plans.
- Use and follow the templates, record results and observations clearly, work safely and independently, to write a short evaluation using evidence to explain what went well, what didn't, and improvements for next time (include one personal development action).

# Content

## Core Biology Concepts

Content area A1: Cells and tissues	
A1.1	<p><b>Students should be able to consider the similarities and differences in the structure and ultrastructure of prokaryotic and eukaryotic cells:</b></p> <p>A1.1.1 Eukaryotic cells (to include plant, fungi, protist and animal). A1.2.2 Prokaryotic cells (to include bacteria and Archaea).</p>
A1.2	<p><b>Students should be able to demonstrate and apply their knowledge and understanding of the ultrastructure of eukaryotic cells and the functions of the different cellular components found within eukaryotic cells, including:</b></p> <p>A1.2.1 Cell-surface membrane (phospholipid bilayer). A1.2.2 Nucleus containing:</p> <ul style="list-style-type: none"><li>• chromosomes (DNA associated with histone proteins)</li><li>• one or more nucleoli.</li></ul> <p>A1.2.3 Nucleolus (dense patch of RNA and site of transcription and site of making ribosomes and rRNAs). A1.2.4 Nuclear envelope. A1.2.5 Mitochondria. A1.2.6 Ribosomes (80s). A1.2.7 Rough endoplasmic reticulum (RER). A1.2.8 Smooth endoplasmic reticulum (SER). A1.2.9 Golgi apparatus and Golgi vesicles. A1.2.10 Lysosomes (membrane-bound organelles that contain hydrolytic enzymes). A1.2.11 Centrioles. A1.2.12 Chloroplasts (in plants and algae). A1.2.13 Cell wall (in plants, algae and fungi). A1.2.14 Large permanent vacuoles (in plants). A1.2.15 Cytoplasm and cytosol. A1.2.16 Cytoskeleton.</p>
A1.3	<p><b>Students should be able to consider the similarities and differences between plant and animal cells in relation to the presence of specific organelles and their function including:</b></p> <p>A1.3.1 Overall cell shape. A1.3.2 Presence of some common organelles. A1.3.3 Presence of different organelles for specialised functions.</p>

A1.4	<p><b>Students should understand the concept of eukaryotic cells becoming specialised in complex multi-cellular organisms to include:</b></p> <p>A1.4.1 Specialisation occurs through differentiation from stem cells</p> <ul style="list-style-type: none"> <li>• source and relative potency of embryonic stem cells</li> <li>• sources and relative potency of adult stem cells.</li> </ul> <p>A1.4.2 Examples of specialised cells and their functions to include:</p> <ul style="list-style-type: none"> <li>• erythrocytes</li> <li>• phagocytes (neutrophils and macrophages)</li> <li>• squamous and ciliated epithelial cells</li> <li>• sperm cells</li> <li>• egg cells</li> <li>• palisade cells</li> <li>• root hair cells.</li> </ul>
A1.5	<p><b>Students should be able to demonstrate and apply their knowledge and understanding of the ultrastructure of prokaryotic cells and how they differ from eukaryotic cells including:</b></p> <p>A1.5.1 Cytoplasm that lacks membrane-bound organelles.</p> <p>A1.5.2 Smaller ribosomes (70s).</p> <p>A1.5.3 No nucleus; instead, they have a single circular DNA molecule that is free in the cytoplasm and is not associated with histone proteins.</p> <p>A1.5.4 A cell wall that contains murein/peptidoglycan.</p> <p>A1.5.5 One or more plasmids.</p> <p>A1.5.6 A capsule surrounding the cell.</p> <p>A1.5.7 One or more simple flagella.</p> <p>A1.5.8 Pili – small hair-like projections for attachment and/or conjugation.</p>
A1.6	<p><b>Students should know the difference between magnification and resolution.</b></p>
A1.7	<p><b>Students should be able to calculate magnification from the size of the image and the size of the object using and manipulating the formula:</b></p> <p>A1.7.1 Magnification = size of image/size of object.</p>
A1.8	<p><b>Students should understand the principles and limitations of the following types of microscopes:</b></p> <p>A1.8.1 Light.</p> <p>A1.8.2 Transmission electron.</p> <p>A1.8.3 Scanning electron.</p> <p>A1.8.4 Confocal.</p> <p>A1.8.5 Dark ground.</p> <p>A1.8.6 Binocular.</p>

A1.9	<p><b>Students should understand how to use a light microscope, including:</b></p> <p>A1.9.1 Preparing slides using simple staining.</p> <p>A1.9.2 Preparing slides using differential staining (to include Gram staining).</p> <p>A1.9.3 Altering magnification and focus.</p> <p>A1.9.4 Using an eyepiece graticule and stage micrometre to calibrate a microscope and measure the size of specimens.</p> <p>A1.9.5 Cell counting, using a haemocytometer.</p>
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<b>Content area A2: Biological molecules (carbohydrates, lipids and proteins)</b>	
A2.1	<p><b>Students should understand the relationship between monomers and polymers:</b></p> <p>A2.1.1 Monomers are small units from which larger molecules are made.</p> <p>A2.1.2 Polymers are molecules made from a large number of monomers joined together.</p> <p>A2.1.3 Amino acids, monosaccharides and nucleotides are examples of monomers.</p> <p>A2.1.4 A condensation reaction joins two molecules together with the formation of a chemical bond and the elimination of a molecule of water.</p> <p>A2.1.5 A hydrolysis reaction breaks a chemical bond between two molecules and involves the addition of a water molecule.</p>
A2.2	<p><b>Students should understand the relationship between the structure, properties and functions of carbohydrates:</b></p> <p>A2.2.1 Carbohydrates are polymers made from monosaccharides. Starch and glycogen are energy stores, and cellulose is structural.</p> <p>A2.2.2 Monosaccharides are the monomer from which all larger carbohydrates are made. Used as respiratory substrates.</p> <p>A2.2.3 Monosaccharides are composed of carbon, hydrogen and oxygen.</p> <p>A2.2.4 Structure of glucose, galactose and fructose as examples of monosaccharides.</p> <p>A2.2.5 Structure of maltose, sucrose and lactose as examples of disaccharides.</p> <p>A2.2.6 A condensation reaction between two monosaccharides forms a glycosidic bond.</p> <p>A2.2.7 Polysaccharides are formed by the condensation of many glucose molecules.</p> <p>A2.2.8 The formation of 1, 4 and 1, 6 glycosidic bonds by condensation.</p> <p>A2.2.9 Glycogen and starch molecules (amylopectin and amylose) are formed by the condensation of <math>\alpha</math>-glucose.</p> <p>A2.2.10 Cellulose is formed by the condensation of <math>\beta</math>-glucose.</p> <p>A2.2.11 The basic structure and functions of glycogen, starch and cellulose.</p>

	A2.2.12 The relationship of structure to function of these substances in animal cells and plant cells.
A2.3	<p><b>Students should understand the relationship between the structure, properties and functions of lipids:</b></p> <p>A2.3.1 Lipids are not polymers because they do not consist of repeating monomer units.</p> <p>A2.3.2 Structure and function of lipids to include triglycerides and phospholipids.</p> <p>A2.3.3 Triglycerides (to include fats and oils) are formed by the condensation of one molecule of glycerol and three molecules of fatty acid.</p> <p>A2.3.4 A condensation reaction between glycerol and a fatty acid (RCOOH) forms an ester bond.</p> <p>A2.3.5 The R-group of a fatty acid is a long hydrocarbon chain which can either be saturated or unsaturated.</p> <p>A2.3.6 Phospholipids are formed by the condensation of one molecule of glycerol with two fatty acid molecules and one phosphate group.</p> <p>A2.3.7 Phospholipid is made up of two parts, a hydrophilic head and a hydrophobic tail. This molecular structure forms a bi-layer that is important for all membrane functions.</p> <p>A2.3.8 Lipids are generally insoluble in water.</p> <p>A2.3.9 Essential fatty acids are fats the body cannot produce and must be obtained through diet to include omega 3 (linolenic) and omega 6 (linoleic) fatty acids (no structural knowledge required).</p> <p>A2.3.10 The main role of phospholipids is in plasma membranes to provide flexibility and determine permeability.</p> <p>A2.3.11 Cholesterol is a lipid and is a crucial component in animal cell surface membranes to regulate fluidity of membrane and is also the basis for all steroid hormones.</p> <p>A2.3.12 Other roles of lipids include providing an energy store, insulation and protection.</p>
A2.4	<p><b>Students should understand the relationship between the structure, properties and functions of proteins:</b></p> <p>A2.4.1 Proteins are polymers of amino acids and play a key role in the body's structure and physiological functions.</p> <p>A2.4.2 Amino acids are the monomers from which all proteins are made.</p> <p>A2.4.3 All amino acids contain an amino group (NH<sub>2</sub>), a carboxyl group (COOH) and a side chain (R).</p> <p>A2.4.4 There are twenty amino acids involved in protein synthesis each differs by the side chain (R).</p> <p>A2.4.5 Nine of the 20 are essential amino acids that must be supplied through diet for adults.</p> <p>A2.4.6 Dipeptides are formed by the condensation of 2 amino acids forming a peptide bond.</p> <p>A2.4.7 Polypeptides are formed by the condensation of many amino acids.</p>

	<p>A2.4.8 The role of hydrogen bonds, ionic bonds and disulfide bridges (a covalent bond) in the structure and shape of proteins and their relation to R groups of the amino acid monomers.</p> <p>A2.4.9 The levels of protein structure to include primary, secondary, tertiary and quaternary structure and how these relate to protein property and function.</p> <p>A2.4.10 Structure and function of globular proteins to include enzymes, haemoglobin and insulin.</p> <p>A2.4.11 Structure and function of fibrous proteins to include collagen, keratin and elastin.</p>
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### Content area A3: Enzyme and protein structure

A3.1	<p><b>Students should understand how enzymes' mechanism of action allows them to catalyse a wide range of reactions, including:</b></p> <p>A3.1.1 Enzymes lower the activation energy of the intracellular and extracellular reaction they catalyse.</p> <p>A3.1.2 The lock and key model of enzyme action.</p> <p>A3.1.3 The induced-fit model of enzyme action.</p> <p>A3.1.4 Enzymes catalyse all metabolic reactions and reactions involved in making and maintaining body structures.</p>
A3.2	<p><b>Students should understand the properties of enzymes that are determined by their tertiary structure, including:</b></p> <p>A3.2.1 The 3D shape of the active site and its ability to combine with complementary-shaped substrate molecules to form enzyme-substrate complexes.</p> <p>A3.2.2 The specificity of enzymes.</p> <p>A3.2.3 The effects of the following factors on the rate of enzyme-controlled reactions:</p> <ul style="list-style-type: none"> <li>• temperature</li> <li>• pH</li> <li>• enzyme concentration</li> <li>• substrate concentration</li> <li>• concentration of competitive and of non-competitive inhibitors.</li> </ul> <p>A3.2.4 Compare the mechanisms of competitive and non-competitive inhibitors.</p>

### Content area A4: DNA and RNA

A4.1	<p><b>Students should understand the structures and functions of nucleic acid:</b></p> <p>A4.1.1 Deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) are important information-carrying molecules.</p> <p>A4.1.2 In all cells, DNA holds genetic information, and RNA transfers genetic information from DNA to the ribosomes.</p> <p>A4.1.3 Nucleotides are the monomers from which DNA and RNA are formed.</p>
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	<p>A4.1.4 Both DNA and RNA are polymers of nucleotides.</p> <p>A4.1.5 Each nucleotide in DNA is made up of a pentose sugar (deoxyribose), a phosphate group and a nitrogen-containing organic base.</p> <p>A4.1.6 The components of a DNA nucleotide are deoxyribose, a phosphate group and one of the organic bases adenine (A), cytosine (C), guanine (G) or thymine (T).</p> <p>A4.1.7 The components of an RNA nucleotide are ribose, a phosphate group and one of the organic bases adenine, cytosine, guanine or uracil (U).</p> <p>A4.1.8 A condensation reaction between 2 nucleotides forms a phosphodiester bond.</p> <p>A4.1.9 A DNA molecule is a double helix made up of 2 polynucleotide chains with a sugar-phosphate backbone. The 2 chains are held together by hydrogen bonds between complimentary base pairs.</p> <p>A4.1.10 An RNA molecule is a relatively short, single stranded polynucleotide chain.</p> <p>A4.1.11 mRNA transfers genetic information from DNA to the ribosomes where proteins are synthesised.</p> <p>A4.1.12 tRNA transfers specific amino acids to the ribosome during protein synthesis.</p> <p>A4.1.13 RNA combines with proteins to form ribosomes, the site of protein synthesis.</p>
A4.2	<p><b>Students should understand the function of complementary base pairing in forming the helical structure of DNA, during DNA replication and during protein synthesis:</b></p> <p>A4.2.1 Purines (A and G) contain two rings in their structure.</p> <p>A4.2.2 Pyrimidines (C, T and U) contain one ring in their structure.</p> <p>A4.2.3 A purine is always matched with a pyrimidine to maintain the consistent width of the double helix.</p> <p>A4.2.4 A bonds to T (and U) with 2 hydrogen bonds.</p> <p>A4.2.5 G bonds to C with 3 hydrogen bonds.</p>
A4.3	<p><b>Students should understand the process and stages of semi-conservative replication of DNA:</b></p> <p>A4.3.1 DNA is progressively unwound.</p> <p>A4.3.2 Breakage of the hydrogen bonds between complementary bases.</p> <p>A4.3.3 This leaves two chains with unpaired bases.</p> <p>A4.3.4 Each chain then acts as a template for the building of a new strand.</p> <p>A4.3.5 Role of DNA helicase and DNA polymerase in this process.</p>
A4.4	<p><b>Students should understand how the semi-conservative replication process ensures genetic continuity between generations of cells:</b></p> <p>A4.4.1 Semi-conservative – the result is two new identical DNA molecules each containing one old strand and one new strand.</p>

A4.5	<p><b>Students should understand the link between the semi-conservative replication process and variation:</b></p> <p>A4.5.1 A change in genetic material (spontaneous change in the DNA sequence) can lead to genetic variation.</p> <p>A4.5.2 Mutations can arise spontaneously during DNA replication and include base insertion, deletion and base substitution. Due to the degenerate nature of the genetic code, not all base substitutions cause a change in the sequence of encoded amino acids.</p>
A4.6	<p><b>Students should understand the difference between genetics and genomics:</b></p> <p>A4.6.1 Genetics focuses on the functioning and composition of single genes.</p> <p>A4.6.2 Genomics focuses on the entire genetic material of an organism (including coding and non-coding DNA).</p>
A4.7	<p><b>Students should understand the role of DNA bases in the production of amino acid chains, which form proteins, including:</b></p> <p>A4.7.1 A gene is a length of DNA that codes for one or more protein or that codes for an RNA molecule.</p> <p>A4.7.2 The sequence of bases in a gene determines the sequence of amino acids in a protein, or the sequence of RNA nucleotides in a piece of RNA.</p> <p>A4.7.3 A sequence of three DNA bases is known as a triplet. A complementary sequence of three bases on an mRNA molecule is called a codon with a complementary anticodon of three bases on tRNA.</p> <p>A4.7.4 The genetic code is universal, non-overlapping and degenerate, meaning that each amino acid can be coded for by more than one codon.</p> <p>A4.7.5 The sequence of bases within a gene specifies the sequence of amino acids that are linked together to form a polypeptide chain.</p>
A4.8	<p><b>Students should understand how the process of protein synthesis occurs:</b></p> <p>A4.8.1 Transcription of genes to include the role of RNA polymerase and mRNA.</p> <p>A4.8.2 In eukaryotes pre-mRNA is formed and then spliced – removal of introns (non-coding DNA) and joining of exons (coding DNA) to produce mature mRNA.</p> <p>A4.8.3 The nucleus as the site of transcription and splicing in eukaryotic cells and requirement that messenger mRNA can leave the nucleus through nuclear pores. Cytoplasm as the site of transcription in prokaryotic cells.</p> <p>A4.8.4 Translation of messenger mRNA, to include the role of transfer tRNA and ribosomal rRNA in the formation of a polypeptide chain.</p> <p>A4.8.5 Ribosomes as the site of translation in both eukaryotic (80s) and prokaryotic (70s) cells.</p>

<b>Content area A5: Cell cycle</b>	
A5.1	<p><b>Students should understand how the process of mitosis results in the formation of 2 genetically identical daughter cells:</b></p> <p>A5.1.1 Interphase: stage that always precedes mitosis when DNA and organelles are replicated.</p> <p>A5.1.2 G1 of interphase – growth and replication of organelles.</p> <p>A5.1.3 S phase – DNA replicated and in animal cells centrosome is duplicated.</p> <p>A5.1.4 G2 phase – more growth, protein synthesis, organelles made and cell prepares to divide.</p> <p>A5.1.5 Characteristics of each of the stages of mitosis, including the behaviour of chromosomes and the cellular structure at each stage:</p> <ul style="list-style-type: none"> <li>• prophase</li> <li>• metaphase</li> <li>• anaphase</li> <li>• telophase</li> <li>• cytokinesis.</li> </ul>
A5.2	<p><b>Students should understand how the process of meiosis, including phase 1 and phase 2, results in the formation of haploid gametes from diploid cells in the reproductive organs:</b></p> <p>A5.2.1 Meiosis takes place in the reproductive organs to form haploid gametes (cells that unite to form a new organism).</p> <p>A5.2.2 It is necessary to have haploid gametes to maintain a constant number of chromosomes from one generation to the next and to produce genetic variation within a population.</p> <p>A5.2.3 Meiosis involves 2 divisions (meiosis I and meiosis II), such that each diploid cell divides to produce 4 haploid gametes</p> <ul style="list-style-type: none"> <li>• meiosis I to include: prophase I, metaphase I, anaphase I and telophase I</li> <li>• meiosis II to include: prophase II, metaphase II, anaphase II and telophase II.</li> </ul> <p>A5.2.4 In meiosis I the chromosome number is halved and the process of ‘crossing over’ takes place.</p> <p>A5.2.5 Crossing over (or genetic recombination) is the process where homologous chromosomes pair up with each other and exchange different segments of genetic material to form a recombinant chromosome.</p> <p>A5.2.6 The process of crossing over, where genetic material is exchanged creates genetic variation.</p> <p>A5.2.7 Independent assortment of the homologous chromosomes along the metaphase plate during metaphase I.</p> <p>A5.2.8 The similarities and differences between meiosis II and mitosis.</p>

A5.3	<p><b>Students should understand the function of both mitosis and meiosis in nuclear division within eukaryotic cells:</b></p> <p>A5.3.1 Mitosis produces two daughter cells that are genetically identical to each other and to the parent cell. The daughter cells have the full complement of genetic information. They are diploid.</p> <p>A5.3.2 As cells produced by the process of mitosis are genetically identical, the production of new differentiated cells results in cells and tissues that perform the function they were intended to perform.</p> <p>A5.3.3 If cells are damaged or die, it is important that new cells produced have identical structure and function to the cells that have been lost. New cells replace damaged or dead ones from the division of undifferentiated stem cells by mitosis.</p> <p>A5.3.4 Meiosis occurs only in reproductive cells to ensure that the cells produced have half (haploid) number of chromosomes to ensure when gametes (for example, eggs and sperm) combine the resulting zygote (fertilised egg) has the correct number of chromosomes (diploid).</p> <p>A5.3.5 Crossing over at prophase I and independent assortment at metaphase I within daughter cells compared to the parent cells.</p>
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<b>Content area A6: Exchange, transport mechanisms and ecosystems</b>	
A6.1	<p><b>Students should understand that the surface area to volume ratio affects the process of exchange and gives rise to specialised systems:</b></p> <p>A6.1.1 The surface area must be large in comparison to the volume for efficient exchange.</p> <p>A6.1.2 Where the surface area is small compared to the volume, specialised exchange and transport mechanisms are required to maximise the rate of diffusion.</p> <p>A6.1.3 Additional factors, including diffusion distance, temperature and metabolic rate and concentration gradient.</p> <p>A6.1.4 The relationship between the size of an organism or structure and its surface area to volume ratio.</p>
A6.2	<p><b>Students should understand the principles of cellular exchange and the transport mechanisms which exist to facilitate this exchange:</b></p> <p>A6.2.1 The structure of the cell surface membrane with reference to the fluid mosaic model.</p> <p>A6.2.2 Components of the fluid mosaic model:</p> <ul style="list-style-type: none"> <li>• phospholipid bilayer</li> <li>• channel and carrier proteins</li> <li>• cholesterol</li> <li>• glycoproteins and glycolipids.</li> </ul> <p>A6.2.3 Passive transport through the cell surface membrane: diffusion, facilitated diffusion and osmosis.</p> <p>A6.2.4 Active transport through the cell surface membrane</p> <p>A6.2.5 Co-transport mechanisms.</p> <p>A6.2.6 Bulk transport: endocytosis and exocytosis.</p>

A6.3	<p><b>Students should understand the advantages of having specialised cells in relation to the rate of transport across internal and external membranes for the following:</b></p> <p>A6.3.1 Squamous epithelial cells of alveolar walls.</p> <p>A6.3.2 Microvilli on epithelial cells of villi.</p> <p>A6.3.3 Specialised root hair cells.</p>
A6.4	<p><b>Students should understand the relationships, interactions and processes in ecosystems</b></p> <p>A6.4.1 Ecology is the study of how living things interact with their environment.</p> <p>A6.4.2 Ecosystem: a biological community including plants, animals and microorganisms</p> <ul style="list-style-type: none"> <li>• biotic and abiotic factors within ecosystems</li> <li>• measuring abiotic factors including light, temperature, humidity, water, soil pH and their effect on plant growth habitats: the physical site where an organism or group of organisms live</li> <li>• populations: group of organisms of the same species</li> <li>• community: all the organisms or populations in an ecosystem</li> <li>• niche: role and position a species has within an ecosystem.</li> </ul> <p>A6.4.3 Processes within ecosystems, including:</p> <ul style="list-style-type: none"> <li>• transfer of biomass (energy) from producers and consumers through a food chain from one trophic level to the next</li> <li>• recycling nutrients, through the carbon and nitrogen cycle, as well as minerals and water, are recycled within ecosystems</li> <li>• decomposing bacteria and fungi break down dead organisms, which recycles minerals and nutrients</li> <li>• bioaccumulation: gradual accumulation of contaminants within an ecosystem and their effects.</li> </ul> <p>A6.4.4 Measuring the distribution and abundance of organisms in an ecosystem:</p> <ul style="list-style-type: none"> <li>• using sampling techniques including quadrats, a belted transect, and mark-release capture</li> <li>• calculating percentage cover or population density from these techniques.</li> </ul>

### Content area A7: Cellular respiration

A7.1	<p><b>Students should understand how respiration results in the breakdown of glucose to produce the energy-carrying molecule Adenosine Triphosphate (ATP):</b></p> <p>A7.1.1 Aerobic respiration – the chemical breakdown of substrate molecules (for example, glucose) in cells to release energy in the form of ATP when oxygen is present.</p> <p>A7.1.2 Overall reaction of glucose + oxygen → carbon dioxide + water (produces ATP) <math>C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O</math> (produces ATP).</p>
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	<p>A7.1.3 Role of the mitochondria as the site of oxygen-dependent stages of aerobic respiration.</p> <p>A7.1.4 Anaerobic respiration – the chemical breakdown of substrate molecules in cells to release energy in the form of ATP in the absence of oxygen.</p> <p>A7.1.5 Process of anaerobic respiration in animals: glucose → lactic acid (produces ATP)  <math>C_6H_{12}O_6 \rightarrow 2C_3H_6O_3</math>.</p> <p>A7.1.6 Process of anaerobic respiration in plants glucose → ethanol + carbon dioxide (produces ATP)  <math>C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2</math>.</p> <p>A7.1.7 Cytoplasm as the location for anaerobic respiration.</p>
A7.2	<p><b>Students should understand how ATP provides a source of energy for biological processes:</b></p> <p>A7.2.1 Adenosine-triphosphate (ATP) consists of an adenosine nucleotide and ribose sugar bonded to 3 phosphate groups in a row.</p> <p>A7.2.2 The bond between the phosphate groups in ATP are easily hydrolysed to form ADP and inorganic phosphate, with energy released in this reaction.</p> <p>A7.2.3 This reaction is catalysed by the enzyme ATPase.</p> <p>A7.2.4 <math>ATP + water = ADP + Pi</math> (energy released).</p>
A7.3	<p><b>Students should understand the comparative amounts of energy released by different respiratory substrates (lipids, proteins and carbohydrates) and from aerobic vs anaerobic respiration.</b></p> <p>A7.3.1 Lipids contain many more CH bonds so more energy is released per gram of mass than carbohydrates and proteins.</p> <p>A7.3.2 Lipids are broken down to short-chain fatty acids and then enter the Krebs cycle.</p> <p>A7.3.3 Proteins are typically only used as a respiratory substrate when glucose and lipid stores are depleted.</p> <p>A7.3.4 The relative importance of lipids, proteins and carbohydrates during rest and exercise.</p> <p>A7.3.5 Amino acids are deaminated, and the rest of the molecule can enter the Krebs cycle.</p> <p>A7.3.6 Net number of molecules of ATP produced in anaerobic respiration (2) vs aerobic respiration (30-32) and percentage calculations related to these numbers.</p>

<b>Content area A8: Pathogens</b>	
A8.1	<p><b>Students should understand the definition of a pathogen:</b></p> <p>A8.1.1 A biological agent that causes disease by damaging host tissues and/or by producing toxins.</p>
A8.2	<p><b>Students should understand different types of pathogens (causative agents) and the diseases they can cause:</b></p> <p>A8.2.1 Bacteria (including those causing chlamydia, gonorrhoea, tuberculosis):</p> <ul style="list-style-type: none"> <li>• use of antibiotics to kill bacteria</li> <li>• calculating the zone of inhibition, with a given radius and using area of circle = <math>\pi r^2</math>.</li> </ul> <p>A8.2.2 Viruses (including those causing common cold, mumps, measles and hepatitis A).</p> <p>A8.2.3 Fungi (including those causing yeast infection (thrush) and fungal sepsis).</p> <p>A8.2.4 Prions (including those causing Creutzfeldt-Jakob disease (CJD)).</p> <p>A8.2.5 Protists (including those causing malaria).</p> <p>A8.2.6 Parasites (including those causing toxoplasmosis).</p>
A8.3	<p><b>Students should understand the different ways in which pathogens (infecting agents) may enter the body:</b></p> <p>A8.3.1 Direct transmission:</p> <ul style="list-style-type: none"> <li>• physical contact with an infected person</li> <li>• unprotected sexual contact.</li> </ul> <p>A8.3.2 Indirect transmission:</p> <ul style="list-style-type: none"> <li>• vehicle transmission, including faecal-oral route and blood from inanimate objects</li> <li>• being bitten by an infected vector</li> <li>• airborne: pathogens (causative agents) are carried by dust or droplets in the air, can exist in the air for some time.</li> </ul>
A8.4	<p><b>Students should understand how infectious diseases can spread among populations and communities:</b></p> <p>A8.4.1 Inadequate sanitation (including lack of access to clean drinking water and inadequate sewage disposal).</p> <p>A8.4.2 Dense populations and social distancing.</p> <p>A8.4.3 Inadequate healthcare/infrastructure.</p> <p>A8.4.4 Lack of accessible health promotion information.</p>

<b>Content area A9: Immunology</b>	
A9.1	<p><b>Students should understand the nature of infection:</b></p> <p>A9.1.1 A microorganism replicating inside the body, resulting in disease.</p> <p>A9.1.2 Infecting agents are pathogens.</p> <p>A9.1.3 Infectious diseases are transmissible or communicable.</p>
A9.2	<p><b>Students should understand the role of phagocytes in the innate immune response, including:</b></p> <p>A9.2.1 Phagocytes are white blood cells involved in non-specific defence.</p> <p>A9.2.2 Neutrophils and macrophages carry out phagocytosis, engulfing and digesting pathogens.</p>
A9.3	<p><b>Students should understand immune response, the differences between cell-mediated immunity and antibody-mediated (humoral) immunity, including:</b></p> <p>A9.3.1 Cell-mediated response is associated with the action of T lymphocytes and does not involve the production of antibodies.</p> <ul style="list-style-type: none"> <li>• T lymphocytes recognise and destroy infected or abnormal body cells, including cancer or transplanted cells.</li> </ul> <p>A9.3.2 Antibody-mediated (humoral) response is associated with the action of B lymphocytes and the production of antibodies for a specific antigen.</p> <ul style="list-style-type: none"> <li>• B lymphocytes differentiate into plasma cells that secrete antibodies, which act in body fluids such as blood and lymph.</li> </ul>
A9.4	<p><b>Students should understand the primary and secondary immune response:</b></p> <p>A9.4.1 Primary response is the initial, slower response when an antigen is first encountered.</p> <p>A9.4.2 Role of T and B memory cells produced during the primary response.</p> <p>A9.4.3 Memory cells upon exposure to the same antigen enable a secondary response that is faster, stronger and longer-lasting, often preventing symptoms.</p>
A9.4	<p><b>Students should understand the different types of immunity:</b></p> <p>A9.4.1 Active immunity is the production of a person's own antibodies and memory cells as a result of their immune system being stimulated by an antigen.</p> <p>A9.4.2 Passive immunity is the introduction of pre-made antibodies from an external source.</p> <p>A9.4.3 Immunity can be natural (active or passive) or artificial (active or passive).</p>

## Core Chemistry concepts

Content area A10: Materials and chemical properties	
A10.1	<p><b>Students should understand the correct names for sub-atomic particles, their relative mass, charge and position in an atom:</b></p> <p>A10.1.1 Protons.</p> <p>A10.1.2 Neutrons.</p> <p>A10.1.3 Electrons.</p>
A10.2	<p><b>Students should understand atomic numbers, mass numbers, ions and isotopes:</b></p> <p>A10.2.1 Number of protons, neutrons and electrons in an atom – atomic number and mass number.</p> <p>A10.2.2 Number of protons, neutrons and electrons in an ion – atomic number, mass number and ionic charge.</p> <p>A10.2.3 Isotopes – atoms with the same atomic number (number of protons) but different mass number (number of neutrons).</p> <p>A10.2.4 Number of protons, neutrons and electrons in an isotope – atomic number, mass number and ionic charge.</p> <p>A10.2.5 Calculations involving isotopic abundance.</p> <p>A10.2.6 Define isotopes as atoms of the same element with different masses due to a different number of neutrons.</p> <p>A10.2.7 Relative isotopic mass is the mass of an atom of an isotope relative to 1/12 of the mass of a C<sub>12</sub> atom.</p>
A10.3	<p><b>Students should understand electron arrangements</b></p> <p>A10.3.1 Number of electrons in the first four quantum shells/ energy levels:</p> <p>A10.3.2 Atomic orbitals:</p> <ul style="list-style-type: none"> <li>• definition</li> <li>• s-, p- and d- orbitals</li> <li>• s- and p- orbital shape.</li> </ul> <p>A10.3.3 Electron configuration of atoms</p> <ul style="list-style-type: none"> <li>• sub-shell notation</li> <li>• s, p and d block locations on periodic table.</li> </ul> <p>A10.3.4 Filling of orbitals from 1s<sup>1</sup> to 4p<sup>6</sup></p> <ul style="list-style-type: none"> <li>• electrons in boxes diagram</li> <li>• Aufbau principle</li> <li>• Hunds rule</li> <li>• Pauli exclusion principle.</li> </ul>
A10.4	<p><b>Students should understand the relationship between the atomic structure and be able to recall physical and chemical properties of metals, including:</b></p> <p>A10.4.1 Metallic bonding:</p> <ul style="list-style-type: none"> <li>• giant metallic structure</li> <li>• regular arrangement of positive ions</li> </ul>

	<ul style="list-style-type: none"> <li>• sea of delocalised electrons</li> <li>• strong electrostatic forces of attraction between positive metal ions and delocalised electrons.</li> </ul> <p>A10.4.2 Physical properties:</p> <ul style="list-style-type: none"> <li>• group 1 alkali metals: <ul style="list-style-type: none"> <li>○ conductivity (electrical and thermal)</li> <li>○ malleability/ductility</li> <li>○ strength and density</li> </ul> </li> <li>• transition metals: <ul style="list-style-type: none"> <li>○ conductivity (electrical and thermal)</li> <li>○ malleability/ductility</li> <li>○ strength and density</li> <li>○ coloured compounds due to multiple oxidation number.</li> </ul> </li> </ul> <p>A10.4.3 Chemical properties:</p> <ul style="list-style-type: none"> <li>• group 1 alkali metals: <ul style="list-style-type: none"> <li>○ reactivity with water and the formation of alkaline solutions, including balanced equations</li> <li>○ reactivity with oxygen, including balanced equations</li> <li>○ reactivity in terms of electronic configurations</li> </ul> </li> <li>• transition metals: <ul style="list-style-type: none"> <li>○ reactivity with oxygen and acids, including balanced equations</li> <li>○ catalytic activity due to multiple oxidation number</li> </ul> </li> <li>• ionisation energy (<math>\text{kJ mol}^{-1}</math>) and its relationship to reactivity.</li> </ul> <p>A10.4.4 The difference in properties of group 1 metals compared with transition metals in terms of their melting points, densities, strength, hardness and reactivity with oxygen, chlorine and water.</p>
A10.5	<p><b>Students should understand ionic bonding:</b></p> <p>A10.5.1 Formation of ions owing to the gain or loss of electrons.</p> <p>A10.5.2 Strong electrostatic force of attraction between oppositely charged ions.</p> <p>A10.5.3 Effects of ionic radius and ionic charge on the strength of an ionic bond.</p> <p>A10.5.4 Drawing dot and cross diagrams of cations and anions.</p> <p>A10.5.5 Writing the formulae of ionic compounds when given the formulae of the constitute ions.</p> <p>A10.5.6 Properties of ionic compounds, including melting points and electrical conductivity (only when molten or in a solution).</p>
A10.6	<p><b>Students should understand the physical and chemical properties of non-metals, including:</b></p> <p>A10.6.1 Covalent bonding:</p> <ul style="list-style-type: none"> <li>• electrostatic attraction between the two nuclei and a shared pair of electrons</li> <li>• construction of dot and cross diagrams for simple covalent molecules, including single, double and triple covalent bonds</li> </ul>

	<ul style="list-style-type: none"> <li>giant covalent compounds including diamond, graphite, graphene and silicon dioxide.</li> </ul> <p>A10.6.2 Polymers (for example, high density (HD) and low density (LD) polyethene, thermosetting and thermosoftening polymers):</p> <ul style="list-style-type: none"> <li>structure of alkenes</li> <li>addition polymerisation of alkenes</li> <li>structure – long chain molecules with forces or bonds between chains to include intermolecular forces in thermosetting polymers and crosslinks in thermosetting polymers</li> <li>structure – identify a monomer that would produce a specific polymer, prediction of the structure of the resulting polymer from a given monomer</li> <li>properties – strong, chemically unreactive, electrical insulators.</li> </ul> <p>A10.6.3 How the properties of these materials are related to their uses, to include simple covalent molecules, polymers and giant covalent molecules.</p>
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<b>Content area A11: Rates of reaction and energy changes</b>	
A11.1	<p><b>Students should understand the principles of collision theory:</b></p> <p>A11.1.1 Particles must collide with enough energy to break and reform bonds (activation energy).</p> <p>A11.1.2 Particles must be in the correct spatial orientation.</p>
A11.2	<p><b>Students should understand the effect of temperature on rates of reaction:</b></p> <p>A11.2.1 An increase in temperature makes particles move faster (increased kinetic energy), resulting in increased frequency of collisions and a higher proportion of successful collisions increasing rates of reaction.</p> <p>A11.2.2 Lower temperatures result in decreased frequency of collisions and smaller proportion of successful collisions, decreasing rates of reaction.</p> <p>A11.2.3 The effect of changing temperature in terms of the Maxwell-Boltzmann distribution.</p>
A11.3	<p><b>Students should understand the definition of a catalyst and the role of catalysts in a reaction:</b></p> <p>A11.3.1 Catalysts are substances that increase the rate of a chemical reaction without themselves being permanently chemically changed.</p> <p>A11.3.2 The effect of catalysts in terms of Maxwell/Boltzmann distribution.</p>

<b>Content area A12: Kinetic changes – rates of chemical reactions</b>	
A12.1	<p><b>Students should understand a range of factors affecting the rates of chemical reactions:</b></p> <p>A12.1.1 Surface area. A12.1.2 Concentration. A12.1.3 Pressure.</p>
A12.2	<p><b>Students should understand how to calculate the rate of reaction from data or graphs:</b></p> <p>A12.2.1 Amount of reactant or product/time.</p>
A12.3	<p><b>Students should understand enthalpy changes:</b></p> <p>A12.3.1 Definition of enthalpy, H and enthalpy changes, <math>\Delta H</math>. A12.3.2 Conservation of energy</p> <ul style="list-style-type: none"> <li>energy transfers can be either an exothermic change or endothermic change.</li> </ul> <p>A12.3.3 Enthalpy changes including diagrams to show an exothermic or endothermic reaction:</p> <ul style="list-style-type: none"> <li>negative enthalpy change for an exothermic reaction</li> <li>positive enthalpy change for an endothermic reaction</li> <li>activation energy (<math>E_a</math>)</li> <li>effect of a catalyst on activation energy.</li> </ul>
A12.4	<p><b>Students should understand the advantages of using a catalyst in industrial reactions:</b></p> <p>A12.4.1 The increase in the rate of reaction gives a faster turnaround time and so reduces costs. A12.4.2 Reducing the activation.</p>
A12.5	<p><b>Students should understand reversible reactions:</b></p> <p>A12.5.1 Dynamic equilibrium:</p> <ul style="list-style-type: none"> <li>definition of a dynamic equilibrium</li> <li>conditions for a dynamic equilibrium.</li> </ul> <p>A12.5.2 Le Chatelier's principle:</p> <ul style="list-style-type: none"> <li>effects of changing concentration on equilibrium</li> <li>effects of changing temperature on equilibrium</li> <li>effects of changing pressure on equilibrium.</li> </ul>
A12.6	<p><b>Students should understand the importance of compromising between chemical equilibrium and reaction rate</b></p> <p>A12.6.1 Haber process:</p> <ul style="list-style-type: none"> <li>conditions</li> <li>economic effect of conditions.</li> </ul>

<b>Content area A13: Acids/bases and chemical change</b>	
A13.1	<p><b>Students should understand the concept of strong and weak acids:</b></p> <p>A13.1.1 Definition of an acid as a substance which releases H<sup>+</sup> ions in a solution.</p> <p>A13.1.2 Formulae for common strong and weak acids such as HCl, H<sub>2</sub>SO<sub>4</sub>, HNO<sub>3</sub>, CH<sub>3</sub>COOH.</p> <p>A13.1.3 The difference between a strong and weak acid and the associated pH values.</p> <p>A13.1.4 For a given concentration of aqueous solution, the stronger the acid, the lower the pH.</p> <p>A13.1.5 As the pH of an acid decreases by one unit, the hydrogen ion concentration of the solution increases by a factor of 10.</p>
A13.2	<p><b>Students should understand the chemical properties of acids:</b></p> <p>A13.2.1 Neutralise bases to form salt and water.</p> <p>A13.2.2 Neutralises bases to include:</p> <ul style="list-style-type: none"> <li>• metal oxides</li> <li>• metal carbonates</li> <li>• metal hydroxides.</li> </ul> <p>A13.2.3 React with metals to form hydrogen gas.</p> <p>A13.2.4 Naming and writing formulae of salts formed.</p> <p>A13.2.5 Word and balanced equations for the reactions listed in A13.2.2.</p>
A13.3	<p><b>Students should understand the principle and stages of acid-base titration, including the role of the following indicators in determining the endpoint:</b></p> <p>A13.3.1 Determining the volumes of acids and alkalis required for neutralisation to occur.</p> <p>A13.3.2 Phenolphthalein.</p> <p>A13.3.3 Methyl orange.</p>
A13.4	<p><b>Students should understand the relationship between the number of moles of solute and the volume in dm<sup>3</sup> of solvent as a measure of concentration (mol/dm<sup>3</sup>)</b></p> <p>A13.4.1 Recall that the number of moles = concentration in mol/dm<sup>3</sup> × volume in dm<sup>3</sup>.</p> <p>A13.4.2. Perform calculations using the number of moles, concentration and volume using given data.</p>
A13.5	<p><b>Students should understand oxidation numbers and redox reactions:</b></p> <p>A13.5.1 Oxidation numbers:</p> <ul style="list-style-type: none"> <li>• rules for elements</li> <li>• rules for compounds and ions</li> <li>• roman numerals</li> <li>• use oxidation numbers to write formulae.</li> </ul>

	<p>A13.5.2 Redox reactions:</p> <ul style="list-style-type: none"> <li>• describe oxidation and reduction in terms of electrons</li> <li>• write half equations for redox reactions between: <ul style="list-style-type: none"> <li>○ metals and acids</li> <li>○ metals and oxygen</li> <li>○ metals and water.</li> </ul> </li> </ul>
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<b>Content area A14: Chemical analysis of substances</b>	
A14.1	<p><b>Students should understand how chromatography can be used to separate substances due to their attraction to the mobile or stationary phase.</b></p>
A14.2	<p><b>Students should understand how to calculate and use the R<sub>f</sub> value to identify a substance:</b></p> <p>A14.2.1 The distance travelled by the substance divided by the distance travelled by the solvent.</p> <p>A14.2.2 The R<sub>f</sub> value should be the same if it is the same substance (under the same conditions).</p>
A14.3	<p><b>Students should understand the principles of the following techniques used to separate substances in order to detect or identify chemical composition:</b></p> <p>A14.3.1 Thin layer chromatography:</p> <ul style="list-style-type: none"> <li>• used to separate non-volatile mixtures based on their affinity for a mobile phase (solvent) or stationary phase (on a coated plate)</li> <li>• used to detect and identify the compounds and their purity.</li> </ul> <p>A14.3.2 Column chromatography:</p> <ul style="list-style-type: none"> <li>• used to separate a single chemical compound from a mixture (in a vertical column).</li> </ul> <p>A14.3.3 Gas chromatography:</p> <ul style="list-style-type: none"> <li>• used to separate and analyse compounds that can be vaporised (in a capillary or packed column)</li> <li>• used to quantify components in a mixture.</li> </ul> <p>A14.3.4 High-performance liquid chromatography:</p> <ul style="list-style-type: none"> <li>• used to separate substances based on their affinity for a mobile (pressurised solvent) or stationary phase (in a capillary or packed column)</li> <li>• used to quantify components in a mixture.</li> </ul> <p>A14.3.5 Mass spectrometry:</p> <ul style="list-style-type: none"> <li>• used to separate substances due to their mass-to-charge ratio and to identify molecular ions and ion fragments</li> <li>• used to identify the components of an unknown sample due to their molecular weights</li> <li>• used to quantify components in a mixture.</li> </ul>

A14.4	<p><b>Students should understand the following applications of chromatography in industry:</b></p> <p>A14.4.1 Forensic investigation (including, to detect the presence of substances like alcohol within human tissue).</p> <p>A14.4.2 Water analysis (including, to determine the presence of pesticides in rivers).</p>
A14.5	<p><b>Students should understand the following applications of chromatography and titration in industry:</b></p> <p>A14.5.1 Used in quality control (including testing food products for consistency).</p> <p>A14.5.2 Purity analysis (including, testing raw materials for the chemical industry).</p>

<b>Content area A15: Formulae and equations</b>	
A15.1	<p><b>Students should understand the concept of the mole:</b></p> <p>A15.1.1 Definition of the mole.</p> <p>A15.1.2 Use of Avogadro's constant in calculations.</p>
A15.2	<p><b>Students should understand the link between balanced equations and the ratio of moles of a substance in a reaction</b></p>
A15.3	<p><b>Students should be able to calculate quantities used in a chemical reaction:</b></p> <p>A15.3.1 Moles, mass and <math>M_r</math>, relative formula mass using values from the periodic table (number of moles = mass <math>\div</math> <math>M_r</math>).</p> <p>A15.3.2 Moles, concentration and volume (number of moles = concentration <math>\times</math> volume).</p> <p>A15.3.3 Empirical formula using given masses or percentage masses.</p> <p>A15.3.4 Reacting masses.</p> <p>A15.3.5 Percentage yield.</p> <p>A15.3.6 Atom economy and the benefits of high atom economy in industrial processes.</p> <p>A15.3.7 Converting between <math>\text{cm}^3</math> and <math>\text{dm}^3</math>.</p>

## Core Physics concepts

Content area A16: Particles and radiation	
A16.1	<p><b>Students should know the correct names for sub-atomic particles and understand their position in the nuclear model of the atom – protons, electrons and neutrons:</b></p> <p>A16.1.1 Protons – found in the nucleus.            A16.1.2 Neutrons – found in the nucleus.            A16.1.3 Electrons – found in orbitals around the nucleus.</p>
A16.2	<p><b>Students should understand the definitions of half-life and count-rate, and analyse data in relation to half-life, and that radioactive decay is a random process that can be predicted for large numbers of nuclei:</b></p> <p>A16.2.1 Half-life – the time taken for half the unstable nuclei in a sample to decay.            A16.2.2 Count-rate – the number of decays recorded each second.</p>
A16.3	<p><b>Students should understand how radiation interacts with matter:</b></p> <p>A16.3.1 Ionisation – by causing electrons to break apart from atoms or molecules.            A16.3.2 Excitation – by transferring energy from radiation or physical interaction to atoms or molecules.</p>
A16.4	<p><b>Students should understand the nature and properties of main types of radioactive decay in relation to unstable nuclei:</b></p> <p>A16.4.1 An alpha particle – consists of 2 neutrons and 2 protons and is equivalent to a helium nucleus, has a positive charge and a relative mass of 4.            A16.4.2 A beta particle – a high-speed electron ejected from the nucleus as a neutron turns into a proton, has a negative charge and a relative mass of approximately 1/2000.            A16.4.3 A gamma ray – electromagnetic radiation from the nucleus, has no charge and no mass.</p>
A16.5	<p><b>Students should understand the following types and properties of ionising radiation:</b></p> <p>A16.5.1 Alpha:</p> <ul style="list-style-type: none"> <li>• high ionising but low penetrating power</li> <li>• range is approximately 1 to 2 centimetres of air.</li> </ul> <p>A16.5.2 Beta:</p> <ul style="list-style-type: none"> <li>• medium ionising and penetrating power</li> <li>• range is approximately 15 centimetres of air.</li> </ul> <p>A16.5.3 Gamma:</p> <ul style="list-style-type: none"> <li>• low ionising and high penetrating power</li> <li>• range is many kilometres of air.</li> </ul>

A16.6	<p><b>Students should understand radioactivity and its application within the scientific, industrial and health sectors, including assessing the suitability of using different types of radiation:</b></p> <p>A16.6.1 Radioactive tracers.</p> <p>A16.6.2 Medical diagnostic applications.</p> <p>A16.6.3 Food preservation.</p> <p>A16.6.4 Dating deceased organisms.</p> <p>A16.6.5 Measuring the thickness of materials.</p>
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<b>Content A17: Electricity</b>	
A17.1	<p><b>Students should understand circuit diagrams and be able to interpret them for a range of scientific and industrial applications.</b></p> <p>A17.1.1 Symbols for the following components within circuit diagrams: bulb, filament lamp, switch, voltmeter, ammeter, potentiometer, capacitor, diode, photodiode, zener diode, LED, cell, battery, AC power supply, DC power supply, ground, fuse, resistor, variable resistor, light dependent resistor, thermistor, transformer, speaker, microphone, heater, motor, buzzer.</p>
A17.2	<p><b>Students should know the definitions of charge and current due to the movement of charged particles:</b></p> <p>A17.2.1 Current – the rate of flow of electric charge.</p> <p>A17.2.2 Charge – a fundamental property of matter that causes it to experience a force in an electric or magnetic field.</p>
A17.3	<p><b>Students should be able to calculate charge, current and time using the formula:</b></p> <p>A17.3.1 <math>Q = I t</math>.</p>
A17.4	<p><b>Students should know the definitions of potential difference and resistance:</b></p> <p>A17.4.1 Potential difference – a measure of the energy transferred per unit of electric charge between two points in an electrical circuit.</p> <p>A17.4.2 Resistance – the measure of how much a material opposes the flow of electric current.</p>
A17.5	<p><b>Students should be able to calculate potential difference, energy transferred and charge:</b></p> <p>A17.5.1 use of <math>V = \frac{E}{Q}</math>.</p>
A17.6	<p><b>Students should be able to calculate current, potential difference and resistance:</b></p> <p>A17.6.1 use of <math>R = \frac{V}{I}</math>.</p>
A17.7	<p><b>Students should understand Ohm's Law and its application in industrial electronic circuits:</b></p> <p>A17.7.1 Applications of Ohm's Law in electronic circuits.</p>

A17.8	<b>Students should understand Kirchhoff's Voltage Law and Kirchhoff's Current law and their application in series and parallel circuits.</b>
A17.9	<p><b>Students should be able to calculate the total resistance of multiple resistors in series and parallel circuits:</b></p> <p>A17.9.1 Series: the total resistance is equal to the sum of the individual resistors, <math>R_T = R_1 + R_2 + R_3</math>.</p> <p>A17.9.2 Parallel: <math>\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}</math>.</p>
A17.10	<b>Students should understand of the difference between alternating and direct current.</b>
A17.11	<p><b>Students should be able to calculate the root mean squared voltage and current and use this value in scientific and industrial applications.</b></p> <p>A17.11.1 Use the equation <math>V_{rms} = \frac{V_{peak}}{\sqrt{2}}</math>.</p>
A17.12	<b>Students should understand of scientific and industrial scenarios where alternating or direct current are used.</b>
A17.13	<p><b>Students should understand the following properties of mains electricity in the United Kingdom:</b></p> <p>A17.13.1 Alternating current.</p> <p>A17.13.2 Potential difference ensures electricity is supplied to residences and most businesses at 230 volts.</p> <p>A17.13.3 Generated at a frequency of 50 Hz.</p>
A17.14	<p><b>Students should understand the following methods of manipulating mains electricity:</b></p> <p>A17.14.1 Simple rectifier circuits to convert AC to DC.</p> <p>A17.14.2 Transformers (including switch-mode transformers) to change the voltage of an AC supply.</p>

### Content area A18: Magnetism and electromagnetism

A18.1	<p><b>Students should understand magnetism and magnetic poles and their application in scientific and industrial processes:</b></p> <p>A18.1.1 The north and south magnetic poles are where the magnetic forces are strongest.</p> <p>A18.1.2 Attraction/repulsion of magnets in close proximity – attraction and repulsion between magnetic poles are examples of non-contact forces.</p> <p>A18.1.3 The difference between permanent and induced magnets.</p> <p>A18.1.4 The uses of permanent and temporary magnetic materials, including iron, steel, cobalt, nickel.</p>
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A18.2	<p><b>Students should understand magnetic fields:</b></p> <p>A18.2.1 The shape and direction of the magnetic field around magnets, and the relationship between the strength of the field and concentration of field lines.</p> <p>A18.2.2 How a magnetic field is produced by the flow of current through conducting wire, including the relationship between:</p> <ul style="list-style-type: none"> <li>• strength of the field</li> <li>• size of the current</li> <li>• distance from the wire.</li> </ul>
A18.3	<p><b>Students should understand electromagnetism and its application in electromechanical devices:</b></p> <p>A18.3.1 Magnetic flux, magnetic flux density and magnetic field lines.</p> <p>A18.3.2 Portative and tractive electromagnets.</p> <p>A18.3.3 Applications of electromagnets in electric and electromechanical devices, including transformers, induction heating and MRI machines.</p>
A18.4	<p><b>Students should be able to calculate force, current, magnetic flux density and length of conductor when a current-carrying conductor is placed in a magnetic field:</b></p> <p>A18.4.1 Use of <math>F = BIl</math>.</p>
A18.5	<p><b>Students should be able to determine the direction of force, current and magnetic field when a current-carrying conductor is placed in a magnetic field:</b></p> <p>A18.5.1 Use of Fleming's Left-Hand Rule.</p>
A18.6	<p><b>Students should understand simple DC electric motors:</b></p> <p>A18.6.1 Principles of the motor effect – causing movement in a motor.</p> <p>A18.6.2 Basic design of an electric motor.</p> <p>A18.6.3 Factors affecting speed of rotation including number of turns, magnetic flux density and relative motion between magnet and coil.</p> <p>A18.6.4 The use of a split ring commutator.</p>
A18.7	<p><b>Students should understand electromagnetic induction and its application generators:</b></p> <p>A18.7.1 Magnetic flux and its application in generators.</p> <p>A18.7.2 Electromagnetic induction – the production of voltage, included a qualitative understanding of Faraday's Law and Lenz's Law, and the factors that could affect the EMF generated.</p>

<b>Content area A19: Waves</b>	
A19.1	<p><b>Students should understand the fundamentals of wave motion:</b></p> <p>A19.1.1 Waves can transfer energy without transferring matter.</p> <p>A19.1.2 Amplitude, frequency, period, speed and wavelength.</p> <p>A19.1.3 Calculate wave speed, frequency and wavelength using the wave equation, <math>v = f \lambda</math>.</p> <p>A19.1.4 Longitudinal waves in terms of the direction of energy transfer, pressure variation and the vibration of molecules.</p> <p>A19.1.5 Transverse waves in terms of the direction of energy transfer and the vibration of molecules.</p> <p>A19.1.6 Graphs representing transverse and longitudinal waves.</p> <p>A19.1.7 Wavefront, coherence, path difference, superposition, interference and phase, including simple diagrams of path difference and phase relationships. Calculations and use of radians are not required.</p>
A19.2	<p><b>Students should understand the transmission, reflection and absorption of radiation:</b></p> <p>A19.2.1 Calculate intensity, power transmitted and area using the equation <math>I = \frac{P}{A}</math>.</p> <p>A19.2.2 Calculate relative intensities of waves using the inverse square law assuming energy spreads uniformly from a point source.</p> <p>A19.2.3 Reflection and transmission characteristics of sound waves at material boundaries, including acoustic impedance, <math>Z</math> and attenuation.</p> <p>A19.2.4 Calculate the relative intensities of incident and reflected waves using the equation <math>\frac{I_r}{I_0} = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}</math>.</p> <p>A19.2.5 Calculate the properties of acoustic impedance using the equations <math>Z = \rho c</math>.</p> <p>A19.2.6 Understand the importance of impedance matching for efficient energy transfer.</p>
A19.3	<p><b>Students should understand refraction and the functioning of lenses and optical fibres:</b></p> <p>A19.3.1 Effects of wave transmission between materials of different optical densities, including the effects on wave speed and wavelength.</p> <p>A19.3.2 Calculate refractive index using <math>n = \frac{c}{v}</math>.</p> <p>A19.3.3 Calculate refractive index and angle using Snell's Law <math>n_1 \sin \theta_1 = n_2 \sin \theta_2</math>.</p> <p>A19.3.4 Total internal reflection and be able to calculate the critical angle using <math>\sin C = \frac{1}{n}</math>, and the conditions needed for total internal reflection.</p> <p>A19.3.5 Methods of measuring the refractive index of a solid material.</p> <p>A19.3.6 Total internal reflection can be used to transmit information, including the function and structure of optical fibres.</p> <p>A19.3.7 Focal length (in relation to converging and diverging lenses), real image and virtual image.</p>

	<p>A19.3.8 Optical ray diagrams, including the meaning of the term 'normal'.</p> <p>A19.3.9 Calculate object distance, image distance and focal length using the thin lens equation, <math>\frac{1}{f} = \frac{1}{u} + \frac{1}{v}</math>.</p> <p>A19.3.10 Calculate the magnification of a thin lens, using <math>M = \frac{v}{u}</math>.</p>
A19.4	<p><b>Students should understand diffraction and its use in scientific and industrial contexts:</b></p> <p>A19.4.1 Diffraction, including the use of Huygens' construction.</p> <p>A19.4.2 Calculate the angle of diffraction for a particular wavelength using <math>n\lambda = d\sin\theta</math> for a diffraction grating.</p> <p>A19.4.3 How diffraction can be used in industrial and scientific applications, including for analysing the chemical composition of gases.</p>
A19.5	<p><b>Students should understand the uses of different types of waves in a range of scientific and industrial contexts:</b></p> <p>A19.5.1 Communication, including optical fibres, mobile phones, Wi-Fi and radio/television broadcasting.</p> <p>A19.5.2 Medical uses, including endoscopy, ultrasound and X-ray imaging.</p> <p>A19.5.3 Food processing, including cooking methods, emulsification and safety purposes.</p> <p>A19.5.4 Environmental monitoring, including sonar, weather radar and light detection and radar (LiDAR).</p>

Content area A20: Gas laws	
A20.1	<p><b>Students should understand the Kelvin temperature scale and know that kelvin temperature is proportional to the average kinetic energy of gas particles.</b></p>
A20.2	<p><b>Students should understand the following gas laws and their application to the behaviour of gases in particular conditions including constant temperature, constant pressure and idealised conditions:</b></p> <p>A20.2.1 Boyle's Law, <math>P_1 V_1 = P_2 V_2</math>.</p> <p>A20.2.2 Charles' Law, <math>\frac{V_1}{T_1} = \frac{V_2}{T_2}</math>.</p> <p>A20.2.3 Pressure Law, <math>\frac{P_1}{T_1} = \frac{P_2}{T_2}</math>.</p> <p>A20.2.4 Ideal gas equation, <math>P V = n R T</math>.</p>
A20.3	<p><b>Students should be able to calculate pressure, volume and temperature using the gas laws in A20.2.</b></p>
A20.4	<p><b>Students should understand the movement of gas particles at different temperatures, including absolute zero:</b></p> <p>A20.4.1 The effect on the movement of particles as temperature approaches absolute zero.</p>

A20.5	<p><b>Students should understand the effect of compression when storing gases in cylinders:</b></p> <p>A20.5.1 High pressure could be hazardous due to the risk of explosion or leakage.</p> <p>A20.5.2 Changes to temperature can affect the pressure.</p> <p>A20.5.3 Cylinders must be stored at a predefined temperature range.</p>
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<b>Content area A21: Pressure/fluid/viscosity</b>	
A21.1	<p><b>Students should know the definitions of:</b></p> <p>A21.1.1 Density (<math>\rho</math>) – mass per unit volume.</p> <p>A21.1.2 Pressure (P) – force per unit area.</p> <p>A21.1.3 Fluid – a substance that is capable of flowing, with no fixed shape.</p> <p>A21.1.4 Viscosity (<math>\eta</math>) – a measure of resistance (internal friction) of a fluid (for example, high viscosity = low flow).</p>
A21.2	<p><b>Students should be able to calculate density, mass, volume, pressure, force, area, viscosity and mechanical properties of an object moving through a fluid using the following equations:</b></p> <p>A21.2.1 <math>\rho = \frac{m}{V}</math>.</p> <p>A21.2.2 <math>P = \frac{F}{A}</math>.</p> <p>A21.2.3 <math>F = 6 \pi \eta r v</math> (Stokes' Law for small spheres moving at low speeds in laminar flow).</p>
A21.3	<p><b>Students should be able to analyse the motion of an object moving through a fluid in terms of the forces acting on it, including weight and resistive force, and relate the resultant force to changes in motion.</b></p>
A21.4	<p><b>Students should understand that an object moving through a fluid may reach a constant speed (terminal velocity) when the resistive forces increase to balance driving force(s), resulting in zero acceleration.</b></p>
A21.5	<p><b>Students should understand the properties of Newtonian and non-Newtonian fluids and interpret data based on these properties:</b></p> <p>A21.5.1 Newtonian – a fluid whose viscosity remains constant as the applied force changes.</p> <p>A21.5.2 Non-Newtonian – a fluid whose viscosity does not remain constant as the applied force changes.</p>
A21.6	<p><b>Students should understand the relationship between depth and hydrostatic pressure in a liquid due to the weight of the fluid above</b></p> <p>A21.6.1 An increase in depth causes an increase in pressure.</p>
A21.7	<p><b>Students should be able to calculate hydrostatic pressure, density, depth and an estimate of the value of g</b></p> <p>A21.7.1 Use of equation <math>P = \rho g \Delta h</math>.</p>

A21.8	<b>Students should understand that pressure differences cause an upward force on immersed objects, and be able to apply this to explain floating, sinking and neutral buoyancy.</b>
A21.9	<b>Students should know the qualitative definitions of volumetric and mass flow rates:</b> A21.9.1 Volumetric flow rate – the volume of a fluid moving through a given area per unit of time. A21.9.2 Mass flow rate – the mass of a fluid moving through a given area per unit of time.
A21.10	<b>Students should understand the difference between steady and turbulent flow, and be able to apply this to scientific and industrial processes, including diagrams of fluid flow and the motion of objects through fluids:</b> A21.10.1 Steady flow is when all parts of a fluid have the same velocity at a certain point. A21.10.2 Turbulent flow is when different parts of the fluid have a different velocity.

#### Content area A22: Units and quantities

A22.1	<b>Students should know the international system of units (SI), and the quantities that they can be used to measure:</b> A22.1.1 Ampere (A) – electric current. A22.1.2 Candela (cd) – luminous intensity. A22.1.3 Kelvin (K) – temperature. A22.1.4 Kilogram (kg) – mass. A22.1.5 Metre (m) – length. A22.1.6 Mole (mol) – amount of substance. A22.1.7 Second (s) – time.
A22.2	<b>Students should understand how to convert between units:</b> A22.2.1 Nanometres, micrometres, millimetres, metres and kilometres. A22.2.2 Milligrams, grams and kilograms. A22.2.3 Millilitres, cubic centimetres, litre and cubic metres.
A22.3	<b>Students should understand the importance of using significant figures and science notation, and use an appropriate number of significant figures during calculations:</b> A22.3.1 Makes calculations with large or small numbers less cumbersome. A22.3.2 Reduces the chances of data errors.

## The science sector (synoptic)

<b>Content area B1: Working in the science sector</b>	
B1.1	<p><b>Students should be able to evaluate the drivers of employment, innovation and commercial activity in the science sector</b></p> <p>B1.1.1 Understand the factors contributing to the diversity of employers and organisations in the science sector:</p> <ul style="list-style-type: none"> <li>• Size (micro, small, medium, large).</li> <li>• Business Activity: research, manufacturing, services.</li> <li>• Commercial status (public/ private/ third sector).</li> <li>• Geographic location.</li> </ul> <p>B1.1.2 Understand the impact of external and internal factors on the commercial activities of science organisations:</p> <ul style="list-style-type: none"> <li>• Government priorities and policies, including food labelling and environmental policies.</li> <li>• Public perception and media influence.</li> <li>• Funding streams, including changes to private and public funding.</li> <li>• Availability of materials and resources.</li> <li>• Market demand.</li> <li>• Cost-effectiveness and efficiency.</li> <li>• Environmental concerns, including reducing waste and carbon footprint.</li> </ul> <p>B1.1.3 Understand the impact of innovation in the science sector on employers/organisation, society and the economy:</p> <ul style="list-style-type: none"> <li>• Employer/organisation: commercial benefits of successful innovation (patents, profit, business growth, reputation, achievement of organisational aims).</li> <li>• Society and Economy: <ul style="list-style-type: none"> <li>○ solving large-scale problems (vaccines and antibiotics, alternative energy sources)</li> <li>○ improving healthcare (Artificial Intelligence (AI) assisted diagnosis, genomic sequencing personalised medicine)</li> <li>○ developing new products and materials (new drugs, composite materials (graphene))</li> <li>○ enabling new scientific discoveries (genome editing, bioinformatics, computational biology)</li> <li>○ fosters economic development (genetically modified crops, mRNA vaccines, offshore wind energy).</li> </ul> </li> </ul>
B1.2	<p><b>Students should be able to evaluate the opportunities that are available within science career pathways:</b></p> <p>B1.2.1 Understand technical, higher technical and professional occupations in science, as defined by Skills England Occupational Maps:</p> <ul style="list-style-type: none"> <li>• Technical: level 2/3 qualifications, entry via college or apprenticeships.</li> </ul>

- Higher technical: level 4/5 qualifications, progression through workplace experience and further technical education.
  - Professional: clear progression from higher technical roles, includes degree apprenticeships.
- B1.2.2 Understand how qualifications and professional opportunities support progression within the science sector:
- Post-16 Level 3 Science Qualifications including T Levels.
  - Apprenticeships (higher and degree level).
  - Higher education pathways (Higher Technical qualifications (HTQs), undergraduate, master's and doctorate degrees).
  - Continuing professional development (CPD) including mid-career apprenticeships and knowledge exchange programmes.
  - Professional registration (RSciTeach, RSci, CSci and CSciTeach).
  - Professional recognition including fellowships by professional bodies.
- B1.2.3 Understand how to use job descriptions and person specifications
- Job descriptions:
    - define the role by outlining duties and responsibilities, reporting structures, required technical and scientific skills, working conditions and regulatory responsibilities.
  - Person specifications:
    - define the attributes of the individual required for the role including essential and desirable qualifications, technical competence and practical experience, transferable skills, professional behaviours and values.
- B1.2.4 Understand the diversity of roles that are available to scientists and the typical qualification and experience requirements
- Science sector roles include work in:
    - research and development
    - teaching, education and outreach
    - data analysis
    - clinical testing and trials
    - quality control and quality assurance
    - product development
    - scientific publishing
    - manufacturing.
  - Career pathways that apply scientific knowledge in non-traditional scientific sectors:
    - communication and outreach: science journalist, publishing, public relations
    - government and policy advisory roles
    - administration within scientific professional bodies
    - public service roles (civil servant).

<p>B1.3</p>	<p><b>Students should be able to evaluate how individual roles fit within teams and organisational structures in the science sector</b></p> <p>B1.3.1 Understand how individuals work with colleagues, teams and departments within an organisation, including interpretations of organisational charts (organigrams):</p> <ul style="list-style-type: none"> <li>• How different scientific and non-scientific teams interact to achieve organisational goals.</li> <li>• The roles of departments (research and development, quality assurance, manufacturing, data analysis and management).</li> </ul> <p>B.1.3.2 Understand management and supervisory responsibilities, including oversight of direct reports, trainees, apprentices and T Level industry placements:</p> <ul style="list-style-type: none"> <li>• Responsibilities for training, mentoring and performance oversight.</li> <li>• Safeguarding and duty of care for learners and early-career staff.</li> <li>• How supervision contributes to skills development and workforce sustainability.</li> <li>• The role of management and supervision on productivity, morale and development.</li> </ul> <p>B1.3.3 Understand the importance of performance reviews in science organisations for both the individual and the organisation:</p> <ul style="list-style-type: none"> <li>• How reviews: <ul style="list-style-type: none"> <li>○ measure performance against standards and expectations</li> <li>○ facilitate constructive feedback and improvement</li> <li>○ allow employees to raise concerns or issues</li> <li>○ support continuing professional development (CPD) and progression.</li> </ul> </li> </ul>
<p>B1.4</p>	<p><b>Students should be able to evaluate the purpose and importance of organisational policies, principles and procedures in the science sector</b></p> <p>B1.4.1 Understand the role of policies in science organisations:</p> <ul style="list-style-type: none"> <li>• How equality, diversity and inclusion (EDI) policies: <ul style="list-style-type: none"> <li>○ ensure compliance and legislation</li> <li>○ promote fairness and equal opportunity</li> <li>○ eliminate discrimination and bias</li> <li>○ support inclusive workplaces that enhance innovation and performance.</li> </ul> </li> <li>• How safeguarding policies: <ul style="list-style-type: none"> <li>○ protect employees, learners, vulnerable individuals and visitors</li> <li>○ set out organisational responsibilities for safe working environments.</li> </ul> </li> <li>• How grievance policies: <ul style="list-style-type: none"> <li>○ allow confidential reporting of concerns</li> <li>○ ensure fair and transparent resolution</li> <li>○ maintain positive working relationships.</li> </ul> </li> </ul>

- How disciplinary procedures:
    - set and maintain expected standards of conduct
    - ensure fairness and consistency
    - provide a structured sequence for disciplinary action.
- B1.4.2 Understand how the key principles of ethical practice apply to the science sector:
- The principle of autonomy and informed consent.
  - The importance of security and confidentiality, including safe and secure use of technology.
  - The principle of beneficence in promoting positive outcomes.
  - The principle of non-maleficence in preventing harm.
  - Justice in science, including fairness, equality, inclusion and respect.
- B1.4.3 Understand the purpose of professional codes of conduct in promoting confidence in science organisations:
- How professional codes of conduct:
    - clarify organisational missions, values and principles
    - define expected professional behaviours and attitudes
    - outline rules and responsibilities for individuals
    - promote trust among colleagues, stakeholders and the public.
- B1.4.4 Understand adherence to quality standards, quality management and audit processes in the science sector:
- The importance of ensuring consistency of approach in scientific work.
  - How quality systems support health and safety.
  - The role of monitoring processes and procedures in maintaining quality.
  - How quality management facilitates continuous improvement.
  - The importance of objective, independent review through audits and inspections.
- B1.4.5 Understand the role of employment contracts in defining professional expectations and legal responsibilities:
- How contracts:
    - set out conditions of employment
    - clarify rights, responsibilities and duties
    - protect employees and organisations.
- B1.4.6 Understand how personal information is protected through legislation, regulation and organisational practice:
- The role of the Data Protection Act 2018 in controlling the use of personal information.
  - The principles of UK GDPR and their application to handling sensitive data.

	<ul style="list-style-type: none"> <li>• Organisational policies and local ways of working that ensure compliance, including: <ul style="list-style-type: none"> <li>○ secure electronic and paper-based data storage</li> <li>○ restrictions on mobile device use</li> <li>○ prevention of conflicts of interest.</li> </ul> </li> </ul>
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<b>Content B2: Good scientific practice</b>	
B2.1	<p><b>Students should be able to evaluate how Standard Operating Procedures (SOPs) are used in laboratory practice:</b></p> <p>B2.1.1 Understand the principles of good practice in scientific settings:</p> <ul style="list-style-type: none"> <li>• How to use Standard Operating Procedures (SOPs).</li> <li>• Effectively managing calibration and maintenance of equipment and work areas.</li> <li>• Effectively managing stock.</li> <li>• Appropriately storing products, materials and equipment.</li> </ul> <p>B2.1.2 Understand the importance for everyone to follow SOPs:</p> <ul style="list-style-type: none"> <li>• Maintaining health and safety.</li> <li>• Enabling consistency of approach.</li> <li>• Meeting any legal or organisational requirements.</li> <li>• Upholding professional standards.</li> <li>• Demonstrating compliance for audit purposes.</li> </ul> <p>B2.1.3 Understand how to correctly access SOPs for a given activity:</p> <ul style="list-style-type: none"> <li>• Carrying out detailed index searches.</li> <li>• Completing detailed staff induction and ongoing training.</li> <li>• Ensuring the SOP is the most up-to-date version.</li> <li>• Ensuring all relevant documentation has been completed and signed.</li> </ul>
B2.2	<p><b>Students should be able to evaluate the importance of preparing and maintaining equipment and work areas:</b></p> <p>B2.2.1 Understand the importance of calibrating and testing equipment to ensure it is fit for use:</p> <ul style="list-style-type: none"> <li>• Ensuring accuracy and reliability of measurements.</li> <li>• Prolonging the life of equipment.</li> <li>• Meeting legal requirements.</li> </ul> <p>B2.2.2 Understand the potential consequences of not regularly cleaning and preparing work areas for use:</p> <ul style="list-style-type: none"> <li>• Risks to health and safety – spread of infection, production of toxic/dangerous by-products.</li> <li>• Invalid results – contamination or cross-contamination including environmental, samples, reagents, DNA.</li> <li>• Inefficient working practice – increased costs and timescales.</li> <li>• Damage to equipment – increased costs and timescales.</li> </ul>

	<p>B2.2.3 Understand the potential consequences of not maintaining cleaning and servicing equipment:</p> <ul style="list-style-type: none"> <li>• Risks to health and safety: <ul style="list-style-type: none"> <li>○ increased risk of injury</li> <li>○ spread of infection.</li> </ul> </li> <li>• Invalid results: <ul style="list-style-type: none"> <li>○ contamination or cross-contamination, to include environmental, samples, DNA and reagents.</li> </ul> </li> <li>• Reduced function of equipment: <ul style="list-style-type: none"> <li>○ decreased lifespan of equipment</li> <li>○ increased cost and timescales.</li> </ul> </li> </ul> <p>B2.2.4 Understand how to escalate concerns if equipment is not correctly calibrated/unsuitable for intended use:</p> <ul style="list-style-type: none"> <li>• Taking the equipment out of action.</li> <li>• Labelling the equipment as being out of use, if appropriate.</li> <li>• Reporting concerns to the relevant person, in line with organisational policies and procedures.</li> </ul>
B2.3	<p><b>Students should be able to evaluate the importance of correctly managing and storing stock</b></p> <p>B2.3.1 Understand the reasons for correctly managing stock:</p> <ul style="list-style-type: none"> <li>• Ensuring sufficient supply of required consumables and materials.</li> <li>• Ensuring that materials are used before their expiry date.</li> <li>• Reducing the costs of excess stock.</li> <li>• Improving efficiency.</li> <li>• Improving productivity.</li> <li>• Ensuring safety of stock (bottles aren't damaged/degraded).</li> </ul> <p>B2.3.2 Understand the consequences of incorrectly storing stock:</p> <ul style="list-style-type: none"> <li>• Cross-contamination.</li> <li>• Breakdown of limited stability products.</li> <li>• Products exceeding expiry dates.</li> <li>• Loss of samples or degradation of reagents not stored at the correct temperature (-20°C, -4°C, 4°C or room temperature).</li> <li>• Risks to health and safety (for example, spread of infection, release of dangerous chemicals, or heavy items not stored at the correct height).</li> <li>• The stock is difficult to locate.</li> <li>• Financial loss.</li> </ul>
B2.4	<p><b>Students should be able to evaluate the effectiveness of health and safety practices in laboratory settings</b></p> <p>B2.4.1 Understand how health and safety at work is promoted:</p> <ul style="list-style-type: none"> <li>• Encouraging individuals to take reasonable care of their own and others' safety.</li> <li>• Modelling good practice, washing hands and wearing appropriate PPE.</li> </ul>

	<ul style="list-style-type: none"> <li>• Following organisational policies and Standard Operating Procedures (SOPs), including site-specific emergency procedures.</li> <li>• Ensuring that there is clearly visible information and guidance.</li> <li>• Following processes for recording and reporting issues and concerns.</li> <li>• Maintaining equipment and removing faulty equipment.</li> <li>• Following correct manual handling techniques.</li> <li>• Ensuring working environments are clean, tidy and hazard-free.</li> <li>• Appropriately storing equipment and materials.</li> <li>• Completing statutory training.</li> </ul> <p>B2.4.2 Understand methods used to deal with situations that can occur in a science environment that could cause harm to self or others:</p> <ul style="list-style-type: none"> <li>• Following organisational health and safety procedures.</li> <li>• Keeping oneself and others safe, including evacuation as appropriate.</li> <li>• Securing the area.</li> <li>• Reporting and/or escalating as appropriate debriefing and reflecting on the root causes, to prevent the situation from recurring.</li> </ul> <p>B2.4.3 Understand the purpose of the following legislation and regulations in the science sector:</p> <ul style="list-style-type: none"> <li>• Regulatory Reform (Fire Safety) Order (RRO) 2005: <ul style="list-style-type: none"> <li>○ purpose: to reduce death, damage and injury caused by fire by placing legal responsibilities on employers to carry out a fire risk assessment. All organisations are required to have procedures for evacuation in the event of a fire.</li> </ul> </li> <li>• Health and Safety (Display Screen Equipment) Regulations 1992: <ul style="list-style-type: none"> <li>○ purpose: defines employers' responsibilities in carrying out risk assessments of workstations used by employees, including the use of display screen equipment, to minimise identified risks.</li> </ul> </li> </ul>
B2.5	<p><b>Students should be able to evaluate how technology can best contribute to scientific practice</b></p> <p>B2.5.1 Understand the advantages and risks of using IT systems to record, retrieve and store information and data:</p> <ul style="list-style-type: none"> <li>• Advantages: <ul style="list-style-type: none"> <li>○ ease of access</li> <li>○ ease of sharing and transferring data</li> <li>○ speed of data analysis</li> <li>○ security include password protection</li> <li>○ standardisation of data</li> <li>○ enables continuous and/or real-time monitoring of data</li> <li>○ cost and space saving</li> <li>○ enables integrated working and supports safeguarding practices.</li> </ul> </li> </ul>

- Risks:
    - security breaches – accidental or malicious
    - potential for corruption of data
    - lack of access due to system failure.
- B2.5.2 Understand how social media can be effectively used in scientific practice:
- Positive uses:
    - awareness campaigns/disseminating information
    - correcting misinformation
    - crisis communication/monitoring
    - monitoring public health
    - data gathering
    - establishing support networks
    - recruitment
    - marketing.
  - Restrictions:
    - not posting sensitive/personal information about oneself or others on social media, in line with an organisation’s code of conduct
    - maintaining professional boundaries when interacting with individuals external to the organisation
    - sharing inaccurate/non-evidence-based information.
- B2.5.3 Understand the security measures used to protect data stored by organisations
- Controlling access to information, including the levels of authorised logins and passwords.
  - Allowing only authorised staff into specific work areas.
  - Requiring regular and up-to-date staff training in complying with data security.
  - Making regular back-ups of files.
  - Using up-to-date cybersecurity strategies to protect against unintended or unauthorised access.
  - Ensuring that back-up data is stored externally, including cloud-based or separate servers.
- B2.5.4 Understand the methods you should use to ensure confidentiality when using digital systems:
- Logging out of systems when unattended.
  - Protecting login credentials.
  - Maintaining awareness of surroundings.
  - Using secure internet connections.
  - Applying privacy screen filters where appropriate.

## Scheme of assessment – Core component

There are four assessments in the Core component of the *T Level Technical Qualification in Science*:

- Core Examination Paper 1 – Chemistry
- Core Examination Paper 2 – Biology
- Core Examination Paper 3 – Physics
- Employer Set Project.

The mapping, timings, scheduling and preparation for the assessments shown below are for the current specimen assessment material. The actual live assessments will have the same overarching number of tasks and overall focus. However, the order of tasks and the details within the task may change each series.

### Core examinations

<b>Paper 1: Chemistry</b>
<b>Written examination: 80 minutes</b> <b>18.3% of the core assessments</b> <b>55 marks</b>
<b>Content overview</b> A10 – Materials and chemical properties A11 – Rates of reaction and energy changes A12 – Kinetic changes – rates of chemical reaction A13 – Acids/bases and chemical change A14 – Chemical analysis of substances A15 – Formulae and equations B1-2 The science sector (synoptic)
<b>Assessment overview</b> An externally assessed written examination comprising three sections. Students answer all questions in Section A, Section B and Section C. Core Examination Paper 2 includes short, medium and extended open-response questions. Core Examination Paper 2 is set and marked by Pearson.
<b>Administration</b> The paper must be assessed under exam conditions, following <a href="#">JCQ's Instructions for Conducting Examinations (ICE)</a> .

## Paper 2: Biology

**Written examination: 105 minutes**

**23.4% of the core assessments**

**70 marks**

### **Content overview**

A1 – Cells and tissues

A2 – Biological molecules

A3 – Enzyme and protein structure

A4 – DNA and RNA

A5 – Cell cycle

A6 – Exchange, transport mechanisms and ecosystems

A7 – Cellular respiration

A8-9 – Pathogens and immunology

B1-2 The science sector (synoptic)

### **Assessment overview**

An externally assessed written examination comprising four sections.

Students answer all questions in Section A, Section B, Section C and Section D.

Core Examination Paper 1 includes short, medium and extended open-response questions.

Core Examination Paper 1 is set and marked by Pearson.

### **Administration**

The paper must be assessed under exam conditions, following [JCQ's Instructions for Conducting Examinations \(ICE\)](#).

<b>Paper 3: Physics</b>
<p><b>Written examination: 80 minutes</b>  <b>18.3% of the core assessments</b>  <b>55 marks</b></p>
<p><b>Content overview</b>  A16 – Particles and radiation  A17 – Electricity  A18 – Magnetism and electromagnetism  A19 – Waves  A20 – Gas laws  A21 – Pressure/ fluid/ viscosity  A22 – Units and quantities  B1-2 The science sector (synoptic)</p>
<p><b>Assessment overview</b>  An externally assessed written examination comprising three sections.  Students answer all questions in Section A, Section B and Section C.  Core Examination Paper 3 includes short, medium and extended open-response questions.  Core Examination Paper 3 is set and marked by Pearson.</p>
<p><b>Administration</b>  The paper must be assessed under exam conditions, following <a href="#">JCQ's Instructions for Conducting Examinations (ICE)</a>.</p>

All three core examinations follow the same paper structure, but assess different core content, and are available as paper-based only.

There are three sections in Paper 1: Chemistry:

### **Paper 1**

Section A is weighted 45.4%

Section B is weighted 38.2%

Section C is weighted 16.4%

There are four sections in Paper 2: Biology:

### **Paper 2**

Section A is weighted 28.6%

Section B is weighted 28.6%

Section C is weighted 30.0%

Section D is weighted 12.8%

There are three sections in Paper 3: Physics **Paper 3**

Section A is weighted 45.4%

Section B is weighted 38.2%

Section C is weighted 16.4%

## Core Examination Assessment Objectives

Assessment Objective	Strands	Descriptor
<b>AO1</b>	1a. Knowledge	Demonstrate knowledge and understanding of the content (knowledge)
	1b. Understanding	Demonstrate knowledge of the content.
<b>AO2</b>	2a. Performs procedure	Demonstrate understanding of the content.
	2b. Application to industry context	Perform a procedure by demonstrating ability related to the content.
<b>AO3</b>	3a. Analysis	Apply knowledge and understanding of the content to different scientific contexts
	3b. Evaluation	Analyse information and issues related to the content.

	<b>AO1a</b>	<b>AO1b</b>	<b>AO2a</b>	<b>AO2b</b>	<b>AO3a</b>	<b>AO3b</b>
Examination 1	14	7	6	16	9	3
Examination 2	14	9	5	24	12	6
Examination 3	14	4	9	16	9	3
Total	42	20	20	56	30	12
Percentage %	23%	11%	11%	31%	17%	7%
	34.4%		42.2%		23.3%	

# Employer Set Project

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<b>Employer Set Project</b>
<b>Externally assessed project: 14 hours 30 minutes</b> <b>40% of the core assessments</b> <b>108 marks</b>
<b>Content overview</b> The assessment of content in the Employer Set Project is synoptic and may draw on any part of the Core content.
<b>Assessment overview</b> Students will be given an overarching scenario to set the scene and individual tasks stimulus to cover all the skills and AOs. The skills are: CS1: Project management CS2: Researching CS3: Working with others CS4: Creativity and innovation CS5: Problem solving CS6: Communication CS7: Reflective evaluation
<b>Administration</b> Providers must follow the guidance in the following: <ul style="list-style-type: none"><li>• General Administrative Support Guide</li><li>• Administration Support Guide for the specific Technical Qualification Employer Set Project (if applicable).</li></ul> These are located on the <a href="#">Training and Admin Support webpage</a> .

## Employer Set Project Assessment Objectives

Assessment Objective	
<b>AO1</b>	Plan their approach to meeting the brief
<b>AO2</b>	Apply core knowledge and skills as appropriate
<b>AO3</b>	Select relevant techniques and resources to meet the brief
<b>AO4</b>	Use maths, English and digital skills as appropriate
<b>AO5</b>	Realise a project outcome and review how well the outcome meets the brief

The ESP has targeted weightings to AOs as shown in the table below:

AO (weighting as a % of the total mark)					
AO1	AO2	AO3	AO4	AO5	Total
33	17	16	25	9	100

## Resources for the delivery of the Core component content

As part of your Provider approval, you will need to show that the necessary material resources and work spaces are available to deliver this Technical Qualification.

Where specific resources are required to deliver the content, these are stated in the relevant component. The following resources would be required for this qualification:

### Core:

- Scientific calculator and ruler
- Periodic table (Chemistry Only)
- Formulae and constants sheet (Physics Only).

### ESP:

- Laboratory equipment, such as:
  - safety equipment, e.g. goggles, lab coat, fume cupboard
  - glassware (beakers, flasks, burettes)
  - measuring cylinders
  - balances and weighing boats
  - Bunsen burners
  - tripods and gauze mats
  - clamps and stands
  - heatproof mats
  - thermometers (digital and alcohol-based)
  - water baths
  - pipettes, tips, fillers and droppers
  - fume cupboard
  - pH meter
  - stopwatch.
- Practical-specific resources include:
  - calcium carbonate chips, large and small sizes
  - calcium carbonate powder
  - mol/dm<sup>3</sup> hydrochloric acid
  - cotton wool.
- Paper and thin layer chromatography (TLC) resources include:
  - chromatography paper
  - TLC plates
  - solvents suitable for the TLC being carried out
  - solution to be separated
  - capillary tubes/micropipettes
  - developing chamber and cover (often a glass cylinder with lid)
  - UV lamp/light source/chemical reagents for developing
  - desiccator/oven/warm space for drying plates
  - spray bottle.

- Distillation/refluxing resources include:
  - connections for flask and condenser/bungs/rubber tubing (as required)
  - condenser
  - cooling water source
  - distillation column/fractionating column depending on task.
- Titration resources include:
  - chemicals – analyte solution, titrant solution, indicator
  - burette clamp
  - white tile.
- Filtration resources include:
  - filter funnel
  - filter paper
  - filter flask (for vacuum filtration)
  - Buchner funnel with rubber stopper
  - Buchner funnel adapter (for vacuum filtration)
  - vacuum pump with necessary tubing.
- Differential staining resources include:
  - light microscope
  - bacterial culture
  - microscope slides
  - cover slips
  - gram stain decolorizer
  - eyepiece graticule/stage micrometer
  - crystal violet stain
  - iodine solution
  - decolorizing agent (for example, ethanol)
  - safranin stain
  - immersion oil
  - incinerator/autoclave.
- Microbiological equipment resources include:
  - petri dish
  - agar
  - wire/inoculating loop
  - bacterial culture
  - incubator
  - glass/plastic spreader
  - ethanol
  - cotton wool
  - disinfectant for surfaces.

- Serial dilution resources include:
  - volumetric flasks
  - mechanical pipette and tips
  - volumetric pipette
  - temperature probe and data logger
  - U-tube manometer and appropriate liquid
  - stopcocks/valves
  - tubing
  - pressure source
  - ruler/scale
  - levelling device
  - sealant/tape (if necessary)
  - rubber bulb (if necessary)
  - conductivity meter.
- Colorimeter resources include:
  - filters for colorimeter
  - cuvettes
  - volumetric, graduated and mechanical (variable volume) pipettes.
- Circuit resources include:
  - ammeter and voltmeter or multimeter
  - connecting leads and probes
  - power source
  - circuit components to include a switch.

# 4 Occupational Specialisms

## 1. Laboratory Sciences

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### Performance Outcome 1: Design and execute scientific tasks using scientific knowledge

What skills do students need to demonstrate?
<p><b>S1.1 Contribute to the preparation of a scientific report:</b></p> <ul style="list-style-type: none"><li>• Abstract, which concisely summarises the completed scientific techniques and the results obtained</li><li>• Introduction</li><li>• Methods</li><li>• Results, including using reliable and verifiable data</li><li>• Discussion/evaluation, including using calculations, diagrams and data representations to support technical arguments</li><li>• Conclusion.</li></ul> <p>(E1, E2, E3, E4, M4, E5, M5, M6, M7, M8, D1, D2, D3, D4)</p>
<p><b>S1.2 Design a scientific task to address a particular hypothesis, taking into consideration a range of factors:</b></p> <ul style="list-style-type: none"><li>• The customer/client requirements</li><li>• Laboratory sampling requirements</li><li>• Laboratory health, safety, environmental and regulatory requirements (for example, COSHH, UK reach)</li><li>• Resources required, including laboratory equipment, reagents and consumables</li><li>• Appropriate scientific methods, equipment and techniques</li><li>• Appropriate controls</li><li>• Any specific storage requirements</li><li>• The most appropriate way to present data.</li></ul> <p>(E1, E2, E3, E4, M4, E5, M5, M6, M7, M8, D1, D2, D3, D4)</p>
<p><b>S1.3 Perform a literature review to extract relevant information to support the planning of a scientific task:</b></p> <ul style="list-style-type: none"><li>• Assessing the quality and reliability of the information accessed</li><li>• Extracting main ideas/key information (for example, methods) from appropriate sections of the paper, relevant to the purpose of the scientific task</li><li>• Selecting fact from opinion</li><li>• Recording relevant information accurately and concisely.</li></ul> <p>(E1, E2, E3, E4, M4, E5, M5, M6, M7, M8, D1, D2, D3, D4)</p>

**S1.4 Apply knowledge of scientific techniques to an unfamiliar context when planning a scientific task:**

- Appropriate scientific techniques and methods
- Required scientific equipment, reagents and consumables
- Laboratory health, safety, environmental and regulatory requirements.

**(E1, E2, E3, E4, M4, E5, M5, M6, M7, M8, M10, D1, D2, D3, D4)**

<b>What underpinning knowledge do students need?</b>	
<b>K1</b>	<b>Literature review</b>
1.1	<p><b>How to undertake literature searches and use scientific papers to plan scientific tasks, by:</b></p> <ul style="list-style-type: none"> <li>• Accessing appropriate databases (for example, PubMed, Merck Index* Online, National Institute for Health and Care Excellence (NICE), IOP science).</li> <li>• Using keywords and Boolean in searches.</li> <li>• Review of literature:               <ul style="list-style-type: none"> <li>○ assess the quality and reliability of the literature to the planned scientific task (for example, who the author is, size of the sample, peer-reviewed status, commercial implications, primary or secondary sources)</li> <li>○ evaluate credibility, relevance and limitations of each article</li> <li>○ review the accuracy of data and statements</li> <li>○ identify advantages and disadvantages of the topic area</li> <li>○ review any ethical issues</li> <li>○ assess the neutrality and potential bias of authors/publications</li> <li>○ identify gaps (gap analysis), missing data or limitations within the research carried out</li> <li>○ saving and organising copies or extracts of sources (for example, downloaded articles, copied sections or screenshots), and recording source weblinks/addresses, all clearly labelled and referenced.</li> </ul> </li> </ul>
1.2	<p><b>How to select information from a method, paper or SOP:</b></p> <ul style="list-style-type: none"> <li>• Identify the purpose and scope of the document to determine which sections are relevant to the task or question.</li> <li>• Interpret and summarise relevant content from a scientific paper to support technique execution:               <ul style="list-style-type: none"> <li>○ locate and extract experimental procedures, materials and conditions from the methods section</li> <li>○ summarise procedural information in a format suitable for replication or adaptation.</li> </ul> </li> <li>• Select relevant facts and data from a scientific paper to inform technique setup:               <ul style="list-style-type: none"> <li>○ identify variables, controls and outcome measures that influence technique design</li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>○ extract and apply findings that justify the choice of method, reagents or equipment.</li> <li>● Evaluate the clarity, completeness and applicability of procedural information: <ul style="list-style-type: none"> <li>○ assess whether the selected information is sufficient and appropriate for the intended technique</li> <li>○ recognise limitations, assumptions or adaptations required when applying published methods.</li> </ul> </li> </ul>
1.3	<p><b>Assessing the validity and reliability of sources:</b></p> <ul style="list-style-type: none"> <li>● Reputation and expertise of the author and/or publication, including peer review status.</li> <li>● Accuracy and reliability of the data and statements, including sample size, date, control and representation.</li> <li>● Identification of any vested interest or conflict of interest, and potential bias of the author and/or publication.</li> <li>● Relevance of the source to the scientific task and objectives.</li> <li>● Identification of limitations, gaps or missing data within the research.</li> </ul>
1.4	<p><b>How the following considerations inform the planning of a laboratory task:</b></p> <ul style="list-style-type: none"> <li>● Customer/client requirements for laboratory analysis (for example, customer needs, what objectives need to be achieved).</li> <li>● Laboratory sampling requirements (for example, what samples are required, frequency of sampling, quantity of sample).</li> <li>● Laboratory health, safety, environmental and regulatory requirements (for example, identifying risks through a risk assessment).</li> <li>● Resources required including laboratory equipment, reagents and consumables (for example, identifying the sources of equipment, reagents and consumables).</li> <li>● Scheduling of laboratory testing (for example, planning timings and potential use of Gantt charts, taking into consideration shared resources).</li> <li>● Scientific methods (for example, identifying the most appropriate methods to meet the objectives).</li> <li>● Storage and transportation of samples (for example, correct temperature, correct storage container, temperature monitoring).</li> <li>● Presentation of the data (for example, identifying most appropriate way of displaying the data, demonstrating whether objectives have been achieved or not, including statistical significance).</li> <li>● The role of others within the laboratory environment.</li> </ul>
1.5	<p><b>The principles of laboratory method validation when planning scientific tasks:</b></p> <ul style="list-style-type: none"> <li>● Using accepted sample preparation methods.</li> <li>● Using certified standards to determine the accuracy of the method.</li> </ul>

	<ul style="list-style-type: none"> <li>• Following accepted guidelines and/or requirements (for example, International Council for Harmonisation of Technical Requirements for pharmaceuticals for Human Use (ICH) requirements).</li> <li>• Following the manufacturers' guidelines for use, where appropriate.</li> </ul>
1.6	<p><b>The principles of laboratory equipment validation when planning scientific tasks:</b></p> <ul style="list-style-type: none"> <li>• Using certified standards to determine the accuracy of the equipment.</li> <li>• Checking the equipment is running the up to-date operating system.</li> <li>• Checking that the equipment is within calibration and service dates (fit for purpose).</li> <li>• Following the manufacturers' guidelines for use, where appropriate.</li> </ul>
1.7	<p><b>The difference between concrete and abstract modelling techniques:</b></p> <ul style="list-style-type: none"> <li>• Concrete: a trial task prior to planning.</li> <li>• Abstract: planning on paper or using computer simulations.</li> </ul>
1.8	<p><b>Apply academic integrity and referencing conventions:</b> Use appropriate citation formats (e.g. Harvard, Vancouver). Understand plagiarism and paraphrasing requirements.</p>

### What skills do students need to demonstrate?

#### S1.5 Apply scientific knowledge when undertaking scientific techniques

- Choosing and justifying appropriate scientific techniques using scientific knowledge
- Planning the steps of the technique in the correct order, ensuring correct quantities and concentrations are used.

**(E1, E2, E3, E4, M4, E5, M1, M2, M3, M4, M5, M6, M7, M8, M10, D1, D2, D3, D4)**

### What underpinning knowledge do students need?

<b>K2</b>	<b>Scientific concepts</b>
2.1	<p><b>Atomic structure:</b></p> <ul style="list-style-type: none"> <li>• The definitions of orbital and nucleus: <ul style="list-style-type: none"> <li>○ orbital – a region of space with the greatest chance of finding an electron</li> <li>○ nucleus – a dense group of protons and neutrons in the centre of an atom.</li> </ul> </li> <li>• How electrons are arranged in s and p sub-orbitals from periods 1 to 4: <ul style="list-style-type: none"> <li>○ filling electron sub-shells in order of increasing energy from 1s<sup>2</sup> to 4p<sup>6</sup>.</li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>• How the electron arrangement in s and p orbitals is linked to the way in which elements are situated in s and p blocks in the periodic table: <ul style="list-style-type: none"> <li>○ s-block elements have their outer electrons in s shells</li> <li>○ p-block elements have their outer electrons in p shells</li> <li>○ d-block elements have their outer electrons in d shells.</li> </ul> </li> <li>• How the position of the element in the periodic table (arrangement of electrons) is related to the reactivity of that element: <ul style="list-style-type: none"> <li>○ metal reactivity generally decreases as you go from left to right in the periodic table</li> <li>○ non-metal reactivity generally increases as you go from left to right in the periodic table (apart from group 0, which are unreactive).</li> </ul> </li> </ul>
2.2	<p><b>Amount of substance:</b></p> <ul style="list-style-type: none"> <li>• The definitions of relative atomic mass and relative molecular mass: <ul style="list-style-type: none"> <li>○ relative atomic mass is the average mass of the atoms of an element compared to carbon-12</li> <li>○ relative molecular mass is the sum of the relative atomic mass of the atoms in the molecule.</li> </ul> </li> <li>• How to use balanced equations to apply the mole and Avogadro's constant to calculate mass and molar concentration (in g/dm<sup>3</sup> or mol/dm<sup>3</sup>) in order to make a solution of defined molar concentration (<math>n = cv</math>).</li> <li>• How to perform calculations for acid-base titrations, based on mean titres, using <math>n = cv</math> and <math>n = \text{mass}/M_r</math>.</li> <li>• The relationship between volume of a gas and the number of moles: <ul style="list-style-type: none"> <li>○ 1 mole of gas occupies a volume of 22.4dm<sup>3</sup> at standard temperature and pressure.</li> </ul> </li> </ul>
2.3	<p><b>Molecular structure and bonding:</b></p> <ul style="list-style-type: none"> <li>• The different types of bonds including ionic, metallic and covalent and how they are formed in relation to electrons: <ul style="list-style-type: none"> <li>○ ionic bonding involves the electrostatic attraction between positive and negative ions formed by the transfer of one or more electrons from a metal to non-metal</li> <li>○ covalent bonding involves sharing of electron pairs</li> <li>○ metallic bonding forms a sea of delocalised electrons throughout the structure.</li> </ul> </li> <li>• The structure of substances in relation to ionic, metallic and covalent bonding: <ul style="list-style-type: none"> <li>○ ionic lattice as a large 3D structure containing oppositely charged ions</li> <li>○ covalent structures as simple molecules or giant covalent structures of many atoms</li> <li>○ metallic structures as an arrangement of closely packed metal ions with a sea of delocalised electrons.</li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>• The relationship between the electron pair repulsion theory and the shapes of the following molecules: <ul style="list-style-type: none"> <li>○ linear: 2 electron pairs repel to be 180° apart</li> <li>○ tetrahedral: 4 electron pairs repel to be 109.5° apart</li> <li>○ trigonal planar: 3 electron pairs repel to be 120° apart.</li> </ul> </li> <li>• The effect of structure and bonding on a range of properties including: <ul style="list-style-type: none"> <li>○ solubility and dissolution</li> <li>○ ionic substances tend to be soluble in polar solvents like water</li> <li>○ metallic substances tend to be insoluble</li> <li>○ simple covalent substances can be soluble, polar molecules tend to be soluble in polar solvents and non-polar molecules tend to be soluble in non-polar solvents.</li> </ul> </li> <li>• Electrical conductivity: <ul style="list-style-type: none"> <li>○ ionic substances conduct electricity only if molten or dissolved</li> <li>○ metallic substances conduct electricity even as solids</li> <li>○ simple covalent substances do not conduct electricity.</li> </ul> </li> <li>• Melting/boiling point: <ul style="list-style-type: none"> <li>○ ionic substances have high melting and boiling points</li> <li>○ metallic substances have high melting and boiling points</li> <li>○ simple covalent substances have low melting and boiling points.</li> </ul> </li> </ul>
2.4	<p><b>Organic Chemistry:</b></p> <ul style="list-style-type: none"> <li>• How to apply the International Union of Pure and Applied Chemistry (IUPAC) rules to name the following organic compounds: <ul style="list-style-type: none"> <li>○ straight chain alkanes and cycloalkanes: <ul style="list-style-type: none"> <li>– methane, ethane, propane, butane, cyclopropane and cyclobutane</li> </ul> </li> <li>○ straight chain alkenes: <ul style="list-style-type: none"> <li>– ethene, propene, butene and pentene</li> </ul> </li> <li>○ alcohols: <ul style="list-style-type: none"> <li>– methanol, ethanol, propan-1-ol, propan-2-ol, butan-1-ol and butan-2-ol</li> </ul> </li> <li>○ carboxylic acids: <ul style="list-style-type: none"> <li>– methanoic acid, ethanoic acid, propanoic acid and butanoic acid</li> </ul> </li> <li>○ aldehydes and ketones: <ul style="list-style-type: none"> <li>– ethanal, propanal, propanone and butanone</li> </ul> </li> <li>○ amines: <ul style="list-style-type: none"> <li>– ethylamine and propylamine.</li> </ul> </li> </ul> </li> <li>• The word and symbol equations to show reactions of the following organic compounds: <ul style="list-style-type: none"> <li>○ alkenes (ethene, propene, butene and pentene): <ul style="list-style-type: none"> <li>– reactions with bromine, hydrogen bromide and hydrogen</li> </ul> </li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>○ alcohols (methanol, ethanol, propanol and butanol): <ul style="list-style-type: none"> <li>- combustion</li> <li>- oxidation to a ketone or carboxylic acid with the use of [O] as the oxidising agent.</li> </ul> </li> <li>● The possible uses of the following techniques used during organic synthesis: <ul style="list-style-type: none"> <li>○ refluxing – used for long reactions with volatile components</li> <li>○ recrystallisation – used for purifying a substance</li> <li>○ separating funnel – used for separating and purifying a substance.</li> </ul> </li> </ul>
2.5	<p><b>Oxidation and reduction:</b></p> <ul style="list-style-type: none"> <li>● The oxidation and reduction process: <ul style="list-style-type: none"> <li>○ oxidation: <ul style="list-style-type: none"> <li>- gaining oxygen: oxidising agents providing oxygen</li> <li>- losing hydrogen: oxidising agents removing hydrogen</li> <li>- losing electrons: oxidising agents removing electrons</li> </ul> </li> <li>○ reduction: <ul style="list-style-type: none"> <li>- losing oxygen: reducing agents removing oxygen</li> <li>- gaining hydrogen: reducing agents providing hydrogen</li> <li>- gaining electrons: reducing agents providing electrons</li> </ul> </li> <li>○ redox: <ul style="list-style-type: none"> <li>- where reduction and oxidation happen in the same reaction.</li> </ul> </li> </ul> </li> <li>● How to use standard electrode potentials to determine the direction of electron flow in electrochemical cells: <ul style="list-style-type: none"> <li>○ electrode that is relatively more negative (oxidation half-cell) will release electrons more readily and electrons will flow from this electrode.</li> </ul> </li> </ul>
2.6	<p><b>Enthalpy and entropy:</b></p> <ul style="list-style-type: none"> <li>● The definition of enthalpy and entropy: <ul style="list-style-type: none"> <li>○ enthalpy change is the amount of energy taken in or given out in a reaction at constant pressure</li> <li>○ entropy is a measure of disorder in how energy is dispersed in a system.</li> </ul> </li> <li>● How to calculate free energy change to link enthalpy and entropy: <ul style="list-style-type: none"> <li>○ using the Gibbs equation (<math>\Delta G = \Delta H - T \Delta S</math> system)</li> <li>○ factors that affect the stability of compounds and the chance of chemical reactions occurring: <ul style="list-style-type: none"> <li>○ the stability of compounds: <ul style="list-style-type: none"> <li>- depends on their internal energy</li> <li>- the lower the internal energy the more stable a compound is</li> </ul> </li> <li>○ the chance of chemical reactions occurring: <ul style="list-style-type: none"> <li>- depends on the free energy change (<math>\Delta G</math>)</li> <li>- a negative value for free energy means the reaction is likely to be feasible at that temperature.</li> </ul> </li> </ul> </li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>• How to apply Hess's cycles, including both calculation from existing cycles and experimental design to determine enthalpy changes: <ul style="list-style-type: none"> <li>○ Hess's cycle and its significance</li> <li>○ Hess cycles (enthalpy cycles)</li> <li>○ unknown enthalpy changes using Hess's cycle</li> <li>○ enthalpy data in Hess cycle calculations</li> <li>○ experiments to determine enthalpy changes indirectly</li> <li>○ sources of error in enthalpy experiments.</li> </ul> </li> <li>• How to perform calculations of enthalpy changes: <ul style="list-style-type: none"> <li>○ from an existing Hess cycle: <ul style="list-style-type: none"> <li>– calculate the sum of the enthalpy changes for each reaction on the indirect route for the chosen reaction (reversing the sign for reactions that are reversed)</li> <li>– students are not expected to know definitions of enthalpy changes, such as enthalpy change of formation and enthalpy change of combustion.</li> </ul> </li> <li>○ bond enthalpy values: <ul style="list-style-type: none"> <li>– add up the bond enthalpies for the reactants (gives a positive value, as bond breaking is endothermic)</li> <li>– add up the bond enthalpies for products (gives a negative value, as bond making is exothermic)</li> <li>– add the enthalpies for bond breaking to bond making (keeping their original signs).</li> </ul> </li> </ul> </li> </ul>
2.7	<p><b>Materials science:</b></p> <ul style="list-style-type: none"> <li>• How the properties of the following materials are related to their applications: <ul style="list-style-type: none"> <li>○ synthetic polymers: <ul style="list-style-type: none"> <li>– properties: electrical insulator, lightweight, chemically unreactive</li> <li>– applications: examples could include – personal protective equipment (PPE) is chemically unreactive yet lightweight, non-stick coating and containers are chemically unreactive</li> </ul> </li> <li>○ alloys: <ul style="list-style-type: none"> <li>– properties: strong, lightweight, resistant to corrosion</li> <li>– applications: examples could include – machine parts are strong but lightweight, lab benching and fume cupboards are strong but resistant to corrosion</li> </ul> </li> <li>○ composites: <ul style="list-style-type: none"> <li>– properties: strong, lightweight</li> <li>– applications: examples could include – structures are strong, electronic screens are lightweight yet still strong.</li> </ul> </li> </ul> </li> </ul>
2.8	<p><b>The definitions and the characteristics of:</b></p> <ul style="list-style-type: none"> <li>• Addition polymerisation: <ul style="list-style-type: none"> <li>○ definition: a polymer made of monomers without generation of other products</li> <li>○ characteristics: high atom economy.</li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>• Condensation polymerisation: <ul style="list-style-type: none"> <li>○ definition: polymer made by chemical reaction producing a small molecule as a by product</li> <li>○ characteristics: lower atom economy.</li> </ul> </li> </ul>
2.9	<p><b>Metabolic pathways and bioenergetics:</b></p> <ul style="list-style-type: none"> <li>• The differences between anabolic and catabolic pathways in terms of energy change: <ul style="list-style-type: none"> <li>○ anabolic pathways: pathways that require energy to synthesise larger molecules (for example, synthesis of proteins from amino acids)</li> <li>○ catabolic pathways: pathways that release energy by breaking down complex molecules to simpler compounds (for example, glycolysis, Krebs cycle).</li> </ul> </li> </ul>
2.10	<p><b>The main activities and outputs of the 4 pathways of aerobic respiration involving glucose and how each of these stages is linked:</b></p> <ul style="list-style-type: none"> <li>• Glycolysis: <ul style="list-style-type: none"> <li>○ initial stage of aerobic respiration involving glucose</li> <li>○ takes place in the cytoplasm</li> <li>○ involves 10 reactions</li> <li>○ reactions at each step are catalysed by different enzymes</li> <li>○ via the hydrolysis of 2 adenosine triphosphate (ATP) molecules, converts a glucose molecule into two pyruvate molecules and transfers two hydrogen ions to nicotinamide adenine dinucleotide (NAD) forming reduced NAD</li> <li>○ energy released is sufficient for the regeneration of 2 molecules ATP.</li> </ul> </li> <li>• Link reaction Acetyl-Coenzyme A oxidation (acetyl-CoA): <ul style="list-style-type: none"> <li>○ short pathway in comparison with other pathways</li> <li>○ pyruvate (from the glycolysis pathway) diffuses from the cytoplasm to the mitochondrial matrix through active transport</li> <li>○ pyruvate is converted to acetyl-CoA.</li> </ul> </li> <li>• Krebs cycle: <ul style="list-style-type: none"> <li>○ acetyl-CoA (from the link reaction) enters the Krebs cycle</li> <li>○ the cycle involves a series of oxidation-reduction reactions that take place in the mitochondrial matrix</li> <li>○ the Krebs cycle is a closed loop; the last part of the pathway reforms the molecule used in the first step</li> <li>○ the cycle includes 8 major steps</li> <li>○ the Krebs cycle produces 2 molecules of carbon dioxide, 3 molecules of reduced NAD, 1 reduced flavin adenine dinucleotide (FAD) and 1 molecule of ATP</li> <li>○ NAD and FAD are high energy coenzyme molecules that act as hydrogen acceptors</li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>○ the Krebs cycle goes around twice for each molecule of glucose that enters cellular respiration (1 cycle for each of the two acetyl-CoA molecules produced from the two pyruvate molecules).</li> <li>● <b>Electron transport chain (ETC) and oxidative phosphorylation:</b> <ul style="list-style-type: none"> <li>○ the electron transport chain is a series of carriers and pumps found in the inner mitochondrial membranes</li> <li>○ the hydrogen acceptors, reduced NAD and reduced FAD from the Krebs cycle and link reaction transfer their hydrogen atoms to the first complex on the ETC, which split them into electrons and hydrogen ions</li> <li>○ in the process, the coenzymes can be reused in other steps of cellular respiration</li> <li>○ as electrons are passed down the redox carriers in the inner membrane, they flow from a higher to lower energy level, releasing enough energy to pump in hydrogen ions into the intermembrane space – the hydrogen ions flow through chemiosmosis through ATP synthase, providing the energy for the formation of ATP.</li> </ul> </li> </ul>
2.11	<p><b>The main activities and outputs of beta oxidation and the role of beta-oxidation in aerobic respiration when an alternative initial substrate is used:</b></p> <ul style="list-style-type: none"> <li>● <b>Beta-oxidation:</b> <ul style="list-style-type: none"> <li>○ lipid is used as a respiratory substrate when carbohydrate levels are low; in aerobic respiration, beta-oxidation becomes the first pathway, rather than glycolysis</li> <li>○ lipid is first split into its constituent molecules of glycerol and fatty acids</li> <li>○ the pathway then involves the breakdown of the fatty acids into acetyl-Coa which can enter the Krebs cycle</li> <li>○ the 4 reactions involved in this pathway are repeated until the entire fatty acid chain has been converted into individual acetyl-CoA molecules.</li> </ul> </li> </ul>
2.12	<p><b>How metabolic pathways are regulated by enzymes and feedback mechanisms:</b></p> <ul style="list-style-type: none"> <li>● Enzymes both catalyse reactions in metabolic pathways and are key to the regulation of the reactions in the metabolic pathways.</li> <li>● Enzymes are inhibited by certain substances known as inhibitors.</li> <li>● If the substance which inhibits an enzyme is a substrate or intermediate product in a pathway reaction, this sets up a feedback system to regulate the pathway. <ul style="list-style-type: none"> <li>○ examples: <ul style="list-style-type: none"> <li>– phosphofructokinase (PFK) is an important enzyme in glycolysis; it is inhibited by several substrates, including ATP</li> <li>– citrate synthase is responsible for the rate of reaction in the first step of the Krebs cycle; it is inhibited by high concentrations of ATP, acetyl-CoA and reduced NAD.</li> </ul> </li> </ul> </li> </ul>

2.13	<p><b>Genotyping and phenotyping:</b></p> <ul style="list-style-type: none"> <li>• The differences between genotyping and phenotyping: <ul style="list-style-type: none"> <li>○ genotyping determines the sequence of nucleotide bases, which can be used to determine the presence of specific genes, regulating sequences and abnormalities that could result in a disease/disorder</li> <li>○ genotyping is used to determine the differences or similarities between samples of DNA</li> <li>○ phenotyping is the process of predicting physical appearance based on genotyping</li> <li>○ phenotyping is used within forensics to indicate characteristics such as ethnicity, sex, eye colour and hair colour.</li> <li>○ advantages and disadvantages of using genotyping and phenotyping.</li> </ul> </li> </ul>
2.14	<p><b>How to determine genotype through investigating deoxyribonucleic acid (DNA) sequencing, using genotyping techniques such as polymerase chain reaction (PCR):</b></p> <ul style="list-style-type: none"> <li>• PCR is the replication of DNA in a test tube.</li> <li>• A sample of target DNA is heated to its melting point to break the bonds between DNA strands and separate these into single strands.</li> <li>• The solution is cooled and the enzyme DNA polymerase, nucleotides and primers are added; the process of DNA amplification is initiated.</li> <li>• Further heating takes place and the DNA polymerase catalyses the synthesis of complementary strand for each of the single DNA strands.</li> <li>• The process is repeated until sufficient DNA is produced to determine genotype.</li> <li>• Advantages and disadvantages of using PCR a laboratory technique.</li> </ul>
2.15	<p><b>Nanoscience and nanotechnology:</b></p> <ul style="list-style-type: none"> <li>• The considerations that need to be made when manipulating matter whose basic components are of a nanoscale size: <ul style="list-style-type: none"> <li>○ the scale of the particles</li> <li>○ exposure limits</li> <li>○ using specialised equipment (for example, atomic force microscope)</li> <li>○ appropriately trained personnel.</li> </ul> </li> </ul>
2.16	<p><b>Electronics:</b></p> <ul style="list-style-type: none"> <li>• The difference between analogue and digital signals: <ul style="list-style-type: none"> <li>– analogue signals are continuous</li> <li>– digital signals are discrete.</li> </ul> </li> <li>• How analogue signals are converted to digital signals so that computers can further interpret them: <ul style="list-style-type: none"> <li>– the analogue signal is first converted into binary code and then into a digital signal.</li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>• The advantage of using a digital signal over an analogue signal: <ul style="list-style-type: none"> <li>○ to improve accuracy by reducing the effect of noise and interference.</li> </ul> </li> <li>• The advantages of using analogue sensors to detect physical inputs and convert them to digital readouts (for example, in a pH probe or temperature probe): <ul style="list-style-type: none"> <li>○ analogue sensors are more precise, with higher resolution</li> <li>○ analogue sensors measure continuously.</li> </ul> </li> </ul>
2.17	<p><b>Nuclear physics:</b></p> <ul style="list-style-type: none"> <li>• The properties of stable and unstable nuclei: <ul style="list-style-type: none"> <li>○ stable: a balance between the number of protons and neutrons in the nucleus</li> <li>○ unstable: an imbalance between the number of protons and neutrons in the nucleus.</li> </ul> </li> <li>• The link between mass and energy (mass energy equivalence) in nuclear fission, using <math>E = mc^2</math>.</li> </ul>

## Performance Outcome 2: Perform scientific techniques to collect experimental data adhering to regulatory and safety requirements

What skills do students need to demonstrate?	
<p><b>S2.1 Work safely in a laboratory when performing specific scientific techniques:</b></p> <ul style="list-style-type: none"> <li>• Follow SOPs (E5, M5)</li> <li>• Follow safe laboratory practice (E5, M5)</li> <li>• Use equipment appropriately (E5, M5, M10)</li> <li>• Use resources safely and efficiently (M1, M10).</li> </ul>	
<p><b>S2.2 Comply with relevant health and safety legislation and regulations, including COSHH and biosafety containment levels, when handling and disposing of solids, liquids and gases relevant for the scientific technique being performed:</b></p> <ul style="list-style-type: none"> <li>• Identify and interpret relevant health and safety legislation (E1, E3, E5, M5)</li> <li>• Correctly label, store and segregate hazardous substances (E1, E3, E5, M5)</li> <li>• Follow correct procedures for the safe handling, transfer and disposal of chemicals and biological materials (E1, E5, M5).</li> </ul>	
<p><b>S2.3 Complete a risk assessment to minimise potential hazards and risks when performing a scientific technique:</b></p> <ul style="list-style-type: none"> <li>• Identify the hazards, taking account of warning symbols and using model risk assessments (E5, M6)</li> <li>• Evaluate the risks and select control measures (E5, M5, M6)</li> <li>• Record findings, following the risk assessment and amending the control measures as necessary (E1, M5)</li> <li>• Review risk assessment and modifying method where required (E5).</li> </ul>	
<p><b>S2.4 Use appropriate PPE when performing scientific tasks:</b></p> <ul style="list-style-type: none"> <li>• Select PPE appropriate to the hazard type, task and environment (E5, M5)</li> <li>• Recognise when PPE is insufficient or inappropriate, and escalate concerns (E1, E3, E5, M5, M6)</li> <li>• Dispose of or clean PPE (E5, M5, M10).</li> </ul>	

What underpinning knowledge do students need?	
<b>K3</b>	<b>Safety, health and environmental practices in laboratory science</b>
3.1	<p><b>How health and safety practices are applied when performing scientific techniques following relevant health and safety legislation and regulations:</b></p> <p>Health and Safety Legislation</p> <ul style="list-style-type: none"> <li>• Health and Safety at Work Act 1974 <ul style="list-style-type: none"> <li>○ purpose: defines employers' responsibilities to protect the health, safety and welfare at work of employees and members of the public, and defines employees' duties to protect themselves and each other.</li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>• Management of Health and Safety at Work Regulations 1999 <ul style="list-style-type: none"> <li>○ purpose: aims to reduce the number and severity of accidents in the workplace, through assessment and management of risk.</li> </ul> </li> <li>• Personal Protective Equipment (PPE) at Work Regulations 1992 <ul style="list-style-type: none"> <li>○ purpose: defines employers' responsibilities to provide appropriate personal protective equipment (PPE) to reduce harm to employees, visitors and clients. This can include safety helmets, masks, goggles and gloves.</li> </ul> </li> <li>• Manual Handling <ul style="list-style-type: none"> <li>○ purpose: requires employers to assess and minimise the risk to employees' health involved in the manual handling, moving and positioning of an object, person or animal and workplace ergonomics.</li> </ul> </li> <li>• Control of Noise at Work Regulations 2005: <ul style="list-style-type: none"> <li>○ consider how employers can protect employees from noise including: <ul style="list-style-type: none"> <li>– generating and ensuring compliance with risk assessments</li> <li>– providing PPE (for example, ear defenders)</li> <li>– providing regular health checks for employees (for example, free hearing checks).</li> </ul> </li> </ul> </li> <li>• Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) 2013 <ul style="list-style-type: none"> <li>○ purpose: defines employers' duties to report serious workplace accidents, occupational diseases and specified dangerous occurrences ('near misses').</li> </ul> </li> </ul>
3.2	<p><b>How hazardous substances are controlled when performing scientific techniques following relevant legislation and regulations:</b></p> <ul style="list-style-type: none"> <li>• Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR): <ul style="list-style-type: none"> <li>○ find out what dangerous substances are in their workplace and what the risks are</li> <li>○ put control measures in place to either remove those risks or, where this is not possible, control them</li> <li>○ put controls in place to reduce the effects of any incidents involving dangerous substances</li> <li>○ prepare plans and procedures to deal with accidents, incidents and emergencies involving dangerous substances</li> <li>○ make sure employees are properly informed about and trained to control or deal with the risks from the dangerous substances</li> <li>○ identify and classify areas of the workplace where explosive atmospheres may occur and avoid ignition sources (from unprotected equipment, for example) in those areas, maintaining.</li> </ul> </li> <li>• Registration, Evaluation, Authorisation and Restriction of Chemicals (UK REACH): <ul style="list-style-type: none"> <li>○ provide a high level of protection of human health and the environment from the use of chemicals</li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>○ make the people who place chemicals on the market (manufacturers and importers) responsible for understanding and managing the risks associated with their use</li> <li>○ promote the use of alternative methods for the assessment of the hazardous properties of substances (for example, quantitative structure-activity relationships and read across).</li> <li>● Control of Major Accident Hazards Regulations (COMAH) 2015 is to prevent or limit: <ul style="list-style-type: none"> <li>○ the consequences of major accidents involving dangerous substances</li> <li>○ to mitigate the effects on people and the environment of those that do occur.</li> </ul> </li> <li>● Control of Substances Hazardous to Health (COSHH) Regulations 2002: <ul style="list-style-type: none"> <li>○ purpose: requirement for employers to control substances hazardous to health by reducing or preventing employees' exposure to these substances by following risk assessments.</li> </ul> </li> </ul>
3.3	<p><b>How environmental practices are applied when performing scientific techniques following relevant environmental legislation and regulations:</b></p> <p>Environmental Protection Legislation</p> <ul style="list-style-type: none"> <li>● Environmental Protection Act 1990: <ul style="list-style-type: none"> <li>○ purpose: makes provision for the improved control of pollution to the air, water and land by regulating the management of waste and the control of emissions</li> <li>○ consider the implications of breaching environmental legislation, including: <ul style="list-style-type: none"> <li>- enforcement notices</li> <li>- business closures</li> <li>- clean-up orders</li> <li>- fines</li> <li>- prison sentences</li> <li>- damage to reputation.</li> </ul> </li> </ul> </li> <li>● Special Waste Regulations 1996: <ul style="list-style-type: none"> <li>○ purpose: measures relating to the regulation and control of the transit, import and export of waste (including recyclable materials), the prevention, reduction and elimination of pollution caused by waste and the requirement for an assessment of the impact on the environment of projects likely to have significant effects on the environment.</li> </ul> </li> <li>● Hazardous Waste Regulations 2005: <ul style="list-style-type: none"> <li>○ purpose: controls the storage, transport and disposal of hazardous waste (waste stream) to ensure it is appropriately managed and any risks are minimised.</li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>• Waste Electrical and Electronic Equipment Regulations (WEEE) 2013: <ul style="list-style-type: none"> <li>○ purpose: to reduce the amount of electronic and electrical equipment incinerated or sent to landfill sites. Places onus on all businesses to correctly store and transport electrical waste.</li> </ul> </li> </ul>
3.4	<p><b>How Health, Safety and Environmental Practices are applied in the Laboratory:</b></p> <ul style="list-style-type: none"> <li>• Safe Working Practices: <ul style="list-style-type: none"> <li>○ following health and safety regulations as a legal requirement and for own wellbeing plus safety of colleagues</li> <li>○ following technical and operational procedures including standard operating procedures (SOPs)</li> <li>○ following safe laboratory practice when performing the scientific techniques</li> <li>○ following risk assessments</li> <li>○ selection of an appropriate space</li> <li>○ selecting equipment and personal protective equipment (PPE)</li> <li>○ suitable to the task (for example, suitable eye protection and gloves)</li> <li>○ maintaining excellent housekeeping (for example, washing/ autoclaving glassware effectively and storing equipment and chemicals appropriately)</li> <li>○ using resources and equipment appropriately for the scientific technique being performed (for example, keeping yourself and others safe)</li> <li>○ reporting any near misses, accidents or injuries, following the appropriate processes</li> <li>○ working to schedule, meeting deadlines and awareness of departmental dependencies.</li> </ul> </li> <li>• Safe Laboratory Technique: <ul style="list-style-type: none"> <li>○ applying safe laboratory practice when performing scientific techniques</li> <li>○ ensuring personal and colleague safety during all stages of laboratory work.</li> </ul> </li> </ul>
3.5	<p><b>How Control of Substances Hazardous to Health (COSHH) is applied when handling and disposing of solids, liquids and gasses including:</b></p> <p>Organic waste (for example, propanone).</p> <ul style="list-style-type: none"> <li>• Toxic (for example, methanol, chlorine, potassium dichromate (VI)).</li> <li>• Corrosive (for example, acid).</li> <li>• Irritants (for example, copper sulphate solution).</li> <li>• Sensitisers (for example, chromium compounds, sulphur dioxide).</li> <li>• Flammable (for example, ethanol, hydrogen).</li> <li>• Air/water sensitive materials (for example, alkali metals).</li> <li>• Compressed gases (for example, oxygen).</li> <li>• Pyrophoric (for example, magnesium).</li> </ul>

	<ul style="list-style-type: none"> <li>• Oxidising agents (for example, hydrogen peroxide).</li> <li>• Radioactive materials (for example, radioactive iodine).</li> <li>• Biohazards (for example, microorganism cultures, containment levels).</li> <li>• Serious health hazards (for example, formaldehyde).</li> <li>• Liquid nitrogen.</li> <li>• Carcinogens (for example, ninhydrin).</li> <li>• Controlled substances and controlled drugs.</li> <li>• The procedures to be followed when working with regulated substances (as defined by Control of Poisons and Explosive Precursors Regulations 2015) and controlled drugs (as defined in the Misuse of Drugs Act 1971 and the Misuse of Drugs Regulations 2001): <ul style="list-style-type: none"> <li>○ undertaking health and safety training</li> <li>○ ensuring safe and secure storage, including storage requirements and restricting personnel access</li> <li>○ undertaking inventory record-keeping</li> <li>○ following sign-in/sign-out protocols.</li> </ul> </li> <li>• The purpose of pressurised clean rooms and localised extraction and ventilation: <ul style="list-style-type: none"> <li>○ protecting individuals and materials against contamination</li> <li>○ protecting the external environment against contamination.</li> </ul> </li> </ul>
3.6	<p><b>The COSHH definition of a biohazard (biological agent):</b></p> <ul style="list-style-type: none"> <li>• The 4 hazard groups in relation to biohazards (biological agents) to include: <ul style="list-style-type: none"> <li>○ category 1: unlikely to cause human disease</li> <li>○ category 2: can cause human disease and may be a hazard to employees, unlikely to spread to the wider population and there are usually effective vaccines or other treatments available</li> <li>○ category 3: can cause human disease and may be a serious hazard to employees, it may spread to the wider population but there are usually effective vaccines or other treatments available</li> <li>○ category 4: causes severe human disease and is a serious hazard to employees, it is likely to spread to the wider population and there are usually no effective vaccines or other treatments available.</li> </ul> </li> </ul>
3.7	<p><b>The potential implications of not adhering to COSHH regulations when dealing with biohazards (biological agents):</b></p> <ul style="list-style-type: none"> <li>• Risks to employees' health to include short and long-term effects of infection.</li> <li>• Risks to the wider population to include disease spread.</li> <li>• Risks to the environment to include vegetation, water supply, soil.</li> <li>• The containment measures used in relation to the 4 hazard groups: <ul style="list-style-type: none"> <li>○ levels of personal protective equipment (PPE)</li> <li>○ laboratory location, access and controls</li> <li>○ required laboratory facilities (for example, HEPA filters, showers)</li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>○ complying with specific waste disposal regulations (for example, chemical decontamination or autoclaving).</li> </ul>
3.8	<p><b>How to use resources efficiently when performing scientific techniques:</b></p> <ul style="list-style-type: none"> <li>● Energy (for example, heating to a required temperature and not above).</li> <li>● Water (for example, recycling of water).</li> <li>● Waste (for example, using re-usable equipment).</li> </ul>
3.9	<p><b>The purpose of material safety data sheets and associated hazard and precautionary codes:</b></p> <ul style="list-style-type: none"> <li>● To contain the information necessary to allow employers to do a risk assessment, as required by the Control of Substances Hazardous to Health Regulations (COSHH), when handling certain chemicals.</li> <li>● Consider the importance of ensuring that material data sheets are kept up to date, in line with relevant legislation, when: <ul style="list-style-type: none"> <li>○ new hazard information, or information that may affect risk management measures, becomes available</li> <li>○ a substance or mixture is classified according to the classification, labelling and packaging of substances and mixtures (CLP) regulation</li> <li>○ an authorisation under REACH is granted or refused</li> <li>○ a restriction under REACH has been imposed.</li> </ul> </li> </ul>
3.10	<p><b>The steps required to carry out a risk assessment:</b></p> <ul style="list-style-type: none"> <li>● Step 1 – identifying the hazards, taking account of warning symbols and using model risk assessments: <ul style="list-style-type: none"> <li>○ chemical (for example, compressed gases, cleaning agents)</li> <li>○ biological (for example, biological samples)</li> <li>○ physical (for example, repetitive tasks, noise levels).</li> </ul> </li> <li>● Step 2 – assessing the risks: <ul style="list-style-type: none"> <li>○ how likely is the scientific technique to go wrong?</li> <li>○ who might be harmed?</li> <li>○ what could be the consequences?</li> </ul> </li> <li>● Step 3 – evaluating the risks and selecting control measures: <ul style="list-style-type: none"> <li>○ identifying alternate or safer methods than those proposed (for example, using a different concentration of chemicals)</li> <li>○ identifying the appropriate PPE to use.</li> </ul> </li> <li>● Step 4 – recording findings, following the risk assessment and amending the control measures as necessary: <ul style="list-style-type: none"> <li>○ in a clear and unambiguous way</li> <li>○ using technical language correctly</li> <li>○ organising the findings logically and coherently</li> <li>○ using the appropriate vocabulary, spelling and grammar.</li> </ul> </li> <li>● Step 5 – reviewing risk assessment and modifying method where required.</li> </ul>

### What skills do students need to demonstrate?

#### **S2.5 Adhere to ethical practice and codes of conduct to ensure confidentiality and meet intellectual property (IP) requirements**

- Apply confidentiality protocols when handling sensitive data, ensuring secure storage and anonymisation where appropriate (E5, M5, D1, D5)
- Recognise and respect intellectual property rights by attributing sources accurately and avoiding plagiarism (E4, E5, D1, D2, D3, D5)
- Follow ethical guidelines (E5, M5)
- Follow professional codes of conduct and escalate concerns about ethical breaches or misuse of IP through appropriate channels (E4, E5, D1, D2, D3, D5).

### What underpinning knowledge do students need?

K4	Ethics
4.1	<p><b>The principles of the ‘Universal Ethical Code for Scientists 2007’ and how it affects ethical practices in a laboratory setting:</b></p> <ul style="list-style-type: none"><li>• Rigour:<ul style="list-style-type: none"><li>○ acting with skill and care in all scientific work</li><li>○ maintaining up-to-date skills and assisting with their development in others</li><li>○ taking steps to prevent corrupt practices and professional misconduct</li><li>○ declaring conflicts of interest</li><li>○ being alert to the ways in which research derives from and affects the work of other people, and respecting the rights and reputations of others.</li></ul></li><li>• Respect:<ul style="list-style-type: none"><li>○ ensuring that your work is lawful and justified</li><li>○ minimising and justifying any adverse effect your work may have on people, animals and the natural environment</li><li>○ promoting equality and supporting diversity</li><li>○ minimising conflict and stress</li><li>○ increasing productivity and job satisfaction</li><li>○ inspiring individuals to be loyal to the organisation and each other.</li></ul></li><li>• Responsibility:<ul style="list-style-type: none"><li>○ seeking to discuss the issues that science raises for society</li><li>○ listening to the aspirations and concerns of others</li><li>○ not knowingly misleading, or allowing others to be misled, about scientific matters</li><li>○ presenting and reviewing scientific evidence, theory honestly and accurately</li><li>○ maintaining high quality ethical and professional standards including objectivity, clarity, reproducibility</li></ul></li></ul>

	<ul style="list-style-type: none"> <li>○ following organisational codes of practice</li> <li>○ following regulatory guidance</li> <li>○ aspiring to excel, not just meet the minimum standards.</li> </ul>
4.2	<p><b>Ethical issues and wider implications of scientific practices:</b></p> <ul style="list-style-type: none"> <li>● Misusing or misinterpreting published research.</li> <li>● Conducting unethical research (for example, with human tissue samples).</li> </ul>
4.3	<p><b>The importance of adhering to codes of conduct to ensure confidentiality:</b></p> <ul style="list-style-type: none"> <li>● To avoid improper disclosure of information and data that could harm the science organisation or individuals within it.</li> <li>● To avoid accidental loss or release of sensitive information or data.</li> <li>● To comply with regulatory requirements and guidance.</li> </ul>
4.4	<p><b>The importance of adhering to codes of conduct to protect intellectual property:</b></p> <ul style="list-style-type: none"> <li>● Intellectual property <ul style="list-style-type: none"> <li>○ theories/ideas</li> <li>○ papers/research</li> <li>○ experimental results and design</li> <li>○ bespoke equipment</li> <li>○ anything with a potentially commercial application (including product/formulation/recipe, software, apps).</li> </ul> </li> <li>● To avoid sharing commercially sensitive information and research through improper disclosure.</li> <li>● To avoid accidental loss or release of sensitive information and research.</li> <li>● To respect the intellectual property of other scientists' work.</li> </ul>

<b>What skills do students need to demonstrate?</b>
<p><b>S2.6 Adhere to all procedures to ensure compliance with all relevant regulations and quality standards when conducting scientific techniques, including GLP and GMP</b></p> <ul style="list-style-type: none"> <li>● Follow documented procedures precisely to ensure compliance with relevant regulations and quality standards, including GLP and GMP (E5, M5)</li> <li>● Maintain accurate, legible and timely records to support traceability, audit readiness and regulatory integrity (E5, M8)</li> <li>● Identify and report deviations from approved protocols or standards, following escalation procedures to uphold scientific and regulatory accountability (E5, M5).</li> </ul>

**S2.7 Follow Standard Operating Procedures where applicable when performing scientific techniques**

- Follow each step of the SOP precisely, maintaining consistency and minimising variation in technique or outcome (E5, M5)
- Ensure procedural accuracy and compliance (E5, M1, M5, M10)
- Record actions and observations in alignment with SOP requirements to support traceability, reproducibility and quality assurance (E5, M5, M6, M8, M10).

**S2.8 Follow SOPs to ensure compliance with regulations and quality standards when performing scientific techniques**

- Adherence to written SOPs for all stages of a scientific technique (E5, M1, M2, M3, M4, M5, M6)
- Application of regulatory, legislative and quality-assurance requirements when following SOPs (E1, E3, E5, M5, M6).

**What underpinning knowledge do students need?**

K5	Legislation, regulations, standards and guidelines
5.1	<p><b>How the following regulations are applied when performing scientific techniques in a laboratory environment:</b></p> <ul style="list-style-type: none"> <li>• Good laboratory practice (GLP):               <ul style="list-style-type: none"> <li>○ requires all techniques that are performed are of high quality, following standard operating procedures</li> <li>○ requires that all techniques performed and results obtained demonstrate uniformity, consistency, reliability, traceability and reproducibility</li> <li>○ requires accurate record-keeping</li> <li>○ often results in automated approaches being implemented within a laboratory setting.</li> </ul> </li> <li>• Good manufacturing practice (GMP):               <ul style="list-style-type: none"> <li>○ requires that all products produced within a laboratory are of high quality</li> <li>○ requires all batches of products to be of consistent quality</li> <li>○ are appropriate for their intended use</li> <li>○ meeting the requirements of the product specification</li> <li>○ requires that all products are safe to use, uncontaminated and effective.</li> </ul> </li> <li>• Quality management systems (QMSs):               <ul style="list-style-type: none"> <li>○ ensures processes and procedures within a laboratory setting are undertaken in specific ways to guarantee the highest level of accuracy and reliability</li> <li>○ are applied across all steps of activity within a laboratory setting, including documentation requirements, use of equipment and chemicals, as well as requirements for staff training ensures that decisions within a laboratory setting are data-driven.</li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>• Good clinical practice (GCP): <ul style="list-style-type: none"> <li>○ requires that all clinical research be performed to international ethical (including confidentiality), scientific and practical standards.</li> </ul> </li> </ul>
5.2	<p><b>The role of the following standards and regulatory bodies (including industry specific) within a laboratory environment:</b></p> <ul style="list-style-type: none"> <li>• United Kingdom Accreditation Service (UKAS).</li> <li>• ASTM International.</li> <li>• International Organisation for Standardisation (ISO).</li> <li>• British Pharmacopoeia.</li> <li>• Medicines and Healthcare products Regulatory Agency (MHRA).</li> <li>• Food and Drug Administration (FDA).</li> <li>• European Medicines Agency (EMA).</li> <li>• Office for Nuclear Regulation (ONR).</li> </ul>
5.3	<p><b>The purpose and importance of SOPs within a laboratory environment:</b></p> <ul style="list-style-type: none"> <li>• Maintaining health and safety by detailing all relevant health and safety requirements (for example, when using hazardous materials).</li> <li>• Enabling consistency of approach across all technicians.</li> <li>• Meeting any legal or organisational requirements (for example, safe storage of controlled materials).</li> <li>• Demonstrating compliance for audit purposes requirements reporting to regulators as appropriate (for example, using standard documentation).</li> <li>• Being adequately trained including knowing the relevant legislation, holding relevant licenses that apply to a specific occupation.</li> </ul>
5.4	<p><b>How to minimise risk of security breach:</b></p> <ul style="list-style-type: none"> <li>• Physical security (for example, locked doors, opaque glass, individual workstations).</li> <li>• Electronic security (for example, controlled access systems, video surveillance).</li> <li>• Operational security (for example, sign-in sheets, restricted access, following non- disclosure policies).</li> <li>• Information security (for example, passwords, back-up systems, recording results securely by using a permanent bound lab book and having each page).</li> </ul>
5.5	<p><b>The importance of using appropriate reagents and raw materials to complete practical scientific tasks, considering factors such as:</b></p> <ul style="list-style-type: none"> <li>• Sources and suppliers (for example, using reputable suppliers to ensure quality).</li> <li>• Handling and storage (for example, adhering to expiry date to ensure integrity).</li> <li>• Quality control and assurance of raw materials and reagents (for example, ensuring reagents meet the standards of those previously used, such as appropriate purity).</li> </ul>

<b>What skills do students need to demonstrate?</b>
<p><b>S2.9 Follow multistep scientific methods (for example, make a defined molar concentration and perform a titration) based on relevant SOPs when performing a range of practical scientific techniques.</b></p> <p style="text-align: right;"><b>(E5, M1, M3, M5, M7, M10, D3)</b></p>
<p><b>S2.10 Apply a range of science and mathematical skills when performing practical scientific techniques</b></p> <ul style="list-style-type: none"> <li>• Measuring (M1, M2, M4, M5, M6)</li> <li>• Manual dexterity (M1, M6)</li> <li>• Observing (M1, M2, M3)</li> <li>• Quantifying (E5, M1, M2, M3, M4, M5, M6, M10, D4)</li> <li>• Predicting (E5, M2, M5, M6)</li> <li>• Analysing (M5, M6, M7, M8, D4)</li> <li>• Evaluating (E1, E2, E3, E4, E5, M6, M7, M8, D2, D3, D4).</li> </ul>
<p><b>S2.11 Use appropriate practical scientific techniques to measure a range of physical properties such as polarity, temperature, pressure, conductivity and radioactivity</b></p> <ul style="list-style-type: none"> <li>• Pressure using a U-tube manometer (E5, M1, M2, M3, M4, M5, M6)</li> <li>• Temperature using a probe and data logger (E5, M1, M2, M3, M4, M5, M6)</li> <li>• Radioactive count rate using Geiger counter (E5, M1, M2, M3, M4, M5, M6)</li> <li>• Conductivity meter to measure conductivity of a solution (E5, M1, M2, M3, M4, M5, M6)</li> <li>• Electrical polarity using an ammeter and a voltmeter (E5, M1, M2, M3, M4, M5, M6).</li> </ul>
<p><b>S2.12 Use appropriate practical scientific techniques to analyse substances and identify microorganisms within biological environments:</b></p> <ul style="list-style-type: none"> <li>• Aseptic culturing (E5, M1, M2, M3, M4, M5, M6)</li> <li>• Differential staining techniques (E5, M1, M2, M3, M4, M5, M6).</li> </ul>
<p><b>S2.13 Use practical scientific techniques to analyse environments and identify microorganisms with biological environments:</b></p> <ul style="list-style-type: none"> <li>• Aseptic sampling and culturing in environmental contexts (E5, M1, M2, M3, M4, M5, M6)</li> <li>• Environmental differential staining or indicator-based techniques (E5, M1, M2, M3, M4, M5, M6).</li> </ul>
<p><b>S2.14 Use practical scientific techniques to prepare, isolate and separate materials paper and thin layer chromatography:</b></p> <ul style="list-style-type: none"> <li>• Applying sample onto chromatogram (E5, M1, M2, M3, M4, M5, M6)</li> <li>• Distillation (E5, M1, M2, M3, M4, M5, M6)</li> <li>• Filtration (for example, vacuum and fluted) (E5, M1, M2, M3, M4, M5, M6)</li> <li>• Refluxing (E5, M1, M2, M3, M4, M5, M6).</li> </ul>

**S2.15 Prepare a solution of defined molar concentration:**

- Calculating the relative molecular mass for the concentration needed ( $n = cV$ ) (E5, M1, M2, M3, M4, M5, M6)
- Using a balance and volumetric flask correctly (M1, M2, M3, M4, M5, M6)
- Ensuring the transfer of all solid and liquid without spilling (E5, M1, M2, M3, M4, M5, M6)
- Rinsing equipment into volumetric flask (E5, M1, M2, M3, M4, M5, M6).

**S2.16 Use appropriate international system of units (SI) and be able to work with a range of appropriate scales when conducting scientific tasks:**

- Accurately select and apply SI (E5, M1, M3, M4, M5)
- Use appropriate measurement tools and techniques to obtain values across a range of scales, ensuring precision and reliability in scientific tasks. (E5, M1, M2, M3, M4, M5, M10).

**S2.17 Convert between SI and non-SI measurement units when conducting scientific tasks:**

- Convert between different units and scales, including milli-, micro-, and nano-prefixes, to ensure accuracy and consistency in calculations and data interpretation (M3, M4, M5, M6).

**S2.18 Follow a method from a scientific paper when performing a technique:**

- Selecting key information from a method or scientific paper and summarising for use in performing the scientific technique (E1, E2, E3, E4, E5, M5, M6, M7, M8, D3)
- Selecting relevant facts from the scientific paper (E1, E2, E3, E4, E5, M5, M6, M7, M8, D3).

**S2.19 Select appropriate equipment to complete practical scientific techniques:**

- Evaluate the requirements of the scientific procedure and choose equipment (E5, M1, M2, M3, M4, M5, M6, M10).

**S2.20 Demonstrate practical technical competence in the use of equipment:**

- Take accurate measurements (E5, M1, M3, M6, M10)
- Correctly manipulating the equipment (M1, M2, M3, M6, M10)
- Using equipment safely and for intended purpose (E5, M1, M5, M10).

**S2.21 Calibrate scientific equipment and check it is fit for use:**

- Identify and select suitable equipment and materials based on the requirements of the scientific technique (E5, M1, M2, M3, M6)
- Justify the choice of equipment by considering factors such as sensitivity, precision, scale, and compatibility with the procedure being performed (E1, E3, E5, M1, M2, M5, M6, D3).

**S2.22 Produce data from scientific techniques, which are reliable and verifiable:**

- Recording data and records (M1, M4, M8, D1, D2, D3, D4)
- Selecting and using appropriate digital technology (M1, M4, M8, D1, D2, D3, D4)
- Critically reviewing data obtained and repeating investigations where appropriate (E4, E5, M1, M2, M3, M4, M5, M6, M7, M8, M10).

**S2.23 Record data and records of work undertaken in a clear and accurate manner:**

- Accurately record experimental observations and measurements (M5, M6, M7, M8)
- Maintain up-to-date and organised records of work undertaken (E1, E2, E3, E4, E5, M5, M6, M7, M8).

**What underpinning knowledge do students need?**

<b>K6</b>	<b>Scientific tasks</b>
6.1	<p><b>How to select information from a practical plan, method, paper or SOP:</b></p> <ul style="list-style-type: none"> <li>• Identify and extract key procedural steps from a practical plan, method or SOP.</li> <li>• Recognise essential actions, measurements and equipment required to perform the technique.</li> <li>• Distinguish between critical steps and contextual or background information.</li> <li>• Interpret technical terminology, units and formats accurately to ensure correct application or comparison.</li> </ul>
6.2	<p><b>How scientific and maths skills are applied when performing a range of scientific techniques:</b></p> <ul style="list-style-type: none"> <li>• Measuring               <ul style="list-style-type: none"> <li>○ volume using a burette</li> <li>○ mass on a 3-Decimal Place (DP) balance (analytical or top pan balance).</li> </ul> </li> <li>• Manual dexterity               <ul style="list-style-type: none"> <li>○ when using a pipette</li> <li>○ performing aseptic technique</li> <li>○ setting up a microscope.</li> </ul> </li> <li>• Observing               <ul style="list-style-type: none"> <li>○ colour changes at titration end point</li> <li>○ microscopic observations.</li> </ul> </li> <li>• Quantifying               <ul style="list-style-type: none"> <li>○ cell counts</li> <li>○ abundance of organisms in an ecosystem.</li> </ul> </li> <li>• Predicting               <ul style="list-style-type: none"> <li>○ melting and boiling points</li> <li>○ possible components of a mixture in chromatography.</li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>• Analysing <ul style="list-style-type: none"> <li>○ trend charts</li> <li>○ calculations</li> <li>○ statistical analysis.</li> </ul> </li> <li>• Evaluating <ul style="list-style-type: none"> <li>○ evaluating the success of the scientific method.</li> </ul> </li> </ul>
6.3	<p><b>The factors to consider when choosing between a range of scientific techniques:</b></p> <ul style="list-style-type: none"> <li>• Health, safety and ethical considerations.</li> <li>• Equipment availability and cost.</li> <li>• Substance/sample to be investigated.</li> <li>• Strengths and limitations of the technique.</li> <li>• Objective of the investigation.</li> </ul>
6.4	<p><b>The purpose of:</b></p> <ul style="list-style-type: none"> <li>• Analysing substances and chemical environments: <ul style="list-style-type: none"> <li>○ to confirm composition and/or quantity of materials.</li> </ul> </li> <li>• Micro and nanoscience: <ul style="list-style-type: none"> <li>○ to analyse matter on an atomic, molecular and supramolecular scale.</li> </ul> </li> </ul>
6.5	<p><b>When it is appropriate to use the following techniques to identify/determine, separate or analyse substances and environments:</b></p> <ul style="list-style-type: none"> <li>• Calorimetry to analyse energy changes in chemical reactions.</li> <li>• Characterisation using mass spectrometry to identify compounds and infrared spectroscopy to identify functional groups.</li> <li>• Colorimetry to determine concentration.</li> <li>• Chromatography to separate and therefore identify the components of a mixture.</li> <li>• Distillation to separate the components of a mixture.</li> <li>• Filtration (for example, vacuum and fluted) to separate insoluble components of a mixture.</li> <li>• Electrolysis to separate compounds (for example, chlorine gas from chlorine compounds).</li> </ul>
6.6	<p><b>How scientific and maths skills are applied when calibrating scientific equipment:</b></p> <ul style="list-style-type: none"> <li>• Calibrate scientific equipment and check it is fit for use: <ul style="list-style-type: none"> <li>○ pH meters: <ul style="list-style-type: none"> <li>– using buffer solutions</li> </ul> </li> <li>○ balances: <ul style="list-style-type: none"> <li>– using calibration masses</li> </ul> </li> <li>○ mechanical (variable volume) pipette: <ul style="list-style-type: none"> <li>– using distilled water and balances</li> </ul> </li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>○ pressure using a U-tube manometer: <ul style="list-style-type: none"> <li>– setting up the manometer vertically</li> <li>– opening one tube to the atmosphere or attaching to gas supply</li> <li>– measuring the height difference in the U-tube</li> </ul> </li> <li>○ temperature using a probe and data logger: <ul style="list-style-type: none"> <li>– attaching the probe to data logger</li> <li>– inserting the probe into substance to be tested</li> <li>– taking the reading from data logger</li> </ul> </li> <li>○ radioactive count rate using Geiger counter: <ul style="list-style-type: none"> <li>– measuring the background count rate</li> <li>– measuring the count rate for a defined period of time, using shielding if appropriate</li> <li>– conductivity meter to measure conductivity of a solution</li> <li>– calibrating the equipment with a solution of known conductivity</li> <li>– rinsing the probe with deionised water and then inserting into test solution</li> <li>– rinsing further between subsequent readings including repeats</li> <li>– electrical polarity using an ammeter and a voltmeter</li> <li>– setting up the circuit with ammeter in series or voltmeter in parallel</li> <li>– noting down the sign and reading from the meter, then reversing the wires on the meter to check that the sign is opposite.</li> </ul> </li> <li>● Calibration curve <ul style="list-style-type: none"> <li>○ use calibration curve in quantitative analysis</li> <li>○ prepare standard solutions and measure their responses</li> <li>○ determine the concentration of an unknown sample</li> <li>○ identify factors affecting the accuracy and reliability of calibration curves.</li> </ul> </li> </ul>
6.7	<p><b>How to use and convert the International System of Units (SI) and scales when conducting scientific tasks:</b></p> <ul style="list-style-type: none"> <li>● Measures <ul style="list-style-type: none"> <li>○ length – metre (m)</li> <li>○ time – second (s)</li> <li>○ concentration/amount of substance – mole (mol)</li> <li>○ voltage – volts (V)</li> <li>○ electric current – ampere (A)</li> <li>○ resistance (<math>\Omega</math>)</li> <li>○ temperature – kelvin (K)</li> <li>○ mass – kilogram (kg)</li> <li>○ volume – cubic metres (m<sup>3</sup>)</li> <li>○ energy – joules (J).</li> </ul> </li> <li>● Conversion between SI and non-SI units, using appropriate factors <ul style="list-style-type: none"> <li>○ length (e.g. inch to metres)</li> <li>○ time (e.g. hours to seconds)</li> <li>○ concentration (e.g. mol per litre to mol per cubic metre)</li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>○ voltage (e.g. kilovolts to volts)</li> <li>○ electric current (e.g. milliamps to amperes)</li> <li>○ resistance (e.g. kilo-ohms to ohms)</li> <li>○ temperature (e.g. Fahrenheit to Kelvin)</li> <li>○ mass (e.g. ounces to kilograms)</li> <li>○ volume (e.g. millilitres to cubic metres)</li> <li>○ energy (e.g. calories to joules)</li> <li>○ recognise when prefixes (e.g. kilo-, milli-, micro-) affect magnitude</li> <li>○ justify unit choices in method planning and data analysis.</li> </ul>
6.8	<p><b>The purpose of electrical calorimeters:</b></p> <ul style="list-style-type: none"> <li>● To measure energy change with minimal heat loss.</li> </ul>
6.9	<p><b>Knowledge of equipment that is used to complete practical scientific techniques:</b></p> <ul style="list-style-type: none"> <li>● Measuring cylinders.</li> <li>● Light microscope.</li> <li>● Light dependant resistors (LDRs).</li> <li>● Burette.</li> <li>● Thermometers.</li> <li>● 3 Decimal Place (DP) balance (analytical or top pan).</li> <li>● Volumetric, graduated and mechanical (variable volume) pipettes.</li> <li>● Meters – ammeters, voltmeters, multi-meters.</li> <li>● Geiger counter.</li> <li>● Heating apparatus.</li> <li>● pH meters.</li> <li>● TLC plates.</li> <li>● Incubator.</li> <li>● Microbiological equipment.</li> <li>● Data loggers with temperature probe.</li> <li>● Fume cupboard.</li> <li>● Autoclave.</li> <li>● Condenser.</li> <li>● Centrifuges: to separate suspensions.</li> </ul>
6.10	<p><b>How practical scientific techniques are used to analyse substances:</b></p> <ul style="list-style-type: none"> <li>● Acid-base and redox titration <ul style="list-style-type: none"> <li>○ measuring quantity of unknown solution using a pipette</li> <li>○ determining the end point by colour change</li> <li>○ using <math>n = cV</math> to work out concentration.</li> </ul> </li> <li>● Preparation of serial dilutions <ul style="list-style-type: none"> <li>○ determining the required dilution</li> <li>○ working with proportion by applying the numerical form of proportion to reach target concentration</li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>○ measuring accurately and transferring the solution to the subsequent diluent.</li> <li>● Colorimetry: <ul style="list-style-type: none"> <li>○ selecting the appropriate filter</li> <li>○ zeroing the colorimeter using a cuvette containing the solvent only</li> <li>○ measuring the absorbance of a cuvette with test solution</li> <li>○ preparing and using Benedict's reagent for quantitative analysis of reducing sugars</li> <li>○ creating and using a calibration curve with Benedict's reagent to determine unknown sugar concentrations</li> <li>○ interpret results from colorimetric measurements involving Benedict's reagent.</li> </ul> </li> <li>● Calorimetry <ul style="list-style-type: none"> <li>○ correctly setting up the equipment (for example electrical calorimeters)</li> <li>○ measure energy change with minimal heat loss.</li> </ul> </li> <li>● Chromatography <ul style="list-style-type: none"> <li>○ correctly setting up the equipment (for example, in column chromatography and gas-liquid chromatography (GLC)).</li> </ul> </li> <li>● Spectroscopy <ul style="list-style-type: none"> <li>○ mass spectrometer</li> <li>○ infrared spectrometer</li> <li>○ nuclear magnetic resonance spectrometer.</li> </ul> </li> </ul>
6.11	<p><b>How practical scientific techniques are used to analyse environments and identify micro-organisms within biological environments:</b></p> <ul style="list-style-type: none"> <li>● Aseptic culturing: <ul style="list-style-type: none"> <li>○ sterilising equipment throughout the technique (flaming wire loop, autoclaving tools)</li> <li>○ transferring cultures quickly with minimal exposure to air</li> <li>○ holding bottles and test tubes at an angle to prevent contamination</li> <li>○ working in a sterile air environment near a Bunsen burner or laminar flow cabinet)</li> <li>○ avoiding contamination by not placing sterile objects on non-sterile surfaces</li> <li>○ to avoid contamination of products (for example, food production)</li> <li>○ to avoid transmission of disease (for example, from samples to individuals/animals)</li> <li>○ following correct handwashing procedures and wearing suitable PPE</li> <li>○ preparing and cleaning work surfaces; only having necessary equipment available</li> <li>○ minimising human traffic and airflow by closing windows and doors</li> <li>○ not consuming food or drink in the workspace</li> <li>○ disinfecting surfaces and equipment after completing the technique.</li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>• Differential staining techniques: <ul style="list-style-type: none"> <li>○ preparing the slide and introducing the smear, using aseptic technique</li> <li>○ fixing the smear (for example, heat fix)</li> <li>○ applying stains and rinses in the correct order</li> <li>○ examining the smear using a light microscope and identifying if bacteria are Gram-positive (violet in colour) or Gram-negative (pink in colour).</li> </ul> </li> <li>• Cryogenic equipment in a laboratory environment: <ul style="list-style-type: none"> <li>○ maintain the integrity of biological material.</li> </ul> </li> </ul>
6.12	<p><b>How practical scientific techniques are used to separate materials:</b></p> <ul style="list-style-type: none"> <li>○ Paper and thin layer chromatography: <ul style="list-style-type: none"> <li>○ applying sample onto chromatogram</li> <li>○ adding solvent to appropriate level (for example, below baseline)</li> <li>○ using a location agent, if appropriate (for example, iodine, UV light and ninhydrin)</li> <li>○ measuring substance from baseline.</li> </ul> </li> <li>• Distillation: <ul style="list-style-type: none"> <li>○ correctly setting up the equipment (for example, attaching condenser correctly)</li> <li>○ using appropriate heating method for sample (for example, heating mantle)</li> <li>○ reading off boiling point using correctly placed thermometer.</li> </ul> </li> <li>• Filtration (for example, vacuum and fluted): <ul style="list-style-type: none"> <li>○ correctly setting up the equipment (for example, attach aspirator correctly)</li> <li>○ choosing and preparing the appropriate size filter paper (for example, fluting if necessary)</li> <li>○ adding suspension at appropriate rate.</li> </ul> </li> <li>• Refluxing: <ul style="list-style-type: none"> <li>○ correctly setting up the equipment (for example, attaching condenser correctly)</li> <li>○ using appropriate heating method for sample (for example, heating mantle)</li> <li>○ adjusting heat and condenser for appropriate drip rate.</li> </ul> </li> </ul>
6.13	<p><b>Knowledge of laboratory techniques and the equipment required to carry out the technique, to include:</b></p> <ul style="list-style-type: none"> <li>• Knowledge of environmental laboratory techniques, such as <ul style="list-style-type: none"> <li>○ Biochemical Oxygen Demand (BOD), dissolved oxygen probe</li> <li>○ Chemical Oxygen Demand (COD), reflux equipment and calorimeter</li> <li>○ Total Organic Carbon (TOC), TOC analysers to measure CO<sub>2</sub> from organic carbon</li> <li>○ suspended solids</li> <li>○ measuring toxicology.</li> </ul> </li> </ul>

6.14	<p><b>Knowledge of laboratory techniques used in the science manufacturing environment, including but not limited to those used in the petrochemical industry and specialist and bulk manufacture of chemicals:</b></p> <ul style="list-style-type: none"> <li>• Sampling.</li> <li>• Testing.</li> <li>• Scaling up to pilot plant.</li> </ul>
6.15	<p><b>Knowledge of physics laboratory techniques in:</b></p> <ul style="list-style-type: none"> <li>○ Electronics to determine input and output voltages of logic circuits</li> <li>○ oscilloscopes: used to display time-varying signals in a graphical form</li> <li>○ search coil: used to measure magnetic flux</li> <li>○ capacitors: used as part of a circuit to store electrical charge</li> <li>○ lasers: used to look at wave patterns</li> <li>○ light gates: used to measure speed/acceleration.</li> <li>• Mechanics to determine stress (force/area) on an object under <ul style="list-style-type: none"> <li>○ tension</li> <li>○ force gauges</li> <li>○ callipers.</li> </ul> </li> <li>• Ionising radiation to determine half-value layer (HVL) of a substance <ul style="list-style-type: none"> <li>○ Geiger counter: used to detect ionising radiation.</li> </ul> </li> <li>• Electricity to determine the voltage across and current through a component <ul style="list-style-type: none"> <li>○ ammeters: used to measure current</li> <li>○ voltmeters: used to measure potential difference</li> <li>○ multimeters: used to measure voltage, current and resistance</li> <li>○ thermistors: used to change resistance with changing temperature in a circuit, used as temperature sensors</li> <li>○ light dependant resistors (LDRs): used to change resistance with changing light intensity in a circuit, used as light sensors</li> <li>○ data logger with temperature probes: used to measure changing temperature.</li> </ul> </li> <li>• Magnetism <ul style="list-style-type: none"> <li>○ to measure the magnetic flux density C.</li> </ul> </li> </ul>
6.16	<p><b>Knowledge of the purpose of the Control of Electromagnetic Fields at Work Regulations 2016:</b></p> <ul style="list-style-type: none"> <li>• To specify requirements for minimising risks of electromagnetic fields.</li> </ul>
6.17	<p><b>The implications of using devices such as radios and mobile phones in the proximity of specific equipment and instrumentation:</b></p> <ul style="list-style-type: none"> <li>• Interference.</li> <li>• Effect on reliability of results.</li> <li>• Damage to the equipment (both the scientific instrumentation and the devices).</li> </ul>

6.18	<p><b>Knowledge of cutting-edge techniques, particularly those related to genomics, including:</b></p> <ul style="list-style-type: none"> <li>• Classification.</li> <li>• Microbiology techniques.</li> <li>• Tissue culture.</li> <li>• Extraction and sequencing of DNA to identify genes.</li> <li>• Cloning, protein purification, genes and enzymes.</li> <li>• Polymerase chain reaction (PCR).</li> <li>• Gel electrophoresis.</li> <li>• Flow cytometry.</li> <li>• Raw spectroscopy (NMR) next generation sequencing.</li> </ul>
6.19	<p><b>The purpose of the following techniques, particularly those related to genomics:</b></p> <ul style="list-style-type: none"> <li>• Nuclear magnetic resonance (NMR) spectroscopy (carbon-13 and proton NMR), used to identify the presence of certain atoms and environments in a sample using electromagnetic radiation.</li> <li>• Polymerase chain reaction (PCR), used to sequence multiple copies of specific sequences of new DNA strands, complementary to a presented template strand.</li> <li>• Gel electrophoresis, used to separate DNA fragments according to their size, also used to separate other macromolecules dependent on size and charge.</li> <li>• Flow cytometry, used in genomics to determine genome size, to give an estimate of amount of nuclear content.</li> <li>• Next generation sequencing range of techniques that allow for sequencing of DNA quickly and cost effectively. These techniques enable the sequencing of thousands to millions of DNA molecules simultaneously.</li> </ul>
6.20	<p><b>Why the following techniques are used:</b></p> <ul style="list-style-type: none"> <li>• Titration (for example, purity analysis) <ul style="list-style-type: none"> <li>○ purity analysis and determining concentration.</li> </ul> </li> <li>• Preparation of serial dilutions: <ul style="list-style-type: none"> <li>○ to alter concentrations to enable analysis.</li> </ul> </li> </ul>
6.21	<p><b>How to produce and record data:</b></p> <ul style="list-style-type: none"> <li>• Demonstrate understanding of the following methods used to collect data and their suitability in science research focus groups: <ul style="list-style-type: none"> <li>○ open question surveys/interviews</li> <li>○ observation</li> <li>○ public databases</li> <li>○ analysis of journals and articles</li> <li>○ carrying out practical investigations</li> <li>○ closed question surveys</li> <li>○ official statistics.</li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>• Recording data and records in a clear and unambiguous way: <ul style="list-style-type: none"> <li>○ using appropriate units, notation and correct number of significant figures</li> <li>○ organising ideas logically and coherently.</li> </ul> </li> <li>• Selecting and using appropriate digital technology (for example, PC connected data logger, multimeter): <ul style="list-style-type: none"> <li>○ to gather data evidence efficiently (for example, using a temperature data logger instead of multiple manual recordings)</li> <li>○ to demonstrate a secure level of competence and confidence in configuring and using digital devices.</li> </ul> </li> <li>• Critically reviewing data obtained and repeating investigations where appropriate.</li> <li>• Demonstrate understanding of the considerations to make when selecting methods to collect and record information and data: <ul style="list-style-type: none"> <li>○ data type: qualitative or quantitative data</li> <li>○ the most appropriate method of data collection (manual versus automated)</li> <li>○ the most appropriate way to present the information or data including graphs, charts and tables)</li> <li>○ depth of analysis required spreadsheets and databases</li> <li>○ the intended audience</li> <li>○ storage method including digital or paper-based).</li> </ul> </li> </ul>
6.22	<p><b>Consider the advantages and risks of using IT systems to record, retrieve and store information and data:</b></p> <ul style="list-style-type: none"> <li>• Advantages: <ul style="list-style-type: none"> <li>○ ease of access</li> <li>○ ease of sharing and transferring data</li> <li>○ speed of data analysis</li> <li>○ security include password protection</li> <li>○ standardisation of data</li> <li>○ enables continuous and/or real-time monitoring of data</li> <li>○ cost and space saving</li> <li>○ enables integrated working and supports safeguarding practices.</li> </ul> </li> <li>• Risks: <ul style="list-style-type: none"> <li>○ security breaches – accidental or malicious</li> <li>○ potential for corruption of data</li> <li>○ lack of access due to system failure.</li> </ul> </li> </ul>
6.23	<p><b>Demonstrate understanding of the security measures used to protect data stored by organisations, by:</b></p> <ul style="list-style-type: none"> <li>• Controlling access to information including the levels of authorised logins and passwords).</li> <li>• Allowing only authorised staff into specific work areas.</li> <li>• Requiring regular and up-to-date staff training in complying with data security.</li> </ul>

	<ul style="list-style-type: none"> <li>• Making regular back-ups of files.</li> <li>• Using up-to-date cyber security strategies to protect against unintended or unauthorised access.</li> <li>• Ensuring that back-up data is stored externally including cloud-based or separate servers).</li> </ul>
6.24	<p><b>Know the requirements of what to do if information is not stored securely:</b></p> <ul style="list-style-type: none"> <li>• Secure the information where possible.</li> <li>• Record and report the incident to the designated person, following organisational policies and procedures.</li> </ul>

## Performance Outcome 3: Review, interpret and present experimental data

What skills do students need to demonstrate?
<p><b>S3.1 Complete relevant calculations on data obtained in the laboratory environment.</b></p> <ul style="list-style-type: none"><li>• Perform arithmetic operations, (M3, M4, M5, M8, D4)</li><li>• Perform experimental calculations (M3, M4, M5, M8, D4).</li></ul>
<p><b>S3.2 Select appropriate statistical techniques to analyse and interpret results from scientific tasks.</b></p> <ul style="list-style-type: none"><li>• Apply mathematical methods to process and present experimental data (M4, M5, M8, D4)</li><li>• Use calculated scientific and statistical values to analyse experimental outcomes (E1, E2, E3, E4, E5, M4, M5, M6, M8, D4).</li></ul>
<p><b>S3.3 Use standard software to process, analyse and present results from scientific tasks</b></p> <ul style="list-style-type: none"><li>• Spreadsheets: process data and produce graphical representations (M4, M5, M7, M8)</li><li>• Word processing and presentation software: presenting results (M4, M5, M7, M8)</li><li>• Perform statistical techniques (M4, M5, M8).</li></ul>
<p><b>S3.4 Use the results of calculations and statistical analysis to interpret and evaluate data from scientific tasks</b></p> <ul style="list-style-type: none"><li>• Determine trends (M4, M5, M6, M7, M8)</li><li>• Assess statistical validity (M5, M6, M7, M8)</li><li>• Support technical arguments (E1, E5, M5, M6, M7, M8)</li><li>• Draw conclusions (E1, E2, E3, E4, E5, M5, M6, M7, M8)</li><li>• Communicate effectively to a range of stakeholders (E5, M7, M8, D2, D3, D4).</li></ul>
<p><b>S3.5 Present data in an appropriate format.</b></p> <ul style="list-style-type: none"><li>• Using appropriate statistical techniques, including the use of data from laboratory information management system (LIMS) (E4, E5, M4, M5, M6, D1, D2, D4)</li><li>• Using technical language correctly, and using graphics and other tools to aid understanding (E5, D1, D2, D3)</li><li>• Using digital technology competently and confidently to produce, design and create charts and graphs: (E5, M5, M7, M8, D1, D3, D4)</li><li>• Organising data logically and coherently (E5, M5, M7, M8, D1, D3, D4).</li></ul>

What underpinning knowledge do students need?	
<b>K7</b>	<b>Calculations and statistical analysis</b>
7.1	<p><b>Consider the links between sample size and effective statistical analysis:</b></p> <ul style="list-style-type: none"> <li>• Sample size determination is often constrained by factors such as cost, time, availability of samples and ethical considerations.</li> <li>• Sample size needs to be sufficient to provide adequate statistical power to reduce risks of error when accepting or rejecting an experimental hypothesis.</li> <li>• Different statistical analysis techniques take account of sample size by specifying the accuracy with which the results are returned.</li> </ul>
7.2	<p><b>How to order numbers by relative size in a data set, using:</b></p> <ul style="list-style-type: none"> <li>• Powers of 10.</li> <li>• Decimal places.</li> </ul>
7.3	<p><b>To ensure proportionality while scaling up or down quantities in a formulation:</b></p> <ul style="list-style-type: none"> <li>• Keeping the same factor including, multiply all quantities by a factor of 10).</li> </ul>
7.4	<p><b>How to complete relevant calculations on data obtained in the laboratory environment:</b></p> <ul style="list-style-type: none"> <li>• Relative molecular mass.</li> <li>• Concentration.</li> <li>• Magnification.</li> <li>• Rf values.</li> <li>• Percentages.</li> <li>• Ratios.</li> <li>• Number of bacteria in a population using known division time.</li> <li>• Electrical resistance.</li> <li>• Pressure difference (from U-tube manometer).</li> <li>• Percentage uncertainty.</li> </ul>
7.5	<p><b>A range of techniques for measuring scientific subject matter at micro and macro scales:</b></p> <ul style="list-style-type: none"> <li>• Mass (for example, balances to different decimal places).</li> <li>• Length (for example, eyepiece graticule, laser measure).</li> <li>• Volume (for example, micro or graduated pipette).</li> </ul>
7.6	<p><b>How to use appropriate statistical techniques to analyse and interpret results from scientific tasks:</b></p> <ul style="list-style-type: none"> <li>• Averages, e.g. mean, mode, median.</li> <li>• Standard deviation.</li> <li>• Chi-squared test.</li> <li>• T-test.</li> </ul>

	<ul style="list-style-type: none"> <li>• Regression analysis (e.g. linear regression).</li> <li>• Analysis of covariance (ANCOVA).</li> <li>• Other advanced statistical methods as appropriate for the data set.</li> </ul>
7.7	<p><b>How to process results, using statistical software, for the following statistical techniques:</b></p> <ul style="list-style-type: none"> <li>• Standard deviation.</li> <li>• Chi-squared test.</li> <li>• T-test.</li> <li>• Spearman's rank to assess the correlation between 2 variables.</li> <li>• Regression/ANCOVA and other advanced statistical methods as required by the task.</li> </ul>
7.8	<p><b>How to use the results of calculations and statistical analysis to interpret and evaluate data from scientific tasks to:</b></p> <ul style="list-style-type: none"> <li>• Determine trends.</li> <li>• Assess statistical validity.</li> <li>• Support technical arguments.</li> <li>• Draw conclusions.</li> <li>• Communicate effectively to a range of stakeholders.</li> </ul>
7.9	<p><b>How to present data in an appropriate format:</b></p> <ul style="list-style-type: none"> <li>• Using appropriate statistical techniques, including the use of data from a laboratory.</li> <li>• Information management system (LIMS).</li> <li>• In a clear and unambiguous way, taking into account the level and experience of the audience and the purpose.</li> <li>• Using technical language correctly, and using graphics and other tools to aid understanding.</li> <li>• Using digital technology competently and confidently to produce, design and create charts and graphs: <ul style="list-style-type: none"> <li>○ line graphs</li> <li>○ pie charts</li> <li>○ bar charts</li> <li>○ results tables</li> <li>○ histograms.</li> </ul> </li> <li>• Organising data logically and coherently.</li> </ul>
7.10	<p><b>Use of standard software to process, analyse and present results from scientific tasks:</b></p> <ul style="list-style-type: none"> <li>• Spreadsheets: process data and produce graphical representations.</li> <li>• Word processing software: present results.</li> <li>• Presentation software: present results.</li> </ul>

7.11	<p><b>How different methods of data storage and recording are used in scientific practice, and the challenges associated with each:</b></p> <ul style="list-style-type: none"> <li>• Physical lab notebooks: <ul style="list-style-type: none"> <li>○ uses: <ul style="list-style-type: none"> <li>– real-time recording of observations, measurements and procedural steps</li> <li>– quick notes, sketches and annotations during practical work</li> <li>– chronological record supporting later evaluation.</li> </ul> </li> <li>○ challenges: <ul style="list-style-type: none"> <li>– not searchable; slower to review</li> <li>– risk of unclear handwriting or incomplete entries</li> <li>– corrections not tracked automatically</li> <li>– vulnerable to loss, damage or wear</li> <li>– limited to whoever physically holds the notebook.</li> </ul> </li> </ul> </li> <li>• Laboratory information management systems LIMs (electronic filing cabinet): <ul style="list-style-type: none"> <li>○ uses <ul style="list-style-type: none"> <li>– organising, storing and managing data after practical work</li> <li>– generating tables, graphs and visual summaries</li> <li>– enabling remote access and easy data sharing</li> <li>– allowing fast searching and retrieval of past data</li> <li>– supporting digital audit trails and data-visualisation tools.</li> </ul> </li> <li>○ challenges <ul style="list-style-type: none"> <li>– vulnerable to software failures or security breaches</li> <li>– requires user training for accurate data entry</li> <li>– maintenance costs for digital systems</li> <li>– less practical for live wet-lab data capture.</li> </ul> </li> </ul> </li> <li>• Application in practical tasks <ul style="list-style-type: none"> <li>○ learners should be able to: <ul style="list-style-type: none"> <li>– choose an appropriate recording method for the task and environment</li> <li>– recognise and mitigate method-specific challenges</li> <li>– understand how recording choices affect later analysis and evaluation</li> <li>– maintain clear, accurate and secure records throughout investigations.</li> </ul> </li> </ul> </li> </ul>
7.12	<p><b>How the following considerations inform data processing and subsequent analysis of the results in a laboratory environment:</b></p> <ul style="list-style-type: none"> <li>• Regulatory requirements (for example, validation, conformity to known analytical standards).</li> <li>• Relevant calculations (for example, magnification and R<sub>f</sub> values).</li> <li>• Conversion of units (for example, consistent use of units across different data sets).</li> <li>• Appropriate statistical techniques to determine the validity or significance of the results (for example, standard deviation, p value, uncertainty values).</li> </ul>

	<ul style="list-style-type: none"> <li>• Customer requirements for the presentation of data (for example, graphs).</li> <li>• Using complementary experimental methodologies from existing peer-reviewed studies to confirm results (for example, by the use of online databases).</li> <li>• Using laboratory control charts and trend charts (for example, to confirm equipment and/or protocols are within tolerance).</li> <li>• Demonstrate understanding of new technology and its application in the recording and reporting of information and data: <ul style="list-style-type: none"> <li>○ AI/machine learning includes the use of bioinformatics tools to analyse and process large data sets)</li> <li>○ mobile technology and applications include capturing health informatics and location data track and trace)</li> <li>○ cloud-based systems include use of electronic health records (EHRs) enables easier data sharing for further analysis)</li> <li>○ digital information management systems to enable a digital audit trail)</li> <li>○ data-visualisation tools to consolidate multiple data sources for presentation.</li> </ul> </li> </ul>
7.13	<p><b>How to establish the validity of results against standards and controls:</b></p> <ul style="list-style-type: none"> <li>• By using ongoing calculations to monitor results and identify anomalies.</li> <li>• Calculating Rf values and comparing to known values.</li> <li>• Using certified reference materials (CRMs).</li> <li>• Using calibration curves to compare results to standards.</li> </ul>
7.14	<p><b>Relevant information from online databases to review scientific tasks, in relation to:</b></p> <ul style="list-style-type: none"> <li>• Appropriateness of statistical techniques in similar published studies.</li> <li>• Data previously obtained.</li> </ul>
7.15	<p><b>The purpose of data processing and analysis in supporting improvements to laboratory techniques:</b></p> <ul style="list-style-type: none"> <li>• Stability studies: to determine the most appropriate storage for preservation of reagents and consumables.</li> <li>• Laboratory trend charts: to determine that laboratory equipment is working within specification (for example, colony-forming unit (CFU) data).</li> <li>• Laboratory method validation results: revalidating methods if results are outside of specification.</li> <li>• Proficiency testing (inter-laboratory comparison): to determine the accuracy and reliability of a laboratory's test results against results obtained by a certified laboratory.</li> </ul>

## Performance Outcome 4: Continuously review scientific tasks, suggesting and implementing improvements

What skills do students need to demonstrate?
<p><b>S4.1 Resolve issues with a range of scientific equipment:</b></p> <ul style="list-style-type: none"> <li>• Ensuring equipment is in working order and free from dirt or contamination (M1, M2, M6, M10)</li> <li>• Recalibrating equipment according to manufacturers' instructions and Standard Operating Procedures (SOPs) (E5, M1, M2, M6, M10)</li> <li>• Resetting, following manufacturers' instructions and SOPs (E5, M1, M2, M6, M10).</li> </ul>
<p><b>S4.2 Carry out and record routine cleaning and maintenance of equipment:</b></p> <ul style="list-style-type: none"> <li>• Following appropriate SOPs for cleaning and maintenance (E5, M1, M2, M6, M10)</li> <li>• Using appropriate cleaning materials before use (E5, M1, M2, M6, M10)</li> <li>• Using appropriate cleaning materials after use (E5, M1, M2, M6, M10)</li> <li>• Using relevant technology effectively (D1, D2, D3, D4).</li> </ul>
<p><b>S4.3 Recognise when a piece of equipment is producing inaccurate data:</b></p> <ul style="list-style-type: none"> <li>• Identifying anomalous results from repeated measurements (M2, M6)</li> <li>• The use of appropriate controls (E5, M1, M2, M6).</li> </ul>
<p><b>S4.4 Recognise when equipment is likely to be damaged or cause injury due to malfunction:</b></p> <ul style="list-style-type: none"> <li>• Inability of the equipment to be zeroed (M2, M3, M6)</li> <li>• Fails calibration check (M2, M6)</li> <li>• Visual checks of the equipment (M2, M10)</li> <li>• By the use of appropriate controls (M1, M2, M6, M10)</li> <li>• Through anomalous results of repeated measurements (M1, M2, M6, M8, M10).</li> </ul>
<p><b>S4.5 Report faults and source expert help when required:</b></p> <ul style="list-style-type: none"> <li>• Following escalation process (E1, E5, M1, M2)</li> <li>• Communicating the issue appropriately (E1, E3, E4, E5, E6, M1, M2, M5, M6, D1, D2, D3, D4)</li> <li>• Accurately describing the issue (E1, E2, E3, E4, E5, E6).</li> </ul>
<p><b>S4.6 Keep sufficient stock levels of all required laboratory equipment, reagents and consumables for planned scientific tasks:</b></p> <ul style="list-style-type: none"> <li>• Assessing stock levels through regular inventory management (E5, M5, M6, M8, D1, D3, D4)</li> <li>• Ensuring all reagents are labelled and dated correctly (E1, E3, M5, M8)</li> <li>• Ordering stock as required (E1, E3, E5, M8, M9, D1, D3).</li> </ul>

What underpinning knowledge do students need?	
<b>K8</b>	<b>Management of Equipment and Resources</b>
8.1	<p><b>The principles of SOP, instructions and the importance of calibrating laboratory equipment:</b></p> <ul style="list-style-type: none"> <li>• Following appropriate SOPs/ practical plan.</li> <li>• Interpreting manufacturers' instructions.</li> <li>• Calibration (including calibration curves).</li> <li>• Employing the correct test equipment.</li> <li>• How to recognise when a piece of equipment is producing inaccurate data: <ul style="list-style-type: none"> <li>○ identifying anomalous results from repeated measurements.</li> </ul> </li> <li>• The use of appropriate controls.</li> <li>• Resolving issues with a range of scientific equipment: <ul style="list-style-type: none"> <li>○ ensuring equipment is in working order and free from dirt or contamination</li> <li>○ recalibrating equipment according to manufacturers' instructions and SOPs</li> <li>○ resetting, following manufacturers' instructions and SOPs.</li> </ul> </li> </ul>
8.2	<p><b>The principles of maintaining, cleaning and validating laboratory equipment used to undertake scientific techniques commonly found in a laboratory environment:</b></p> <ul style="list-style-type: none"> <li>• Routine cleaning and maintenance of equipment: <ul style="list-style-type: none"> <li>○ following appropriate SOPs for cleaning and maintenance (for example, maintenance schedule)</li> <li>○ using appropriate cleaning materials before use (for example, rinsing burette with deionised water)</li> <li>○ using appropriate cleaning materials after use</li> <li>○ using relevant technology effectively (for example, on LIMS).</li> </ul> </li> <li>• How to decontaminate a range of common scientific equipment and substances: <ul style="list-style-type: none"> <li>○ sterilisation including autoclave, antiseptis, ultraviolet</li> <li>○ disinfection using hydrogen peroxide)</li> <li>○ incineration of clinical waste and sharps</li> <li>○ dissolution by rinsing with a solvent in order to remove solid contaminants)</li> <li>○ neutralisation using spillage kits.</li> </ul> </li> <li>• Keep sufficient stock levels of all required laboratory equipment, reagents and consumables for planned scientific tasks <ul style="list-style-type: none"> <li>○ assessing stock levels through regular inventory management</li> <li>○ ensuring all reagents are labelled and dated correctly</li> <li>○ ordering stock as required</li> <li>○ safely disposing of equipment that cannot be repaired.</li> </ul> </li> </ul>

8.3	<p><b>The importance of recognising equipment faults/technical issues in laboratory equipment used to undertake scientific techniques commonly found in a laboratory environment:</b></p> <ul style="list-style-type: none"> <li>• Signs equipment is likely to be damaged or cause injury due to malfunction: <ul style="list-style-type: none"> <li>○ inability of the equipment to be zeroed</li> <li>○ fails calibration check</li> <li>○ visual checks of the equipment (for example, exposed wires)</li> <li>○ by the use of appropriate controls</li> <li>○ through anomalous results of repeated measurements.</li> </ul> </li> <li>• Report faults and source expert help when required, by: <ul style="list-style-type: none"> <li>○ following escalation process</li> <li>○ communicating the issue appropriately: <ul style="list-style-type: none"> <li>– labelling the equipment as out of action</li> <li>– using digital communication where appropriate (for example, email, virtual/collaborative meeting tools)</li> </ul> </li> <li>○ accurately describing the issue: <ul style="list-style-type: none"> <li>– summing up key points</li> <li>– expressing opinions and supporting these with relevant and persuasive arguments</li> <li>– asking and responding to questions for clarifications.</li> </ul> </li> </ul> </li> <li>• Potential impacts of equipment faults/technical issues: <ul style="list-style-type: none"> <li>○ the potential impact on laboratory results</li> <li>○ potential health and safety risks</li> <li>○ financial impact (for example, lost time, equipment needs to be replaced)</li> <li>○ impact on other users' ability to use the equipment.</li> </ul> </li> </ul>
8.4	<p><b>The understanding of the principles of continuous improvement in relation to scientific tasks:</b></p> <ul style="list-style-type: none"> <li>• Making data driven decisions, capturing data at each stage of production (to feed into the evaluation cycle).</li> <li>• Using the evaluation cycle (PDCA): <ul style="list-style-type: none"> <li>○ plan: identify potential problems and plan required improvements</li> <li>○ do: implement potential solution</li> <li>○ check: analyse the results</li> <li>○ act: review the solution and retest if necessary.</li> </ul> </li> <li>• Standardising and refine standard operating procedures to include current best practice, using new technologies/outsourcing).</li> <li>• Reviewing costs including using new reagents or products to lower expenditure, automating where possible.</li> </ul>

<b>What skills do students need to demonstrate?</b>	
<p><b>S4.7 Identify how data errors could have occurred in scientific tasks:</b></p> <ul style="list-style-type: none"> <li>• Contamination of samples or equipment (M2, M5, M6)</li> <li>• Incorrect sample storage (M2, M5, M6)</li> <li>• Equipment working outside acceptable tolerances (M2, M3, M6)</li> <li>• Incorrect laboratory equipment used (M2, M6)</li> <li>• Equipment incorrectly used or set up (M2)</li> <li>• Method not followed (for example, standard operating procedure not followed) (E5, M2)</li> <li>• Transcription errors (M2, M3, M5, M6, M8, D4).</li> </ul>	
<p><b>S4.8 Identify when a random or systematic error has occurred in scientific tasks:</b></p> <ul style="list-style-type: none"> <li>• Gathering and interpreting data efficiently and in an appropriate format (E4, E5, M2, M6, M7, M8, D1, D2, D3, D4)</li> <li>• Comparing results against previous data (E4, E5, M2, M5, M6, M7, M8, D3, D4).</li> </ul>	
<p><b>S4.9 Recognise when results are invalid against standards and controls:</b></p> <ul style="list-style-type: none"> <li>• Using ongoing calculations to monitor results and identify anomalies (M2, M5, M6, M7, M8, D4)</li> <li>• Comparing to known values (M2, M6, M7, M8, D4).</li> </ul>	
<p><b>S4.10 Use relevant information from online databases to review scientific tasks:</b></p> <ul style="list-style-type: none"> <li>• Appropriateness of statistical techniques (E5, M4, M5, M6, M7, M8, D1, D3, D4)</li> <li>• Data previously obtained (E5, M4, M5, M6, M7, M8, D1, D3, D4).</li> </ul>	
<p><b>S4.11 Source expert help, when required, in relation to laboratory data processing and analysis:</b></p> <ul style="list-style-type: none"> <li>• Following escalation process (E1, E5, M5)</li> <li>• Communicating the issue appropriately: (E1, E2, E3, D1, D2, D3)</li> <li>• Accurately describing the issue: (E1, E2, E3, E4, E5, E6, M5, M6, M7, M8, D1, D2, D3, D4).</li> </ul>	

<b>What underpinning knowledge do students need?</b>	
<b>K9</b>	<b>Data processing and analysis</b>
9.1	<p><b>The use of data</b></p> <ul style="list-style-type: none"> <li>• How data errors could have occurred in scientific tasks: <ul style="list-style-type: none"> <li>○ contamination of samples or equipment</li> <li>○ incorrect sample storage</li> <li>○ equipment working outside acceptable tolerances</li> <li>○ incorrect laboratory equipment used (for example, using the wrong sized pipette)</li> <li>○ inadequate training (for example, misuse of the equipment)</li> <li>○ equipment incorrectly used or set up</li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>○ method not followed (for example, standard operating procedure not followed)</li> <li>○ transcription errors</li> <li>○ inaccurate findings</li> <li>○ wasted time and resources</li> <li>○ damage to reputation</li> <li>○ risks to health and safety.</li> <li>● When a random or systematic error has occurred in scientific tasks: <ul style="list-style-type: none"> <li>○ positive control produces a known result so can be used to ensure that any negative results are true negatives and not a result of an issue with equipment or reagents</li> <li>○ negative control confirms that no other variable is responsible for positive results in the test</li> <li>○ gathering and interpreting data efficiently and in an appropriate format (for example, chart or graph)</li> <li>○ comparing results against previous data.</li> </ul> </li> <li>● Use of relevant information from to review scientific tasks, in relation to: <ul style="list-style-type: none"> <li>○ appropriateness of statistical techniques (for example, similar published studies)</li> <li>○ data previously obtained (for example, from a LIMS).</li> </ul> </li> <li>● How to recognise when results are invalid against standards and controls by: <ul style="list-style-type: none"> <li>○ using ongoing calculations to monitor results and identify anomalies</li> <li>○ calculating Rf values and comparing to known values.</li> </ul> </li> <li>● Using certified reference materials (CRMs)</li> <li>● How to source expert help, when required, in relation to laboratory data processing and analysis by: <ul style="list-style-type: none"> <li>○ accurately describing the issue</li> <li>○ summing up key points</li> <li>○ expressing opinions and supporting these with relevant and persuasive arguments asking and responding to questions for clarification.</li> </ul> </li> </ul>
9.2	<p><b>The purpose of data processing and analysis in supporting improvements to laboratory techniques:</b></p> <ul style="list-style-type: none"> <li>● Stability studies: to determine the most appropriate storage for preservation of reagents and consumables.</li> <li>● Laboratory trend charts: to determine that laboratory equipment is working within specification (for example, colony-forming unit (CFU) data).</li> <li>● Laboratory method validation results: revalidating methods if results are outside of specification.</li> <li>● Proficiency testing (inter-laboratory comparison): to determine the accuracy and reliability of a laboratory's test results.</li> </ul>

<b>What skills do students need to demonstrate?</b>	
<p><b>S4.12 Address non-routine problems with samples and instrumentation in a scientific task:</b></p> <ul style="list-style-type: none"> <li>• Identify the error (M1, M2, M5, M6)</li> <li>• Quantify the error to determine if this is within accepted tolerance (M2, M5, M6, M8, D4)</li> <li>• Remove or minimise the sources of error (M2, M5, M6)</li> <li>• Record the source of error and the action taken (E1, E2, E3, M2, M6, D3).</li> </ul>	
<p><b>S4.13 Take steps to minimise errors in scientific tasks following continuous improvement techniques:</b></p> <ul style="list-style-type: none"> <li>• Plan (E1, E2, E3, E4, E5, M5)</li> <li>• Do (E4, M5)</li> <li>• Check (M1, M2, M3, M4, M5, M6, M8, M10)</li> <li>• Act (M1, M2, M3, M4, M5, M6, M8, M10).</li> </ul>	
<p><b>S4.14 Review and modify a scientific method to improve the task:</b></p> <ul style="list-style-type: none"> <li>• Ensuring correct order of steps for efficiency and effectiveness (E5, M10)</li> <li>• Equipment in terms of precision and accuracy (M1, M10)</li> <li>• Ensuring the techniques used are efficient and effective (M1, M2, M10).</li> </ul>	
<p><b>S4.15 Implement changes to a scientific task through the adoption of a continuous improvement cycle:</b></p> <ul style="list-style-type: none"> <li>• Identify the issue, organise ideas and information logically (E5, M10)</li> <li>• Plan and record required improvements, using digital tools and other aids (E5, M10, D1)</li> <li>• Implement the improvements (E5, M10, D1)</li> <li>• Check the effectiveness of the improvements by responding to questions/ feedback from colleagues (E5, E6, M10, D1)</li> <li>• Review improvements and adjust, if required (E5, M10, D1).</li> </ul>	

<b>What underpinning knowledge do students need?</b>	
<b>K10</b>	<b>Continuous improvement cycle</b>
10.1	<p><b>Minimising errors:</b></p> <ul style="list-style-type: none"> <li>• Reading and following the risk assessment and COSHH sheets.</li> <li>• Planning the work and workplace requirements.</li> <li>• Following a validated method.</li> <li>• Maintaining excellent housekeeping (for example, ensuring samples do not become contaminated).</li> <li>• Ensuring equipment is calibrated, set up and used correctly.</li> <li>• Only undertaking scientific tasks following adequate training.</li> <li>• Storing and labelling samples and standards correctly.</li> <li>• Working safely in a laboratory setting (for example, safely disposing of materials).</li> </ul>

	<ul style="list-style-type: none"> <li>• Take steps to minimise errors in scientific tasks following continuous improvement techniques: <ul style="list-style-type: none"> <li>○ plan: <ul style="list-style-type: none"> <li>– planning the work and workplace requirements</li> <li>– reading the risk assessment and COSHH sheets</li> </ul> </li> <li>○ do: <ul style="list-style-type: none"> <li>– following the risk assessment and COSHH sheets</li> <li>– following a validated method</li> <li>– maintaining excellent housekeeping (for example, ensuring samples do not become contaminated)</li> <li>– only undertaking scientific tasks following adequate training</li> <li>– working safely in a laboratory setting (for example, safely disposing of materials)</li> </ul> </li> <li>○ check: <ul style="list-style-type: none"> <li>– checking equipment is calibrated, set up and used correctly</li> <li>– checking that storage and labelling of samples and standards is correct</li> <li>– continuously monitoring data and ensuring procedures are carried out correctly.</li> </ul> </li> <li>○ act: <ul style="list-style-type: none"> <li>– implementing changes to equipment or method</li> <li>– repeating any measurements as required.</li> </ul> </li> </ul> </li> </ul>
10.2	<p>Improvements to scientific tasks:</p> <ul style="list-style-type: none"> <li>• Address non-routine problems with samples and instrumentation in a scientific task: <ul style="list-style-type: none"> <li>○ identify the error</li> <li>○ quantify the error to determine if this is within accepted tolerance</li> <li>○ remove or minimise the sources of error</li> <li>○ record the source of error and the action taken.</li> </ul> </li> <li>• Review and modify a scientific method to improve the task: <ul style="list-style-type: none"> <li>○ ensuring correct order of steps for efficiency and effectiveness (for example, substances are at the correct temperature at the required stage)</li> <li>○ checking equipment in terms of precision and accuracy (for example, measuring cylinder versus burette)</li> <li>○ ensuring the techniques used are efficient and effective.</li> </ul> </li> <li>• Implement changes to a scientific task through the adoption of a continuous improvement cycle: <ul style="list-style-type: none"> <li>○ identify the issue, organise ideas and information logically (for example, faulty equipment/reagents)</li> <li>○ plan and record required improvements, using digital tools and other aids</li> <li>○ implement improvements</li> <li>○ check the effectiveness of the improvements by responding to questions/feedback from colleagues</li> <li>○ review improvements and adjust, if required.</li> </ul> </li> </ul>

10.3	<p><b>How to minimise errors in scientific tasks, by:</b></p> <ul style="list-style-type: none"> <li>• Reading and following the risk assessment and COSHH sheets.</li> <li>• Planning the work and workplace requirements.</li> <li>• Following a validated method.</li> <li>• Maintaining excellent housekeeping (for example, ensuring samples do not become contaminated).</li> <li>• Ensuring equipment is calibrated, set up and used correctly.</li> <li>• Only undertaking scientific tasks following adequate training.</li> <li>• Storing and labelling samples and standards correctly.</li> <li>• Working safely in a laboratory setting (for example, safely disposing of materials).</li> </ul>
10.4	<p><b>The principles of professional documentation practice (GDocP) to prevent data errors:</b></p> <ul style="list-style-type: none"> <li>• Creation: <ul style="list-style-type: none"> <li>○ recording information as the work is performed</li> <li>○ handwritten entries are in indelible ink and are legible and in full.</li> </ul> </li> <li>• Approval: <ul style="list-style-type: none"> <li>○ signed and dated by authorised personnel.</li> </ul> </li> <li>• Document maintenance: <ul style="list-style-type: none"> <li>○ regularly reviewed and kept current</li> <li>○ ensuring electronic records are backed up.</li> </ul> </li> <li>• Document modification: <ul style="list-style-type: none"> <li>○ signed and dated by authorised personnel</li> <li>○ ensuring access to documents is controlled.</li> </ul> </li> </ul>
10.5	<p><b>How to report and correct recording errors:</b></p> <ul style="list-style-type: none"> <li>• Crossing out the error so it is still visible and entering new value.</li> <li>• Signing and dating correction.</li> <li>• Reattaching sheets that have become loose with sticky tape and ensuring the edges have been signed.</li> <li>• Implementing tracked changes on electronic databases.</li> <li>• Giving reasons why the correction has been made following laboratory protocols for error reporting.</li> </ul>
10.6	<p><b>How laboratory documents can be amended to implement improvements both to methods and equipment use, by:</b></p> <ul style="list-style-type: none"> <li>• Proposing amendments to working instructions/procedures.</li> <li>• Gaining approval for changes and amendments.</li> <li>• Validating amendments.</li> <li>• Adopting amendments and editing associated documentation.</li> <li>• Monitoring the process/results.</li> </ul>

10.7	<p><b>The purpose of computer modelling and simulation in the laboratory environment:</b></p> <ul style="list-style-type: none"> <li>• To identify the possible effects of modelling changes to complex procedures before implementing them.</li> <li>• To try out changes to method or equipment without dismantling and incurring the associated costs or disruption.</li> </ul>
10.8	<p><b>The stages of analytical method transfer when adopting an alternative laboratory method, following regulatory guidelines:</b></p> <ul style="list-style-type: none"> <li>• Determining the feasibility of methods and available equipment for own laboratory (receiving laboratory).</li> <li>• Setting the scope and objectives of the transfer.</li> <li>• Acquiring samples or standards from the transferring laboratory.</li> <li>• Training of laboratory staff at the receiving laboratory.</li> <li>• Validating results from both laboratories.</li> <li>• Adopting the alternative method within the laboratory.</li> </ul>
10.9	<p><b>The importance of using laboratory-reviewing strategies:</b></p> <ul style="list-style-type: none"> <li>• To identify possible problems and recommend improvements with laboratory methods, tasks and use of equipment.</li> </ul>
10.10	<p><b>Why laboratory documents are created, reviewed and approved:</b></p> <ul style="list-style-type: none"> <li>• To ensure consistency and quality.</li> <li>• To follow regulatory requirements (for example, good laboratory practice (GLP)).</li> </ul>
10.11	<p><b>The importance of quality control in the laboratory environment:</b></p> <ul style="list-style-type: none"> <li>• To determine appropriate performance of laboratory equipment.</li> <li>• To ensure methods are producing consistent results.</li> <li>• To ensure quality assurance procedures are designed to prevent errors and defects in products or processes.</li> <li>• To ensure quality control focuses on the identification of errors and defects in completed products or processes.</li> </ul>
10.12	<p><b>The principles of producing reliable and verifiable results:</b></p> <ul style="list-style-type: none"> <li>• Recording in a clear and unambiguous way (for example, use of tables, indelible ink, not using sticky notes or loose papers, ensuring writing is legible).</li> <li>• Using appropriate units, notation and correct number of significant figures.</li> <li>• Critically reviewing data obtained (for example, identifying any anomalous results).</li> <li>• Repeating investigations and referencing why any action was taken, where appropriate.</li> </ul>

10.13	<p><b>The purpose of the following analysis methods to produce reliable and verifiable results when dealing with large sets of data in genomics:</b></p> <ul style="list-style-type: none"><li>• Computation and statistical analysis: used to manage and appropriately analyse the large data sets that result from genome sequencing.</li><li>• Algorithms: programmed codes that allow large data sets from genome sequencing to be analysed and compared effectively and efficiently.</li><li>• Recording in order to ensure that:<ul style="list-style-type: none"><li>○ data or information is repeatable</li><li>○ data or information is relevant to the experimental purpose (valid recording)</li><li>○ data or information truly reflects the results obtained (accurate recording).</li></ul></li></ul>
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# Scheme of Assessment

There is a single synoptic assessment for this Occupational Specialism, which is an extended project. The synoptic element of the project is important to ensure students can demonstrate threshold competence and are able to evidence all the skills required by the Performance Outcomes.

The assessment consists of several activities grouped into five substantive tasks.

Each task is completed during a window set by Pearson, during which Providers mostly schedule supervised assessment sessions.

<b>Occupational Specialism project – Laboratory Sciences</b>
<b>Internally assessed project: 22 hours 180 marks</b>
<b>Performance Outcomes</b> In this project, students will: <b>PO1</b> – Design and execute scientific tasks using scientific knowledge <b>PO2</b> – Perform scientific techniques to collect experimental data, adhering to regulatory and safety requirements <b>PO3</b> – Review, interpret and present experimental data <b>PO4</b> – Continuously review scientific tasks, suggesting and implementing improvements
<b>Assessment overview</b> There are 8 parts to the assessment. Task 1: 1a: Review of literature – not assessed 2b: Literature report. Task 2: Practical plan Task 3: 3a: Contributing to scientific reporting 3b: Contributing to scientific reporting Task 4: 4a: Experimental practical assessment 4b: Experimental practical assessment Task 5: 5a: Data analysis report 5b: Data analysis report Students respond to a given scenario to complete the project. They are assessed on their application of the skills listed for the Performance Outcomes. Students are not assessed against specific ‘knowledge’ outcomes but are expected to draw on and apply related knowledge to ensure appropriate outcomes when applying the skills in response to an assessment scenario. Students undertake the project under a combination of supervised and controlled conditions.

The assessment takes place over multiple sessions, up to a combined duration of 22 hours.

The project outcomes consist of the student's responses to tasks submitted electronically.

This project is externally assessed, apart from the practical task 4 where it is to be centre assessed and moderated by Pearson.

The practical task 4 will sample from the following 13 practical skills:

1. Paper and thin-layer chromatography (TLC)
2. Distillation
3. Acid-base and redox titration and prepare a solution of defined molar concentration
4. Refluxing
5. Filtration
6. Differential staining (microorganisms) and aseptic culture of microorganisms
7. Preparation of serial dilution and colorimetry
8. Pressure using a U-tube manometer
9. Temperature using a probe and data logger
10. Radioactive count rate using a Geiger counter
11. Conductivity meter to measure the conductivity of a solution
12. Electrical polarity using ammeter and voltmeter
13. Calibrating a pH meter, balance and a mechanical (variable volume) pipette.

#### Administration

Providers must follow the guidance in the following:

- General Administrative Support Guide
- Administration Support Guide for the specific Technical Qualification Employer Set Project (if applicable).

These are located on the [Training and Admin Support webpage](#).

Performance Outcome		Weighting	
		Raw marks	% of total marks
1	Design and execute scientific tasks using scientific knowledge	56	31.1
2	Perform scientific techniques to collect experimental data adhering to regulatory and safety requirements	64	35.6
3	Review, interpret and present experimental data	36	20.0
4	Continuously review scientific tasks, suggesting and implementing improvements	24	13.3

## Resources for the delivery of Occupational Specialism: Laboratory Sciences

Providers are required to have the following resources to deliver this OS:

- Providers would benefit from a good IT suite with access to Microsoft Office software and the internet and for students to have regular access to this.
- Teachers with qualifications and/or experience in the science sector.
- Teaching will need to be shared across a curriculum team which together will have the experience and knowledge that spans the breadth of the qualification content and has some experience of teaching to external assessments.

Assessment Task	Resource required
1	<ul style="list-style-type: none"><li>• Microsoft Office 365 package</li><li>• Internet (Activity 1a)</li></ul>
2	<ul style="list-style-type: none"><li>• Microsoft Office 365 package</li></ul>
3	<ul style="list-style-type: none"><li>• Microsoft Office 365 package</li></ul>
4	<ul style="list-style-type: none"><li>• Microsoft Office 365 package</li><li>• You will need laboratory equipment for this task in alignment with the technician's notes provided for each series.</li></ul>
5	<ul style="list-style-type: none"><li>• Microsoft Office 365 package</li></ul>

## 2. Food Sciences

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### Content Summary

The content is separated into four Performance Outcomes, with the skills needed to achieve threshold competence and the knowledge to underpin skill application across the following areas. Where skills are linked to knowledge in the Core Component these are indicated.

### Performance Outcome 1: Perform appropriate activities to support the food supply chain complying with regulatory requirements

What skills do students need to demonstrate?	
<b>S1.1 Use a range of planning methodologies when performing activities to support the food supply chain</b>	
(E5, M1, M2, M5, M6, D1, D3)	
<b>S1.2 Identify the appropriate food safety and health and safety procedures that need to be in place to support food safety and regulatory compliance, within a specific area of the food supply chain</b>	
(E1, E5, M1, M2, M6, M10, D1, D3, D4)	

What underpinning knowledge do students need?	
<b>Planning methodologies</b>	
1.1	<p>How to use the following planning methodologies when performing activities to support the food supply chain:</p> <ul style="list-style-type: none"> <li>• Planning time to achieve objectives</li> <li>• Prioritising tasks</li> <li>• Risk assessments: identifying how to mitigate risk</li> <li>• Critical path analysis: identifying areas of weakness</li> <li>• Objective setting: determining specific, measurable, achievable, realistic and timely objectives.</li> </ul>
1.2	<p><b>Use a range of planning methodologies when performing activities to support the food supply chain:</b></p> <ul style="list-style-type: none"> <li>• Time management:               <ul style="list-style-type: none"> <li>○ planning time to achieve objectives</li> <li>○ prioritising tasks</li> </ul> </li> <li>• Risk assessments:               <ul style="list-style-type: none"> <li>○ identifying how to mitigate risk</li> </ul> </li> <li>• Critical path analysis:               <ul style="list-style-type: none"> <li>○ identifying areas of weakness</li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>• Objective setting: <ul style="list-style-type: none"> <li>○ determining specific, measurable, achievable, realistic and timely objectives</li> </ul> </li> </ul>
1.3	<p><b>How to identify the appropriate food safety and health and safety procedures that need to be in place to support food safety and regulatory compliance, within a specific area of the food supply chain (for example, growers/suppliers, transportation, production, distribution, retail):</b></p> <ul style="list-style-type: none"> <li>• Health and safety: applicable to all areas of the food supply chain</li> <li>• Hazard Analysis and Critical Control Points (HACCP): applicable to all areas of the food supply chain</li> <li>• Food safety management: applicable to all areas of the food supply chain</li> <li>• Technical and quality management: applicable to all areas of the food supply chain</li> <li>• Microbiology: applicable to all areas of the food supply chain</li> <li>• Raw materials: applicable to growers and suppliers</li> <li>• Food science: applicable to production</li> <li>• Food technology: applicable to food production</li> <li>• Food supply chain from end to end: applicable to all areas of the food supply chain</li> </ul>

<b>What skills do students need to demonstrate?</b>	
<b>S1.3 Identify the labelling requirements of food and drink products to comply with the required legislation and regulations</b>	<b>(E1, E5, M6, M10, D1, D3)</b>
<b>S1.4 Carry out a Threat Assessment and Critical Control Points (TACCP) risk assessment on potential areas of weakness</b>	<b>(E1, E2, E3, E4, E5, M2, M4, M5, M6, M10, D1, D3)</b>
<b>S1.5 Utilise horizon scanning tools to search for and gather evidence efficiently, in relation to potential food fraud</b>	<b>(E4, E5, M5, M6, D1, D3)</b>

<b>What underpinning knowledge do students need?</b>	
<b>Legislation, regulations and ethics in the food and drink industry</b>	
1.4	<p><b>The difference between safety and quality within the food and drink industry:</b></p> <ul style="list-style-type: none"> <li>• Safety – ensuring food and drink products are not going to cause foodborne illness, or be injurious to health.</li> <li>• Quality – ensuring food and drink products are consistent with the quality and contents indicated on the nutritional information and ingredient labels.</li> </ul>

1.5	<p><b>The required legal characteristics of food and drink businesses:</b></p> <ul style="list-style-type: none"> <li>• The requirement to register any food/drink business with the local authority before trading, either online or direct to the public (including the number of days in advance the registration needs to take place).</li> <li>• The requirement for all food handlers to be trained commensurate with the activities they intend to undertake within the food/drink business.</li> <li>• The requirement for specific authorisation to practise in certain industries (for example, meat, dairy, slaughterhouse).</li> <li>• The requirement for traceability of raw materials from point of origin, including cattle movement (field to fork).</li> <li>• The requirement for the welfare and handling of animals.</li> </ul>
1.6	<p><b>The purpose of relevant legislation and regulations that apply to the food and drink industry, in relation to:</b></p> <ul style="list-style-type: none"> <li>• Food and drink safety: ensure the production environment is suitable, food is safe to eat, product is as specified and food will not cause harm to the consumer.</li> <li>• Food and drink labelling: ensure consumers can make informed choices about food by making it mandatory to display certain information (for example, allergen information).</li> <li>• Weights and measures: ensure product meets required standards and protects the consumer.</li> </ul>
1.7	<p><b>Labelling requirements of food and drink products to comply with the required legislation and regulations:</b></p> <ul style="list-style-type: none"> <li>• Nutritional information.</li> <li>• Quantitative ingredients declaration (QUID).</li> <li>• Calorific values.</li> <li>• All ingredients, with allergens emphasised (for example, in bold).</li> <li>• Origin of raw materials.</li> <li>• Use by and best before dates.</li> <li>• Weights and measures.</li> </ul>
1.8	<p><b>The difference between legislation and industry standards/codes of practice within the food and drink industry:</b></p> <ul style="list-style-type: none"> <li>• Legislation: what food and drink suppliers must do by law.</li> <li>• Industry standard/code of practice: what food and drink suppliers do to ensure that what is produced meets the required standard.</li> </ul>
1.9	<p><b>The principles of the ‘Universal Ethical Code for Scientists 2007’ and how it affects ethical practices in a laboratory setting:</b></p> <ul style="list-style-type: none"> <li>• Rigour: <ul style="list-style-type: none"> <li>○ acting with skill and care in all scientific work</li> <li>○ maintaining up-to-date skills and assisting with their development in others</li> <li>○ taking steps to prevent corrupt practices and professional misconduct</li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>○ declaring conflicts of interest</li> <li>○ being alert to the ways in which research derives from and affects the work of other people, and respecting the rights and reputations of others.</li> <li>● Respect: <ul style="list-style-type: none"> <li>○ ensuring that your work is lawful and justified</li> <li>○ minimising and justifying any adverse effect your work may have on people, animals and the natural environment</li> <li>○ promoting equality and supporting diversity</li> <li>○ minimising conflict and stress</li> <li>○ increasing productivity and job satisfaction</li> <li>○ inspiring individuals to be loyal to the organisation and each other.</li> </ul> </li> <li>● Responsibility: <ul style="list-style-type: none"> <li>○ seeking to discuss the issues that science raises for society</li> <li>○ listening to the aspirations and concerns of others</li> <li>○ not knowingly misleading, or allowing others to be misled, about scientific matters</li> <li>○ presenting and reviewing scientific evidence, theory honestly and accurately</li> <li>○ maintaining high quality ethical and professional standards including objectivity, clarity, reproducibility</li> <li>○ following organisational codes of practice</li> <li>○ following regulatory guidance</li> <li>○ aspiring to excel, not just meet the minimum standards.</li> </ul> </li> </ul>
1.10	<p><b>Ethical issues and wider implications of scientific practices:</b></p> <ul style="list-style-type: none"> <li>● Misusing or misinterpreting published research.</li> <li>● Conducting unethical research (for example, with human tissue samples).</li> </ul>
1.11	<p><b>The importance of adhering to codes of conduct to ensure confidentiality:</b></p> <ul style="list-style-type: none"> <li>● To avoid improper disclosure of information and data that could harm the science organisation or individuals within it.</li> <li>● To avoid accidental loss or release of sensitive information or data.</li> <li>● To comply with regulatory requirements and guidance.</li> </ul>
1.12	<p><b>The importance of adhering to codes of conduct to protect intellectual property:</b></p> <ul style="list-style-type: none"> <li>● Intellectual property <ul style="list-style-type: none"> <li>○ theories/ideas</li> <li>○ papers/research</li> <li>○ experimental results and design</li> <li>○ bespoke equipment</li> <li>○ anything with a potentially commercial application (including product/formulation/recipe, software, apps).</li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>• To avoid sharing commercially sensitive information and research through improper disclosure.</li> <li>• To avoid accidental loss or release of sensitive information and research.</li> <li>• To respect the intellectual property of other scientists' work.</li> </ul>
1.13	<p><b>The requirements of industry standards and codes of practice within the food and drink industry:</b></p> <ul style="list-style-type: none"> <li>• Industry standards (for example, BRCGS, Red Tractor Assurance): require that food is produced to a specified standard.</li> <li>• Technical processes/quality management systems (for example, good manufacturing practice): provide frameworks for processes and procedures to ensure that food is safe to eat.</li> <li>• Industry codes of practice (for example, ice cream, meat, dairy): provide industry/product specific processes and procedures to ensure food and drink meet required standards.</li> <li>• Internal and external specifications (for example, raw material specifications, internal manufacturing/production specifications and final product specifications): define the food safety and quality of the product to meet customer requirements.</li> </ul>
1.14	<p><b>The purpose of relevant environmental legislation and regulations that apply to the food and drink industry:</b></p> <ul style="list-style-type: none"> <li>• Pollution of water sources (for example, avoiding the release of effluent into streams/water courses, avoiding flushing food down drains): to avoid contamination of water sources.</li> <li>• Recycling (for example, food and packaging waste): to reduce waste going to landfill.</li> <li>• Emissions (for example, light, noise or odour from food and drink processing): to reduce emissions.</li> </ul>
1.15	<p><b>The purpose of social, environmental and economic sustainability within the food supply chain:</b></p> <ul style="list-style-type: none"> <li>• To protect local communities and the environment from the impact of the food and drink industry.</li> </ul>
1.16	<p><b>The purpose of the following risk assessment procedures used at each stage of the food supply chain, including procurement, food production, processing, packaging, storage requirements and distribution:</b></p> <ul style="list-style-type: none"> <li>• Supplier assurance risk assessment: ensures raw materials are purchased from safe sources.</li> <li>• TACCP: protects food from malicious acts (for example, food defence).</li> <li>• Vulnerability Assessment and Critical Control Points (VACCP): prevents adulteration or substitution of ingredients (for example, food fraud).</li> <li>• Horizon scanning: to identify potential alerts, natural disasters and civil disturbances that could result in food fraud.</li> </ul>

1.17	<p><b>How to carry out a supplier assurance risk assessment for a variety of ingredients to ensure food safety:</b></p> <ul style="list-style-type: none"> <li>• Achievement grading and how recent external certification has been achieved by the supplier (for example, Brand Reputation through Compliance Global Standards (BRCGS), Safe and Local Supplier Approval (SALSA)).</li> <li>• The controls that the supplier has in place (for example, prerequisites, HACCP plan, allergen controls).</li> <li>• The training of the supplier’s staff (for example, food safety, health and safety, standard operating procedures).</li> <li>• The supplier’s reputation in industry (for example, references from other companies, customer satisfaction).</li> <li>• The supplier’s experience of supplying that ingredient.</li> <li>• Previous use of the supplier.</li> </ul>
1.18	<p><b>How to carry out a Threat Assessment and Critical Control Points (TACCP) risk assessment on the following potential areas of weakness:</b></p> <ul style="list-style-type: none"> <li>• People: <ul style="list-style-type: none"> <li>○ internal, including disaffected workers and agency staff</li> <li>○ external, including screening and escorting of contractors and visitors, unauthorised access by radical groups (bioterrorism).</li> </ul> </li> <li>• Premises: <ul style="list-style-type: none"> <li>○ access for people, including between car parks and production areas</li> <li>○ access for delivery vehicles</li> <li>○ general site security, including boundary fencing/walls, lighting, mail security, prohibited use of portable electronic equipment.</li> </ul> </li> <li>• Process: <ul style="list-style-type: none"> <li>○ access to production areas (for example, lone workers’ unsupervised access in production areas)</li> <li>○ machine security to prevent unauthorised access</li> <li>○ raw material intake checks, product security (for example, tamper-proof packaging).</li> </ul> </li> <li>• Services: <ul style="list-style-type: none"> <li>○ protection of utilities, drainage systems, air inlets/vents, cleaning systems, particularly chemical controls.</li> </ul> </li> <li>• Distribution: <ul style="list-style-type: none"> <li>○ access to depot and vehicles, vehicles en route, service and rest areas.</li> </ul> </li> </ul>
1.19	<p><b>How to utilise horizon scanning tools to search for and gather evidence efficiently, in relation to potential food fraud:</b></p> <ul style="list-style-type: none"> <li>• Alerts: <ul style="list-style-type: none"> <li>○ checking the Food Standards Agency (FSA) website.</li> </ul> </li> <li>• Checking the Food Authenticity Network website.</li> </ul>

	<ul style="list-style-type: none"> <li>• Checking the Rapid Alert System for Food and Feed (RASFF) website portal.</li> <li>• Natural disasters: <ul style="list-style-type: none"> <li>○ checking the Foreign, Commonwealth &amp; Development Office website.</li> </ul> </li> <li>• Civil disturbance: <ul style="list-style-type: none"> <li>○ checking the Home Office website.</li> </ul> </li> </ul>
1.20	<p><b>The purpose of ethical trading initiatives in the food and drink industry:</b></p> <ul style="list-style-type: none"> <li>• To ensure the sustainability of raw materials (for example, fishing, farming and use of palm oil).</li> <li>• To ensure the welfare of workers, including modern slavery, working time and fair trade.</li> <li>• To ensure the welfare of animals, including free range, transportation and slaughter.</li> </ul>

<b>What skills do students need to demonstrate?</b>	
<b>S1.6 Work safely in a food or drink environment when carrying out a specific task, by always adhering to SOPs</b>	<b>(E5, M1, M2, M4, M6, M10)</b>
<b>S1.7 Carry out a health-and-safety risk assessment, identifying risks and mitigating factors</b>	<b>(E1, E5, M1, M2, M4, M6, M10)</b>

<b>What underpinning knowledge do students need?</b>	
<b>Health and safety in the food and drink industry</b>	
1.21	<p><b>The importance of the following in the food and drink industry to support health and safety:</b></p> <ul style="list-style-type: none"> <li>• Personal protective equipment (PPE): to protect the employee and reduce the possibility of physical contamination and injury risks.</li> <li>• Correct manual handling: to prevent injury.</li> <li>• Ergonomics techniques: to improve the fit between employees and the environment in which they work.</li> <li>• Using the correct equipment for the task: to prevent injury.</li> <li>• Safe use of equipment: to prevent injury.</li> <li>• Standard Operating Procedures (SOPs): to ensure the safety of employees.</li> </ul>
1.22	<p><b>An employee's responsibility in adhering to health and safety controls within the food and drink industry:</b></p> <ul style="list-style-type: none"> <li>• PPE: <ul style="list-style-type: none"> <li>○ wearing PPE.</li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>• Staff training: <ul style="list-style-type: none"> <li>○ only carrying out tasks and using equipment for which the individual is trained.</li> </ul> </li> <li>• Risk assessments: <ul style="list-style-type: none"> <li>○ carrying out and following risk assessments.</li> </ul> </li> <li>• SOPs: <ul style="list-style-type: none"> <li>○ following the step-by-step guide which includes photographic instructions and PPE requirements</li> <li>○ knowing to whom to escalate issues to.</li> </ul> </li> <li>• Control of Substances Hazardous to Health (COSHH) Regulations 2002: <ul style="list-style-type: none"> <li>○ following controls for food additives</li> <li>○ following SOPs for use and storage of chemicals.</li> </ul> </li> </ul>
1.23	<p><b>How to work safely in a food or drink environment when carrying out a specific task, by always adhering to SOPs:</b></p> <ul style="list-style-type: none"> <li>• Wearing the appropriate PPE correctly.</li> <li>• Using correct manual handling techniques: <ul style="list-style-type: none"> <li>○ not picking up loads from the floor if possible</li> <li>○ ensuring adequate space to prevent twisting or bending</li> <li>○ ensuring a clear, level work area</li> <li>○ taking rest breaks when needed</li> <li>○ not carrying double loads</li> <li>○ adhering to job rotation policies.</li> </ul> </li> <li>• Using the specified equipment safely.</li> <li>• Using ergonomic techniques: <ul style="list-style-type: none"> <li>○ minimising repetition</li> <li>○ varying tasks.</li> </ul> </li> </ul>
1.24	<p><b>How to carry out a health-and-safety risk assessment, identifying risks and mitigating factors:</b></p> <ul style="list-style-type: none"> <li>• Step 1: identifying the hazard: <ul style="list-style-type: none"> <li>○ machinery and facility hazards (for example, equipment without guards, maintenance of building and equipment)</li> <li>○ microbiological hazards (for example, hygiene practices)</li> <li>○ chemical hazards (for example, ammonia leak, cleaning fluids mixed incorrectly)</li> <li>○ manual handling hazards (for example, incorrect lifting)</li> <li>○ slips, trips and falls hazards (for example, spillages, incorrectly stored materials, obstructions in walkways)</li> <li>○ blocked fire exit hazards (for example, incorrectly stored materials)</li> <li>○ electrical hazards (for example, isolation of equipment)</li> <li>○ vehicle hazards (for example, forklifts, vehicles reversing into loading bays).</li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>• Step 2: identifying who might be harmed (for example, machine operator, visitors, contractors, hygiene specialists).</li> <li>• Step 3: evaluating the risk and selecting appropriate control measures (for example, identifying if any alternative or safer methods than those proposed can be used, identifying control measures that need to be in place to minimise risks at all times, identifying appropriate PPE, ensuring adequate guarding, identifying the isolation and lock-off of machinery).</li> <li>• Step 4: recording the findings and implementation (for example, ensuring any significant findings that require further changes to manage the risks better are recorded, such as use of additional PPE): <ul style="list-style-type: none"> <li>○ in a clear and unambiguous way</li> <li>○ using technical language correctly</li> <li>○ organising the findings logically and coherently</li> <li>○ using the appropriate grammar, vocabulary and spelling.</li> </ul> </li> <li>• Step 5: monitoring and reviewing risk management: <ul style="list-style-type: none"> <li>○ are the current controls still working?</li> <li>○ is there any new equipment that needs to be considered?</li> </ul> </li> </ul>
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<b>What skills do students need to demonstrate?</b>
<p><b>S1.8 Contribute to a HACCP plan for a simple product, by creating a HACCP flow diagram outlined in step 4 of the 12 HACCP steps</b>  <b>(E1, E2, E3, E4, E5, M1, M2, M4, M6, M10, D1, D2, D3)</b></p>

<b>What underpinning knowledge do students need?</b>	
<b>Hazard Analysis and Critical Control Points (HACCP) in the food and drink industry</b>	
1.25	<p><b>The importance of implementing an effective HACCP-based food safety management procedure:</b></p> <ul style="list-style-type: none"> <li>• Legal requirement for all food and drink organisations to identify hazards and put controls in place to eliminate the hazard or reduce it to a safe level.</li> <li>• Assures the product is safe to eat.</li> </ul>
1.26	<p><b>The prerequisite procedures that need to be in place in a food or drink business prior to implementing a HACCP-based food safety management system:</b></p> <ul style="list-style-type: none"> <li>• Approved suppliers: <ul style="list-style-type: none"> <li>○ process for supplier approval.</li> </ul> </li> <li>• Allergen procedure and controls: <ul style="list-style-type: none"> <li>○ segregation</li> <li>○ separate, colour-coded PPE (for example, red hairnets)</li> <li>○ captive tools, utensils and equipment.</li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>• Incoming materials specifications: <ul style="list-style-type: none"> <li>○ goods-in checks.</li> </ul> </li> <li>• Training for staff: <ul style="list-style-type: none"> <li>○ basic food hygiene</li> <li>○ critical control points.</li> </ul> </li> <li>• Cleaning: <ul style="list-style-type: none"> <li>○ schedules</li> <li>○ equipment.</li> </ul> </li> <li>• Suitable premises: <ul style="list-style-type: none"> <li>○ glass/hard plastic procedure.</li> </ul> </li> <li>• Pest control: <ul style="list-style-type: none"> <li>○ types of pests</li> <li>○ use of contractors.</li> </ul> </li> <li>• Internal auditing to maintain best practice: <ul style="list-style-type: none"> <li>○ good manufacturing practice (GMP)</li> <li>○ good hygiene practice (GHP).</li> </ul> </li> </ul>
1.27	<p><b>The application of the 7 principles of HACCP in order to implement and maintain a HACCP-based food safety management system:</b></p> <ul style="list-style-type: none"> <li>• Principle 1: conducting a hazard analysis, considering all possible hazards, risk assessing all hazards and identifying controls: <ul style="list-style-type: none"> <li>○ microbiological hazards: bacteria, viruses, protozoans, moulds, parasites, algae</li> <li>○ controls: effective training, effective personal hygiene, effective cleaning procedures, effective cooking procedures, effective cooling procedures, effective stock control</li> <li>○ physical hazards: foreign bodies from the potential following sources: people, pests, raw materials, packaging, equipment, cleaning activities, buildings, sabotage</li> <li>○ controls: effective training and supervision of staff, effective personal hygiene, effective pest control, following SOPs, regular planned preventative maintenance, effective cleaning</li> <li>○ chemical hazards: from the potential following sources: in raw materials from pesticides, fungicides, metals in fish or vegetables, antibiotics/hormones in meat, industrial chemicals, natural toxins, during preparation, fumes, cleaning chemicals, pesticides, metals, excess additives, migration from packaging</li> <li>○ controls: use of reputable suppliers and safe packaging, following manufacturer instructions for use of cleaning chemicals, correct storage of cleaning chemicals, use of approved pest control contractors, no cleaning over open food</li> <li>○ allergenic hazards: introduced as a result of poor segregation or cleaning</li> <li>○ controls: use of approved suppliers, following stringent allergen control procedure, strict segregation.</li> </ul> </li> </ul>

- Principle 2: identifying critical control points (CCPs):
  - control is used to eliminate a food safety hazard or reduce it to a safe level.
- Principle 3: establishing the critical limits:
  - a maximum and/or minimum value (must not be a range) is allocated to a hazard in order to prevent, eliminate or reduce the hazard to an acceptable level.
- Principle 4: monitoring CCP:
  - what: is being monitored (for example, critical limits, target levels and tolerances)
  - how: the monitoring should be undertaken, including equipment and calibration
  - where: the monitoring should be undertaken (at, or as close as possible to, the CCP)
  - who: is responsible for the monitoring
  - when: the monitoring should be undertaken, including continuous or batch (must be frequent enough to ensure that the hazard is controlled – without requiring significant destruction of product).
- Principle 5: establishing corrective actions:
  - identifying actions to be taken if the process breaches the critical limits
  - corrective actions should take place before the critical limit is breached
  - corrective actions will bring CCP back under control and deal with any affected product.
- Principle 6: verifying and validating:
  - verification: the methods, procedures, tests, which are used in addition to monitoring, to establish if the HACCP system is functioning as planned
    - verification questions such as:
      - are the critical limits being complied with?
      - are monitoring procedures being accurately followed?
      - are corrective actions being implemented as per the HACCP plan?
      - is the plan being regularly verified?
  - validation: obtaining evidence (for example, from scientific literature, legislation, ongoing reviews, international guidance, food standards and industry guides, pre-production trials) to validate that the HACCP plan is effective, especially the CCP and critical limits
  - reviews – at regular intervals (at least annually): if new scientific data emerges, when a confirmed complaint or illness occurs, when the raw materials or recipe changes, when equipment or the process is changed, when storage conditions or product use changes, when packing or distribution is changed, following modification of the HACCP plan.

	<ul style="list-style-type: none"> <li>● Principle 7: record-keeping, documentation required for: due diligence, legal requirement, customer requirement, assists in investigation of complaints, identifying areas of weakness, may identify training needs, can be used for trend analysis. Records to include: <ul style="list-style-type: none"> <li>○ HACCP plan, including details of how it was developed</li> <li>○ prerequisite programmes</li> <li>○ floor plan including segregation of high/low-risk areas</li> <li>○ approved supplier list</li> <li>○ monitoring records.</li> </ul> </li> </ul>
1.28	<p><b>How to implement and maintain a HACCP-based food safety management system, by following the detailed requirements of the following 12 steps:</b></p> <ul style="list-style-type: none"> <li>● Step 1: assembling the HACCP team, including: <ul style="list-style-type: none"> <li>– training of staff</li> <li>– responsibilities of the team.</li> </ul> </li> <li>● Step 2: describing the product and its distribution, including <ul style="list-style-type: none"> <li>– composition</li> <li>– hazards</li> <li>– suitability for microbial growth</li> <li>– processing methods</li> <li>– storage</li> <li>– distribution</li> <li>– shelf life</li> <li>– packaging</li> <li>– labelling</li> <li>– legal requirements.</li> </ul> </li> <li>● Step 3: identifying the intended use of the product and consumers, including: <ul style="list-style-type: none"> <li>○ likely consumers, including sensitive and vulnerable groups</li> </ul> </li> <li>● Step 4: constructing the flow diagram to describe the process: <ul style="list-style-type: none"> <li>○ a systematic representation of the steps or operations involved, often from purchase to the consumer.</li> </ul> </li> <li>● Step 5: on-site confirmation of flow diagram: <ul style="list-style-type: none"> <li>– ensuring the flow diagram represents what happens in practice (for example, is it accurate for every occasion, and over every shift?).</li> </ul> </li> <li>● Step 6: conducting a hazard analysis: <ul style="list-style-type: none"> <li>○ identifying possible hazards at the steps in which they are likely to occur risk-assessing all hazards</li> <li>○ identifying controls to mitigate the risks.</li> </ul> </li> <li>● Step 7: determining critical control points: <ul style="list-style-type: none"> <li>○ determining the steps in the process where control measures need to be in place to prevent, eliminate or reduce the hazard to an acceptable level</li> <li>○ control procedures must be in place for each CCP</li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>○ CCPs to be identified using the Codex Alimentarius decision tree, which is essentially a series of questions to determine whether a step is a control point or a critical control point.</li> <li>● Step 8: establishing critical limits for each critical control point: <ul style="list-style-type: none"> <li>○ these are the values of monitored actions, separating the acceptable from the unacceptable</li> <li>○ quantifiable limits are preferred and, if possible, the results should be obtained immediately on-site</li> <li>○ target levels can also be identified, and these may enable a potential breach of a critical limit to be detected and remedied before the food becomes unfit.</li> </ul> </li> <li>● Step 9: establishing a monitoring system for each critical control point: <ul style="list-style-type: none"> <li>○ monitoring of control measures at each CCP</li> <li>○ this is essential to confirm that a process is under control and critical limits are not exceeded</li> <li>○ it can be automatic or manual, and must permit rapid detection and correction</li> <li>○ procedures should state what the critical limits are, where the monitoring should be undertaken, when the monitoring should be done and who is responsible for the monitoring.</li> </ul> </li> <li>● Step 10: establishing corrective actions, including: <ul style="list-style-type: none"> <li>○ the actions to take when a critical limit is breached</li> <li>○ usually there are 2 distinct actions: <ul style="list-style-type: none"> <li>– deal with the affected product</li> <li>– bring the process back under control</li> </ul> </li> <li>○ procedures should specify the action to be taken, who is responsible for taking the action, who should be notified and whether production needs to be stopped/restarted.</li> </ul> </li> <li>● Step 11: establishing verification procedures: <ul style="list-style-type: none"> <li>○ this involves the use of methods, procedures and tests in addition to those used in monitoring to determine compliance with the HACCP plan and ensure it is effective and valid.</li> </ul> </li> <li>● Step 12: establishing documentation and record-keeping requirements: <ul style="list-style-type: none"> <li>○ these must be proportionate to the size and type of business</li> <li>○ must demonstrate food safety is being managed; records are also useful to support a due diligence defence when investigating complaints and when auditing a system.</li> </ul> </li> </ul>
1.29	<p><b>How to contribute to a HACCP plan for a simple product, by creating a HACCP flow diagram as outlined in step 4 of the 12 HACCP steps:</b></p> <ul style="list-style-type: none"> <li>● Using the appropriate style for the type of communication and audience (for example, technical function, engineering function, production function).</li> <li>● Ensuring that the diagram is clear and concise.</li> <li>● Using the appropriate level of detail for audience and purpose.</li> </ul>

	<ul style="list-style-type: none"> <li>• Using correct terminology, grammar, spelling and punctuation, and proofreading to ensure accuracy.</li> <li>• Using relevant digital devices and media as appropriate (for example, computer and application diagramming software) to construct the flow diagram.</li> </ul>
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<b>What skills do students need to demonstrate?</b>	
<b>S1.9 Maintain and implement a food safety management system within a production facility</b>	<b>(E1, E2, E3, E4, M6, D1, D2, D3)</b>
<b>S1.10 Carry out monitoring and recording of food safety controls, ensuring all information is recorded accurately and precisely</b>	<b>(E1, E2, E3, E4, M1, M2, M5, M6, M8, D1, D2, D3, D4)</b>
<b>S1.11 Review food safety management controls</b>	<b>(E1, E4, M2, M5, M6, D1, D2, D3)</b>

<b>What underpinning knowledge do students need?</b>	
<b>Food safety management</b>	
1.30	<p><b>The importance of food safety management systems in the food and drink industry:</b></p> <ul style="list-style-type: none"> <li>• Ensures a systematic approach.</li> <li>• Ensures regulatory compliance required by law.</li> <li>• Ensures control of risks and hazards to ensure food is safe.</li> <li>• Ensures the production of safe food.</li> <li>• Ensures traceability.</li> <li>• Ensures due diligence (for example, recordkeeping).</li> </ul>
1.31	<p><b>The importance of following the correct practices for maintaining good personal hygiene within the food and drink industry:</b></p> <ul style="list-style-type: none"> <li>• Handwashing: to reduce the risk of microbiological contamination.</li> <li>• PPE, including restrictions of use: to reduce the risk of physical contamination.</li> <li>• Restrictions on the wearing of make-up (for example, false nails, eyelashes): to reduce the risk of physical contamination.</li> <li>• Restrictions on the wearing of jewellery: to reduce the risk of physical contamination.</li> <li>• Fitness to work including reporting of illnesses and infections: to reduce the risk of microbiological contamination.</li> <li>• Covering of wounds with correct dressings (for example, blue, waterproof, metal detectable strip): to reduce the risk of microbiological or physical contamination.</li> <li>• Restrictions on the use of perfumes/aftershave: to reduce the risk of chemical contamination.</li> </ul>

1.32	<p><b>The correct procedures for maintaining good food safety and hygiene within the food and drink industry (the 4 Cs):</b></p> <ul style="list-style-type: none"> <li>• Cleaning, including cleaning schedules.</li> <li>• Cooking, including correct temperature and cooking times.</li> <li>• Chilling, including correct temperature, keeping food out of the danger zone and correct storage.</li> <li>• Cross-contamination, including segregation.</li> </ul>
1.33	<p><b>The 4 food safety hazards and the risks associated with them:</b></p> <ul style="list-style-type: none"> <li>• Microbiological (for example, bacteria, viruses, fungi – yeasts and moulds): <ul style="list-style-type: none"> <li>○ risks to include: food poisoning, foodborne disease, food spoilage.</li> </ul> </li> <li>• Physical (for example, hairs, buttons, fingernails, pest droppings/fur/feathers): <ul style="list-style-type: none"> <li>○ risks to include: choking, cuts in the mouth, broken teeth.</li> </ul> </li> <li>• Chemical (for example, cleaning chemicals, natural chemicals, pesticides, food additives): <ul style="list-style-type: none"> <li>○ risks to include: sickness, unpleasant taste, long-term damage to the body.</li> </ul> </li> <li>• Allergenic (for example, peanuts, cereals containing gluten, tree nuts, sesame seeds, eggs, milk, soya beans, mustard, sulphur dioxide, lupin, celery, fish, crustaceans, molluscs): <ul style="list-style-type: none"> <li>○ risks to include: mild to moderate allergic reactions, anaphylaxis, death.</li> </ul> </li> </ul>
1.34	<p><b>The main responsibilities for all food and drink businesses in relation to food safety management, with reference to the relevant food safety legislation:</b></p> <ul style="list-style-type: none"> <li>• Businesses must not include anything in food or drink, remove anything from food or drink, or treat food or drink in any way which means it would be injurious to the health of the identified consumer.</li> <li>• The food and drink that businesses serve or sell must be of the nature, substance or quality which consumers would expect.</li> <li>• Food and drink must be labelled, advertised and presented in a way that is not false or misleading.</li> </ul>
1.35	<ul style="list-style-type: none"> <li>• <b>The potential implications of not complying with the relevant food safety legislation:</b></li> <li>• Prosecution of individual and/or business.</li> <li>• Loss of custom.</li> <li>• Reputational damage.</li> <li>• Fines.</li> <li>• Prison sentence.</li> <li>• Staff wellbeing (for example, morale).</li> <li>• Loss of job.</li> <li>• Possible closure of food and drink operations.</li> <li>• Injury to consumer.</li> </ul>

1.36	<p><b>The responsibilities of employers in relation to the maintenance of a food safety management system in a food and drink business:</b></p> <ul style="list-style-type: none"> <li>• Providing the correct premises and equipment, including PPE.</li> <li>• Providing ongoing resources (for example, raw materials, staffing, utilities).</li> <li>• Carrying out preventative maintenance.</li> <li>• Implementing the correct prerequisite requirements.</li> <li>• Implementing an effective food safety management system based on the HACCP principles.</li> <li>• Staff training.</li> <li>• Internal audits.</li> </ul>
1.37	<p><b>The responsibilities of employees in relation to the maintenance of food safety management in a food business:</b></p> <ul style="list-style-type: none"> <li>• Undertaking mandatory training dependent on role.</li> <li>• Following policies and procedures as detailed in the SOPs.</li> <li>• Completing necessary paperwork.</li> <li>• Wearing the PPE provided.</li> <li>• Being fit for work and reporting illnesses, as per organisational policies and procedures.</li> <li>• Escalating hazards.</li> </ul>
1.38	<p><b>The purpose of monitoring food safety management systems:</b></p> <ul style="list-style-type: none"> <li>• Ensuring food safety hazards are under control.</li> <li>• Ensuring procedures are being correctly implemented and followed.</li> <li>• Ensuring regulatory requirements are met.</li> </ul>
1.39	<p><b>How to maintain and implement a food safety management system within a production facility:</b></p> <ul style="list-style-type: none"> <li>• Following policies and procedures (for example, prerequisite and critical control procedures).</li> <li>• Completing necessary paperwork (for example, for monitoring and recording).</li> <li>• Wearing the PPE provided.</li> <li>• Being fit for work and reporting illnesses, as per organisational policies and procedures.</li> <li>• Escalating hazards.</li> </ul>
1.40	<p><b>The purpose of a range of checks that are carried out to verify food safety:</b></p> <ul style="list-style-type: none"> <li>• Equipment and maintenance checks: to detect the potential for physical contamination, calibration of equipment.</li> <li>• Incoming raw material verification checks: to ensure the required specifications are met and the raw materials are free from contaminants.</li> <li>• Cleaning: to ensure work/production areas are free from contaminants.</li> </ul>

	<ul style="list-style-type: none"> <li>• Training records: to ensure staff are competent to carry out the task in line with the current procedures.</li> <li>• Allergen controls: to ensure allergenic materials are handled correctly to prevent cross-contamination.</li> <li>• Temperature checks: to ensure the product meets the required cooking/chilling temperature and remains safe to consume.</li> <li>• Final product checks: to ensure it meets the final product specifications.</li> </ul>
1.41	<p><b>How to carry out monitoring and recording of food safety controls, ensuring all information is recorded accurately and precisely:</b></p> <ul style="list-style-type: none"> <li>• Temperature checks: <ul style="list-style-type: none"> <li>○ to check consistent cooking and chilling temperatures and times.</li> </ul> </li> <li>• Equipment and maintenance checks: <ul style="list-style-type: none"> <li>○ to detect the potential for physical contamination, calibration of equipment to ensure accuracy of equipment.</li> </ul> </li> <li>• Incoming raw material verification checks: <ul style="list-style-type: none"> <li>○ to ensure they meet the raw materials specifications and are contamination free.</li> </ul> </li> <li>• Final product checks: <ul style="list-style-type: none"> <li>○ to ensure it meets the final product specifications.</li> </ul> </li> <li>• Cleaning checks: <ul style="list-style-type: none"> <li>○ to ensure work/production areas are contamination free.</li> </ul> </li> <li>• Training records: <ul style="list-style-type: none"> <li>○ to ensure staff are trained to carry out the task against the current procedure.</li> </ul> </li> <li>• Allergen controls: <ul style="list-style-type: none"> <li>○ to ensure allergenic ingredients are segregated.</li> </ul> </li> </ul>
1.42	<p><b>How to review food safety management controls:</b></p> <ul style="list-style-type: none"> <li>• Identifying non-conformities.</li> <li>• Suggesting corrective actions.</li> </ul>
1.43	<p><b>The methods used for pest control and prevention within the food and drink industry:</b></p> <ul style="list-style-type: none"> <li>• Staff training to recognise and report signs and types of pests.</li> <li>• Pest-proofing of premises: <ul style="list-style-type: none"> <li>○ fly screens on windows</li> <li>○ strip curtains</li> <li>○ drain covers.</li> </ul> </li> <li>• Clean-as-you-go procedures.</li> <li>• Waste control procedures.</li> <li>• Reduction of vegetation around buildings.</li> <li>• Building maintenance (for example, having a rock or gravel perimeter around facility).</li> <li>• Correct storage of raw materials.</li> </ul>

	<ul style="list-style-type: none"> <li>• Scheduled monitoring procedures: <ul style="list-style-type: none"> <li>○ the use of external qualified contractors for monitoring and control</li> <li>○ bait boxes</li> <li>○ electric fly killers</li> <li>○ traps.</li> </ul> </li> <li>• Inspection of deliveries: <ul style="list-style-type: none"> <li>○ raw materials and their transportation.</li> </ul> </li> </ul>
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<b>What skills do students need to demonstrate?</b>
<b>S1.12 Carry out an internal audit by following the appropriate stages and demonstrating skills of a good auditor</b> (E1, E2, E3, E4, M2, M5, M6, M7, M8, D1, D2, D3, D4)
<b>S1.13 Review a specific food safety and quality management procedure to ensure that the food quality or food safety standard will be met</b> (E1, E2, E3, E4, M1, M2, M3, M4, M5, M6, M7, M8, D1, D2, D3, D4)

<b>What underpinning knowledge do students need?</b>	
<b>Technical and quality management in the food industry</b>	
1.44	<b>The difference between quality assurance and quality control within the food and drink industry:</b> <ul style="list-style-type: none"> <li>• Quality assurance: <ul style="list-style-type: none"> <li>○ failure prevention</li> <li>○ in-process checks against specification</li> <li>○ ongoing planned maintenance</li> <li>○ instrument calibration</li> <li>○ ownership of stages in the process.</li> </ul> </li> <li>• Quality control: <ul style="list-style-type: none"> <li>○ failure detection</li> <li>○ final product testing</li> <li>○ final specification checks.</li> </ul> </li> </ul>
1.45	<b>The function of the following organisations in relation to the safety and quality of food and drink:</b> <ul style="list-style-type: none"> <li>• Food Standards Agency (FSA): ensures food is safe to consume, concerned with national and global issues.</li> <li>• Local authority: concerned with local issues: <ul style="list-style-type: none"> <li>○ Trading Standards: to maintain integrity of product, weights and measures</li> <li>○ Environmental Health: ensures food is safe to consume.</li> </ul> </li> <li>• Advisory research organisations (for example, Leatherhead Food Research, Campden BRI): provide expertise and specialist advice to manufacturers to help make food safe.</li> </ul>

1.46	<p><b>The procedures and controls that contribute to a food safety and quality management system within food and drink operations:</b></p> <ul style="list-style-type: none"> <li>• Prerequisite procedures.</li> <li>• Traceability procedures.</li> <li>• Industry standards including specific product standards, labelling requirements and Brand Reputation through Compliance Global Standards (BRCGS).</li> <li>• Customer specifications.</li> <li>• Nutritional analysis process.</li> <li>• Critical controls.</li> <li>• Weight control/portion size as identified in the product specification.</li> </ul>
1.47	<p><b>The difference between internal and external audits in the food and drink industry:</b></p> <ul style="list-style-type: none"> <li>• Internal audits: carried out by an employee (first-party audit): <ul style="list-style-type: none"> <li>○ to ensure the whole operation is meeting the specified requirements</li> <li>○ identifying actions and controls to improve systems.</li> </ul> </li> <li>• External audits: carried out by the manufacturer on the supplier (second-party audit) and/or carried out by an external organisation (for example, FSA/local authorities/certification bodies such as BRCGS) on the food and drink manufacturer (third-party audit): <ul style="list-style-type: none"> <li>○ to ensure the business is meeting customer and/or accreditation requirements.</li> </ul> </li> </ul>
1.48	<p><b>The purpose of different types of audits:</b></p> <ul style="list-style-type: none"> <li>• System audit: identifies if a documented food safety and quality system meets specific requirements of a relevant food safety and quality standard (ISO 17025).</li> <li>• Compliance audit: examines if all aspects of a prescribed food safety and quality system, including observation of the activity, are being complied with, working well and are maintained on a continual basis.</li> <li>• Horizontal audit: looks at one discrete or particular aspect of the quality system (for example, training).</li> <li>• Vertical audit: a narrow focus on a particular aspect of a product.</li> <li>• Follow-up audit: to verify corrective actions have been implemented and have resolved the non-conformity.</li> <li>• Unannounced audit: unscheduled; used to ensure audit standards are maintained at all times, and can be implemented if a customer has complained, if there is an internal non-conformity or if there is a breakdown in process.</li> </ul>
1.49	<p><b>How to carry out an internal audit by following the appropriate stages and demonstrating skills of a good auditor:</b></p> <ul style="list-style-type: none"> <li>• Opening meeting, responding to any questions for clarification as appropriate.</li> </ul>

	<ul style="list-style-type: none"> <li>• Using an audit checklist, ensuring all previous non-conformities have been closed out.</li> <li>• Observing practices, asking appropriate and relevant questions to clarify any required areas, and listening actively to responses.</li> <li>• Recording non-conformities and good practice.</li> <li>• Writing the report.</li> <li>• Closing meeting, summing up key points, and agreeing corrective actions and timescales for completion.</li> </ul>
1.50	<b>Review a specific food safety and quality management procedure to ensure that the food quality or food safety standard will be met (for example, cooking temperature, overall product quality, storage requirements, allergen controls, product nutritional value).</b>

<b>What skills do students need to demonstrate?</b>	
<b>S1.14 Take swabs from food contact surfaces, including hard-to-reach areas, following a sampling procedure</b>	<b>(E4, E5, M1, M3, M4, M5, M6)</b>
<b>S1.15 Use laboratory techniques, skills and equipment to identify any pathogens (causative agents) present on swabbed food surface areas</b>	<b>(E4, E5, M1, M3, M4, M5, M6)</b>
<b>S1.16 Identify hygiene process failures</b>	<b>(E1, E2, M1, M2, M4, M5, M6)</b>

<b>What underpinning knowledge do students need?</b>	
<b>Microbiology</b>	
1.51	<p><b>A range of common pathogenic bacteria that can cause foodborne illness and disease and examples of the food products with which they are associated:</b></p> <ul style="list-style-type: none"> <li>• Campylobacter jejuni – chicken, other raw meats.</li> <li>• Bacillus cereus – white rice.</li> <li>• Salmonella spp. – chicken, eggs.</li> <li>• Clostridium botulinum – low acid canned goods.</li> <li>• Clostridium perfringens – stews, rolled meats.</li> <li>• Staphylococcus aureus – poor personal hygiene.</li> <li>• Listeria monocytogenes – soft cheese, chilled products.</li> <li>• Escherichia coli O157 – raw and undercooked meats.</li> </ul>
1.52	<p><b>How pathogenic agents may affect at-risk groups:</b></p> <ul style="list-style-type: none"> <li>• Infants and babies (for example, pathogenic agents such as Salmonella spp. and Escherichia coli O157 can cause diarrhoeal diseases, which can lead to dehydration in babies and infants).</li> </ul>

	<ul style="list-style-type: none"> <li>• The elderly (for example, gastrointestinal pathogenic bacteria such as <i>Campylobacter jejuni</i>, <i>Clostridium perfringens</i> and <i>Salmonella</i> spp. can affect the elderly as they have slower digestion, which allows bacteria extended time to grow in the gastrointestinal tract).</li> <li>• Pregnant people (for example, <i>Listeria monocytogenes</i> infection during pregnancy can cause miscarriage, stillbirth, uterine infection and preterm delivery).</li> <li>• Immuno-compromised (for example, decreased immune systems means they may be more susceptible to foodborne illness).</li> </ul>
1.53	<p><b>How to identify pathogenic bacteria that cause foodborne illness and disease:</b></p> <ul style="list-style-type: none"> <li>• Observation of, and reported, symptoms can signal initial awareness of a foodborne illness.</li> <li>• Laboratory techniques used to identify pathogens (causative agents): <ul style="list-style-type: none"> <li>○ general identification techniques (for example, Gram-positive, Gram-negative).</li> </ul> </li> <li>• Aseptic techniques (for example, plating): purposeful growing of pathogens (causative agents) to allow for identification, can make use of selective media to allow for isolation of specific pathogens (causative agents) <ul style="list-style-type: none"> <li>○ differential staining techniques: use of specific stains and dyes that provide contrast images that enable identification of specific pathogens (causative agents) by their shape or specific features.</li> </ul> </li> <li>• Microscopic examinations: identification of pathogens (causative agents) by direct observation of the gross structures and specific observable features, using a range of microscopes, including scanning electron microscopes <ul style="list-style-type: none"> <li>○ specific identification techniques (for example, identification of a specific strain of bacteria).</li> </ul> </li> <li>• Biochemical reactions: identification based on biochemical characteristics of pathogens (causative agents) such as nutritional and metabolic capabilities.</li> <li>• Subtyping: genetic analysis of different samples of pathogens (causative agents) to identify the similarity between them.</li> <li>• Serological typing: identification of pathogens (causative agents), particularly those that are difficult to culture, through testing for the presence of pathogen-specific antibodies in blood.</li> <li>• Phage typing: used for the identification of a single strain of bacteria by the use of bacteriophages.</li> <li>• Immunoassay: identification of pathogens (causative agents) through testing for the presence of pathogen specific antibodies.</li> </ul>
1.54	<p><b>How a range of food safety and hygiene measures are used to control pathogenic bacteria:</b></p> <ul style="list-style-type: none"> <li>• HACCP: <ul style="list-style-type: none"> <li>○ food safety management system that identifies hazards and puts controls in place.</li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>• Personal and environmental hygiene practices: <ul style="list-style-type: none"> <li>○ cleaning schedules</li> <li>○ handwashing procedures.</li> </ul> </li> <li>• Policies and procedures: <ul style="list-style-type: none"> <li>○ staff sickness reporting procedure</li> <li>○ sickness exclusion.</li> </ul> </li> </ul>
1.55	<p><b>How to sample an environment, using appropriate laboratory skills and equipment, to identify pathogens (causative agents):</b></p> <ul style="list-style-type: none"> <li>• Scheduled environmental swab testing: <ul style="list-style-type: none"> <li>○ conducted on both food contact surfaces and non-food contact surfaces (for example, conveyor belts, drains and rollers)</li> <li>○ frequency of swabbing of specific areas and number of swabs, determined by <ul style="list-style-type: none"> <li>○ where they are within the production process</li> <li>○ ‘zone of risk’ approach taken to environmental swabbing is of that is dependent on product and environment</li> <li>○ following the swabbing process.</li> </ul> </li> </ul> </li> <li>• Hand swabs: <ul style="list-style-type: none"> <li>○ conducted to ensure the implementation of effective personal hygiene requirements (including handwashing techniques)</li> <li>○ frequency of swabbing dependent on products being handled and an individual’s role in the production process</li> <li>○ following the swabbing process.</li> </ul> </li> <li>• Water testing: <ul style="list-style-type: none"> <li>○ conducted on water samples from a range of sources within the production process</li> <li>○ frequency of testing determined by regulatory guidelines and organisational SOPs (including HACCP)</li> <li>○ samples taken by trained individuals</li> <li>○ processing of samples in-house or by contracted laboratories.</li> </ul> </li> <li>• Adenosine triphosphate (ATP) swabbing and monitoring techniques: <ul style="list-style-type: none"> <li>○ a test which determines if ATP is present within a sample</li> <li>○ ATP is present in all animals, vegetables and microorganisms, and, therefore, the presence of ATP is used as an assessment of contamination</li> <li>○ standard swabbing techniques used in environmental and hand swabbing are employed, but with ATP specific swab sticks</li> <li>○ swab sticks are analysed using a luminometer, which determines the level of contamination in a sample.</li> </ul> </li> </ul>
1.56	<p><b>How to take swabs from food contact surfaces, including hard-to-reach areas, following a sampling procedure:</b></p> <ul style="list-style-type: none"> <li>• Identifying the area to be swabbed (food contact surfaces, non-food contact surfaces, zones of risk).</li> <li>• Identifying the required number of swabs.</li> </ul>

	<ul style="list-style-type: none"> <li>• Taking appropriate number of swabs to produce reliable results.</li> <li>• Following the specified swabbing process: <ul style="list-style-type: none"> <li>○ removing moistened sterile swabs from the holding tube and wiping across the test area in a rotating movement.</li> </ul> </li> <li>• Maintaining integrity of swabs.</li> </ul>
1.57	<p><b>How to use laboratory techniques, skills and equipment to identify any pathogens (causative agents) present on swabbed food surface areas:</b></p> <ul style="list-style-type: none"> <li>• Laboratory skills: <ul style="list-style-type: none"> <li>○ accurate recording of information</li> <li>○ hand-to-eye coordination</li> <li>○ problem solving.</li> </ul> </li> <li>• Laboratory techniques and equipment: <ul style="list-style-type: none"> <li>○ using pre-prepared detection kits: <ul style="list-style-type: none"> <li>– after swabbing the area, the swabs should immediately be placed into the detection tube</li> <li>– detection tubes should be incubated as per manufacturers’ instructions</li> <li>– detection tubes are observed for colour changes and results recorded</li> </ul> </li> <li>○ using aseptic technique to transfer sample from swabs to growth medium: <ul style="list-style-type: none"> <li>– holding the swab in one hand, using sterile tweezers</li> <li>– (if required) and lifting the lid of the petri dish with the other hand</li> <li>– only lifting the lid as far as required to drag the swab across the surface in a zig-zag pattern</li> <li>– replacing the lid of the petri dish, sealing, and labelling</li> <li>– disposing of the swab correctly (for example, not placing it on the bench)</li> <li>– using differential staining technique for Gram staining:</li> <li>– rolling the swab over a clean slide, using sterile tweezers if needed</li> <li>– heat-fixing the slide</li> <li>– applying stains and rinses in the correct order</li> <li>– examining the smear, using a light microscope, and identifying if bacteria are Gram-positive (violet in colour) or Gram-negative (pink in colour).</li> </ul> </li> </ul> </li> </ul>
1.58	<p><b>How to identify hygiene process failures, by:</b></p> <ul style="list-style-type: none"> <li>• Interpreting results of samples.</li> <li>• Providing evidence-based recommendations to improve the hygiene controls of the swabbed areas (for example, cleaning procedures, personal hygiene improvements).</li> </ul>

What skills do students need to demonstrate?
<b>S1.17 Select raw materials as per recipe/client requirement</b> <b>(E1, E5, M1, M3, M4, M8, D3)</b>
<b>S1.18 Follow segregation procedures for handling raw materials in order to protect the integrity of products, and to ensure origin of product is maintained</b> <b>(E1, E5, M1, M2, M3, M4, M6, M10)</b>
<b>S1.19 Follow segregation procedures for handling raw materials to prevent deoxyribonucleic acid (DNA), allergen or microbial cross-contamination</b> <b>(E1, E5, M1, M2, M3, M4, M6, M10)</b>

What underpinning knowledge do students need?	
<b>Raw materials in the food industry</b>	
1.59	<b>What to consider when choosing sources and suppliers of raw materials:</b> <ul style="list-style-type: none"> <li>• Supplier reputation.</li> <li>• Self-assessment and/or external audit results.</li> <li>• Ability to meet specification requirements.</li> <li>• Industry recognised certification.</li> <li>• Sustainability.</li> <li>• Risk assessment to determine suitability of supplier and procedures for any subsequent vetting required.</li> <li>• Impact of defective raw materials on cost and production.</li> </ul>
1.60	<b>The purpose of specifications of raw materials:</b> <ul style="list-style-type: none"> <li>• To ensure that companies purchase and distribute food that is safe, of good quality and able to satisfy the needs of each customer.</li> <li>• To specify requirements for raw materials.</li> <li>• To ensure consistency of raw material supply (for example, seasonal and geographical variations, soil chemical composition).</li> </ul>
1.61	<b>What the minimum requirements are for a specification of raw materials:</b> <ul style="list-style-type: none"> <li>• Physical parameters (for example, size, shape, colour).</li> <li>• Appearance.</li> <li>• Odour.</li> <li>• Flavour.</li> <li>• Texture.</li> <li>• Foreign bodies/physical defects.</li> <li>• The name of the product and the supplier's item number.</li> <li>• Components or composition of the material.</li> <li>• The presence of regulated or customer recognised food allergens.</li> <li>• Pertinent physical, chemical and microbiological information.</li> </ul>

	<ul style="list-style-type: none"> <li>• Shipping and storage information.</li> <li>• Shelf life.</li> <li>• Handling instructions.</li> </ul>
1.62	<p><b>The functionality of raw materials:</b></p> <ul style="list-style-type: none"> <li>• To meet recipe requirements.</li> <li>• To provide the required nutritional value and organoleptic requirements.</li> <li>• To meet specific product requirements (for example, preservatives, colour, binding agent, emulsifier).</li> </ul>
1.63	<p><b>Systems available for handling raw materials to ensure the integrity of the product is maintained and to prevent cross contamination:</b></p> <ul style="list-style-type: none"> <li>• Storage systems and handling equipment: <ul style="list-style-type: none"> <li>○ racks/trays</li> <li>○ shelves</li> <li>○ segregated areas</li> <li>○ storage bins</li> <li>○ colour coded utensils and equipment.</li> </ul> </li> <li>• Engineered systems: <ul style="list-style-type: none"> <li>○ conveyor</li> <li>○ robotic.</li> </ul> </li> <li>• Handling of bulk items: <ul style="list-style-type: none"> <li>○ bucket elevators</li> <li>○ silos.</li> </ul> </li> <li>• Industrial trucks: <ul style="list-style-type: none"> <li>○ hand trucks</li> <li>○ pallet jacks</li> <li>○ forklifts.</li> </ul> </li> <li>• Stock rotation procedures: <ul style="list-style-type: none"> <li>○ date coding/day coding/batch identification.</li> </ul> </li> </ul>
1.64	<p><b>What to consider when selecting raw materials for a particular product:</b></p> <ul style="list-style-type: none"> <li>• Legal requirements.</li> <li>• Functionality requirements.</li> <li>• Food safety requirements (for example, allergens).</li> <li>• Final product specification.</li> </ul>
1.65	<p><b>How to select raw materials as per recipe/client requirement, to ensure that the finished product:</b></p> <ul style="list-style-type: none"> <li>• Meets recipe requirements.</li> <li>• Provides the required nutritional value and organoleptic requirements.</li> <li>• Meets product specification (for example, preservatives, colour, binding agent, emulsifier, origin of raw materials).</li> </ul>

1.66	<p><b>How to ensure the quality assurance of raw materials:</b></p> <ul style="list-style-type: none"> <li>• Best before and use by dates.</li> <li>• Checking batch codes.</li> <li>• Checking labelling.</li> <li>• Supplier approval.</li> <li>• Ensuring packaging is not damaged.</li> <li>• Food allergen information.</li> <li>• Organoleptic.</li> <li>• Physical testing.</li> </ul>
1.67	<p><b>The importance of the correct storage of raw materials, in particular segregation and protection of integrity:</b></p> <ul style="list-style-type: none"> <li>• To prevent contamination (for example, microbial, foreign bodies, pest infestation, chemical).</li> <li>• To prevent cross-contamination (for example, DNA, allergens and pathogens (causative agents)).</li> <li>• To ensure durability and prevent spoilage.</li> <li>• To ensure functionality and materials are fit for purpose.</li> </ul>
1.68	<p><b>How to follow segregation procedures for handling raw materials in order to protect the integrity of products, and to ensure origin of product is maintained:</b></p> <ul style="list-style-type: none"> <li>• Using separate PPE/equipment.</li> <li>• Using separate storage areas.</li> <li>• Following personal hygiene procedures.</li> </ul>
1.69	<p><b>How to follow segregation procedures for handling raw materials to prevent deoxyribonucleic acid (DNA), allergen or microbial cross-contamination:</b></p> <ul style="list-style-type: none"> <li>• Using separate PPE/equipment.</li> <li>• Using contaminant free preparation areas.</li> <li>• Using separate storage areas.</li> <li>• Following personal hygiene procedures.</li> </ul>
1.70	<p><b>The considerations to make when storing raw materials:</b></p> <ul style="list-style-type: none"> <li>• Designated areas.</li> <li>• Segregated areas.</li> <li>• Temperatures and humidity.</li> <li>• Stock rotation.</li> <li>• Adequate space and lighting.</li> </ul>

**What skills do students need to demonstrate?**

**S1.20 Check all customer requirements have been met in order to ensure quality of product and shelf life of food**

**(E1, E4, E5, M1, M2, M3, M5, M6, M8, D1, D3)**

**What underpinning knowledge do students need?**

**Food science**

1.71

**The general composition and fundamental role of the main components of different foods:**

- Carbohydrates:
  - macromolecules, composed of one or more monomers containing carbon, hydrogen and oxygen atoms – classified as monosaccharides, disaccharides or polysaccharides
  - a source of energy
  - glucose and fructose are examples of monosaccharides; sucrose and maltose are examples of disaccharides; starch is an example of a polysaccharide
  - found naturally in honey and fruit (sugars)
  - found naturally in the form of fibre, within wholegrain cereals and certain vegetables
  - added to a range of confectionery, chocolates and drinks (sugars)
  - found in bread, rice, potatoes and pasta (starch).
- Lipids:
  - a diverse range of molecules, the lipids found in food are commonly referred to as oils and fats and are mainly triglycerides
  - used as an energy store, as insulation, in hormone production and in cell membrane formation
  - lipids in food include the oils of seeds and grains, as well as animal fats that are found in cheese, milk and meat.
- Proteins:
  - complex macromolecules made up of amino acids, consisting mainly of carbon, hydrogen, nitrogen, oxygen and sulphur
  - play a role in the structure and function of cells, including growth and development
  - found in eggs, milk, meat (animal sources) and nuts, grains and legumes (vegetable sources).
- Water:
  - is a simple molecule
  - plays an essential role in all the activities of body cells, as well as specific roles such as the absorption of nutrients and the removal of waste
  - has a number of roles within food including: maintaining texture, enabling enzyme activity in food, and conducting heat within food

- the amount of water activity in food ( $a_w$ ) affects the growth of bacteria in food; for example, lowering water content can slow down microbial growth
- found in virtually all foods, but amount varies considerably; fruit and vegetables are 80 to 90% water.
- **Vitamins:**
  - a range of compounds that are either water soluble (for example, vitamin C) or fat soluble (for example, vitamin D)
  - required in small amounts for essential metabolic reactions, contributing to the prevention of diseases, and supporting immune system processes. Specific vitamins have specific functions. Vitamins work together (synergistically), supporting a large number of different functions in the body
  - found in fruit and vegetables (vitamins A, C, E, K), meat, poultry, fish, eggs and dairy (vitamins B, D).
- **Minerals:**
  - a range of chemical elements, such as calcium, phosphorus, magnesium, iron and zinc
  - required for various functions in the body, including developing strong teeth and bones, controlling body fluids inside and outside of cells and to support the transfer of food into energy.
  - different minerals are needed in different amounts by the body
  - often work synergistically with vitamins
  - found in a range of foods such as cereals, bread, meat, fish, milk, fruit and vegetables.
- **Enzymes:**
  - a specific group of proteins that act as catalysts for biochemical reactions both inside the human body as well as in food
  - many foods contain useful digestive enzymes that can help the body's digestive process, but if food is cooked/processed, these enzymes will be destroyed
  - foods containing enzymes include fruit and vegetables (for example, pineapple; also spices such as ginger and natural products such as honey).
- **Food additives:**
  - a diverse group of substances
  - some food additives are natural additives or are found in natural sources
  - there is a system for the numbering of additives and different groups of additives such as anti-caking agents, carriers and stabilisers
  - used to enhance taste or appearance of foods, also for preservation of food
  - many synthetically produced additives are now common in a range of processed foods.

	<ul style="list-style-type: none"> <li>• Flavourings: <ul style="list-style-type: none"> <li>○ a range of natural and artificial compounds used in very small amounts, considered to be a food additive</li> <li>○ used to enhance flavours, modify taste and/or smell of foods</li> <li>○ found in a majority of processed foods.</li> </ul> </li> <li>• Colourings: <ul style="list-style-type: none"> <li>○ a range of substances from natural sources (for example, lycopene) or artificially produced (for example, titanium dioxide); considered to be a food additive</li> <li>○ used to modify or enhance the colour of food</li> <li>○ caramel is an example of a natural food colouring which is widely used in a range of food products from soft drinks to bread.</li> </ul> </li> </ul>
1.72	<p><b>The purpose of daily reference intake (RI) in relation to human nutritional requirements (as recommended by the NHS):</b></p> <ul style="list-style-type: none"> <li>• Provides an approximation of the quantity of nutrients an individual should consume daily (for example, how much energy, fat, saturates, carbohydrates, total sugars, protein and salt).</li> <li>• Provides guidance to support customers in making healthy dietary choices based on an average-sized woman doing an average amount of physical activity.</li> </ul>
1.73	<p><b>What RIs are used to show:</b></p> <ul style="list-style-type: none"> <li>• Whether a product is high (red), medium (amber) or low (green) in fat, saturated fat, salt and sugars.</li> <li>• How much energy (calories and kilojoules) a product provides.</li> </ul>
1.74	<p><b>The characteristics of a range of fermentation processes, including the food and drink products that are produced as a result of these processes:</b></p> <ul style="list-style-type: none"> <li>• Lactic acid fermentation: <ul style="list-style-type: none"> <li>○ anaerobic conversion of carbohydrates by a group of bacteria (lactic acid bacteria)</li> <li>○ these bacteria can independently initiate the fermentation process but may also act in combination with yeast, as in the production of sourdough</li> <li>○ process does not necessarily require heat</li> <li>○ results in the preservation and production of a range of food products, including yoghurts and sauerkraut.</li> </ul> </li> <li>• Ethanol fermentation: <ul style="list-style-type: none"> <li>○ also known as alcohol fermentation</li> <li>○ anaerobic conversion of simple sugars into ethanol and carbon dioxide by the action of yeasts</li> <li>○ in this process, venting the carbon dioxide (allowing it to escape) is an especially important requirement to avoid pressure build-up which could cause an explosion within the fermentation vessel</li> <li>○ wine is produced using this process through the fermentation of natural sugars in grapes</li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>○ beer, whiskey and vodka are produced using this process, through the fermentation of grain starches.</li> <li>● Fermentation in baking: <ul style="list-style-type: none"> <li>○ anaerobic conversion of sugars within bakery products (such as bread) will produce carbon dioxide, which will cause a dough to rise</li> <li>○ this conversion is carried out mainly by yeast</li> <li>○ this process is usually carried out at room temperature, but there are instances where the temperature can be altered</li> <li>○ it is possible to use additives in the dough to speed up the fermentation process</li> <li>○ the length of fermentation time has an impact on the overall taste, texture and quality of bakery products, especially in the case of bread.</li> </ul> </li> </ul>
1.75	<p><b>The intrinsic and extrinsic factors used to determine the shelf life of food:</b></p> <ul style="list-style-type: none"> <li>● Intrinsic factors: <ul style="list-style-type: none"> <li>○ initial quality</li> <li>○ ingredients</li> <li>○ the inherent nature of the food</li> <li>○ the product formulation.</li> </ul> </li> <li>● Extrinsic factors: <ul style="list-style-type: none"> <li>○ processing methods</li> <li>○ packaging</li> <li>○ transportation and storage</li> <li>○ consumer handling.</li> </ul> </li> </ul>
1.76	<p><b>The differences between the use by and best before dates of food and drink and when each are applicable:</b></p> <ul style="list-style-type: none"> <li>● Use by: unsafe to eat beyond the use by date and illegal to sell beyond the use by date: <ul style="list-style-type: none"> <li>○ applicable to: short shelf life, high-risk products including chilled salads and chilled cooked meats.</li> </ul> </li> <li>● Best before: refers to the quality of food; not unsafe to eat beyond the best before date: <ul style="list-style-type: none"> <li>○ applicable to: long shelf life, low-risk products including canned foods and dried foods.</li> </ul> </li> </ul>
1.77	<p><b>How a range of food additives (including preservatives) and ingredients with food additive properties can extend the shelf life of food:</b></p> <ul style="list-style-type: none"> <li>● Salt: reduces bacteria.</li> <li>● Sugar: reduces water.</li> <li>● Nitrates: inhibit microbial growth.</li> <li>● Sulfites: inhibit microbial growth and enzymic action.</li> <li>● Sorbic acid: inhibits mould and yeast growth.</li> </ul>

	<ul style="list-style-type: none"> <li>• Calcium propionate: inhibits mould and yeast growth.</li> <li>• Sodium benzoate: inhibits mould and yeast growth in high-acid foods.</li> </ul>
1.78	<p><b>How to check all customer requirements have been met in order to ensure quality of product and shelf life of food:</b></p> <ul style="list-style-type: none"> <li>• Quality of product (for example, to meet nutritional requirements, to reduce additives and preservatives in product formulation).</li> <li>• Shelf life of product (for example, increasing additives and preservatives, change of packaging, processing methods).</li> </ul>

<b>What skills do students need to demonstrate?</b>	
<b>S1:21 Verify existing procedures are meeting food safety and quality standards</b>	
<b>(E1, E4, M1, M2, M3, M4, M5, M6)</b>	

<b>What underpinning knowledge do students need?</b>	
<b>Food technology</b>	
1.79	<p><b>The 3 main types of energy transfer used in food technology, including examples of where they are used:</b></p> <ul style="list-style-type: none"> <li>• Conduction: transferring heat to another item by contact (for example, frying, grilling).</li> <li>• Radiation: transferring heat through waves (for example, in the use of microwaves).</li> <li>• Convection: transferring heat through the use of liquids (for example, boiling).</li> </ul>
1.80	<p><b>How to carry out heat processing techniques in a kitchen:</b></p> <ul style="list-style-type: none"> <li>• Heat-processing techniques for cooking food: <ul style="list-style-type: none"> <li>○ baking: <ul style="list-style-type: none"> <li>– dry heat cooking method carried out in an enclosed space</li> <li>– used as a way to uniformly cook foods</li> <li>– time and temperature dependent on food being produced</li> </ul> </li> <li>○ frying: <ul style="list-style-type: none"> <li>– involves the immersion of food in boiling oil</li> <li>– time and temperature dependent on food being produced</li> </ul> </li> <li>○ grilling: <ul style="list-style-type: none"> <li>– involves cooking food on a rack over a heat source</li> <li>– direct heat quickly sears the outside of food, producing distinctive robust, roasted and sometimes pleasantly charred flavour and crust</li> <li>– time and temperature dependent on food being produced</li> </ul> </li> <li>○ boiling: <ul style="list-style-type: none"> <li>– is a moist-heat cooking method that happens when the temperature of the liquid reaches 100°C</li> </ul> </li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>- food is completely submerged in water for even heat distribution</li> <li>- the full boil is a vigorous one, where bubbles rapidly and violently break over the entire surface of the water.</li> <li>• Heat processing techniques for preserving food: <ul style="list-style-type: none"> <li>○ pasteurisation: <ul style="list-style-type: none"> <li>- involves heating to a specific temperature, usually less than 100°C</li> <li>- acidity of the food determines the exact time and temperature required</li> <li>- can be undertaken on food and drink either before or after packaging</li> </ul> </li> <li>○ blanching: <ul style="list-style-type: none"> <li>- involves the rapid immersion of food in steam or boiling water followed by a rapid cooling</li> <li>- often used with fruit and vegetables to maintain flavour, colour, texture and nutritional value</li> </ul> </li> <li>○ evaporation: <ul style="list-style-type: none"> <li>- evaporation is the partial removal of water from liquid food by boiling (for example, liquid products can be concentrated from 5% dry solids to 72%, or even higher, depending on the viscosity of the concentrates)</li> <li>- evaporation is used to pre-concentrate food, to increase the solid content of food, to change the colour of food and to reduce the water content of a liquid product almost completely.</li> </ul> </li> </ul> </li> <li>• How other heat processing techniques are carried out in commercial environments: <ul style="list-style-type: none"> <li>○ sterilisation: <ul style="list-style-type: none"> <li>- involves heating to a specific temperature above 100°C</li> <li>- usually, the product is canned or bottled and then heat-treated in a steriliser with steam or hot (superheated) water</li> </ul> </li> <li>○ ultra heat treatment: <ul style="list-style-type: none"> <li>- involves a very short heat treatment of temperatures above 135°C for one second</li> <li>- can only be used within specific production plants that are able to maintain a sterile atmosphere.</li> </ul> </li> </ul> </li> </ul>
1.81	<p><b>How heat processing techniques may change food and drink:</b></p> <ul style="list-style-type: none"> <li>• Colour (for example, caramelisation).</li> <li>• Texture (for example, coagulation, gelatinisation).</li> <li>• Flavour.</li> <li>• Nutritional value.</li> <li>• Enzyme functionality.</li> <li>• Microbial growth, spore formation and survival which impacts on shelf life of food.</li> </ul>

1.82

**The difference between a range of heat removal-based food technology used within the food and drink industry:**

- Pellet freezing:
  - involves freezing liquids and semi-solids into pellet form
  - commonly used for spinach, cream, orange juice, eggs and soups.
- Plate freezing:
  - used for food packed in flat cartons, such as ready meals
  - cartons are placed in between narrow metal shelves in which a very cold refrigerant circulates to ensure freezing
  - revolving plate freezers are used; for example, for boil-in-the-bag products
  - plate freezing usually takes 2 to 3 hours.
- Blast freezing:
  - air blast freezers are the most common methods used for blast freezing and include:
    - static tunnels, where trolleys of boxed products such as beef and cakes are pushed through
    - solid continuous belt freezers, which are used for fish fillets, burgers and pizzas
    - spiral belt freezers, which are relatively small and allow the refrigerated air to pass through the open belt
  - air circulates around the food at temperatures of  $-30^{\circ}\text{C}$  to  $-40^{\circ}\text{C}$
  - freezing time depends on the dimensions of the product but normally takes between 2 to 3 hours.
- Nitrogen freezing:
  - is a rapid freezing technique where the food is sprayed with, or dipped into, liquid nitrogen
  - normally used for high-cost, small products such as prawns or raspberries.
- Chilling:
  - food is portioned and chilled to below  $3^{\circ}\text{C}$  within 2 hours of cooking
  - chillers must be capable of reducing the temperature of a 50mm layer of food from  $70^{\circ}\text{C}$  to  $3^{\circ}\text{C}$  in under 90 minutes when fully loaded
  - automatic controls are required including an accurate ( $0.5^{\circ}\text{C}$ ) indicating thermometer and recorder
  - product depth may need to be reduced to achieve the chilling specification
  - joints of meats should not exceed 2kg and 100mm in thickness.
- Blast chill:
  - cools food rapidly without freezing
  - chilled air at  $2^{\circ}\text{C}$  to  $-7^{\circ}\text{C}$  is circulated around the product
  - some blast chillers may also use liquid nitrogen and solid carbon dioxide.

1.83	<p><b>Why heat-removal based food technology is used within the food and drink industry:</b></p> <ul style="list-style-type: none"> <li>• To prevent the growth and multiplication of microorganisms</li> <li>• To keep food out of the danger zone (for example, between 5°C – 63°C)</li> <li>• To achieve a specific processing requirement.</li> </ul>
1.84	<p><b>The difference between a range of ambient temperature processing technologies:</b></p> <ul style="list-style-type: none"> <li>• Fermentation: <ul style="list-style-type: none"> <li>○ the process of converting carbohydrates to alcohol or organic acids using microorganisms (yeasts or bacteria) under anaerobic conditions</li> <li>○ usually used for the chemical conversion of sugars into ethanol to produce alcoholic drinks such as wine, beer and cider</li> <li>○ a similar process takes place in the leavening of bread (CO<sub>2</sub> produced by yeast activity) and in the preservation of sour foods with the production of lactic acid such as in sauerkraut and yoghurts</li> <li>○ other fermented foods include vinegar, olives and cheese.</li> </ul> </li> <li>• Irradiation: <ul style="list-style-type: none"> <li>○ used to kill bacteria that cause food poisoning such as Salmonella spp., Campylobacter spp. and Escherichia coli</li> <li>○ also helps to preserve food and extend shelf life</li> <li>○ during irradiation, food is exposed to electron beams, X-rays or gamma rays</li> <li>○ the effect is similar to pasteurisation or cooking but the appearance and texture of the food changes less during irradiation.</li> </ul> </li> <li>• Chemical preservation methods: <ul style="list-style-type: none"> <li>○ chemical preservatives commonly used in food include benzoates (for example, sodium benzoate), nitrates (for example, sodium nitrate) and sulfites (for example, sulphur dioxide)</li> <li>○ these chemicals either inhibit the activity of the bacteria or destroy them; sorbic acid is also used for the same purpose.</li> </ul> </li> </ul>
1.85	<p><b>Why ambient temperature processing is used within the food and drink industry:</b></p> <ul style="list-style-type: none"> <li>• To control pH levels and water activity.</li> <li>• To retain nutritional quality and sensory characteristics of food.</li> <li>• To prevent the growth and multiplication of microorganisms.</li> </ul>
1.86	<p><b>The advantages, limitations and uses of the following different types of packaging used in the food and drink industry:</b></p> <ul style="list-style-type: none"> <li>• Aseptic processing (for example, Tetra Pak): aseptic processing is a high-temperature, short-time thermal process to commercially sterilise a product and fill the cooled sterile product into a pre-sterilised package, all within a sterile environment:</li> </ul>

- advantages:
  - aseptic technology keeps food safe and flavourful for at least 6 months, without refrigeration or preservatives
  - extends the storage life of food products, optimising product quality and reducing cost
  - allows food to retain more colour, texture, taste and nutrients
- limitations:
  - requires sterilisation
  - more expensive than other types of packaging as the materials require different machinery and can be complex
  - maintaining air sterility in the processing room can be difficult
  - only low-viscosity liquids can be processed using steam injection, and high-quality steam is required to ensure sterilisation
  - dairy products could have a cooked flavour because of exposure to sulphhydryl groups and could change in colour, an effect caused by Maillard browning
- uses:
  - milk
  - fruit juice
  - salad dressing
  - liquid egg.
- Modified atmosphere packaging (MAP): uses gases such as carbon dioxide, nitrogen and oxygen, which are set at appropriate concentrations for the product. A mixture of the right type of gases is injected during sealing. Products must be stored in a refrigerated environment to maintain quality, food safety and shelf life:
  - advantages:
    - the atmosphere in which the food is packaged is modified so that spoilage is markedly reduced, and the shelf life of the product is increased, without the need of additives
  - limitations:
    - risk of oxidation (for example, in the red colour pigments in red meat, especially prominent in beef)
    - loss of colour in the food product can result in an unappetising appearance
    - a low oxygen content in protective gas packaging may result in oxidation
    - seal integrity is vital to ensure carefully selected proportion of MAP gases do not escape, which has an impact on the quality and safety of the product
  - uses:
    - beef
    - pork
    - chicken
    - fish (cooked or fresh).

- Canning: various types of hermetically sealed containers can be used for canning, including cans, restorable plastic trays and pouches. Use of the term 'canning' applies to all of these:
  - advantages:
    - canning alters the food chemically, by changing the moisture, pH or salinity levels to protect it against bacteria, moulds and yeasts
    - canning also limits food enzyme activity
  - limitations:
    - canning is time-consuming
    - improper methods can be dangerous
    - when jars fail to seal, spoilage will occur
    - inadequate processing or poor sanitation can result in Clostridium botulinum contamination
  - uses:
    - canned fish, meats and vegetables.
- Trays/bags/boxes/cartons: paper or plastic trays, bags, boxes or cartons:
  - advantages:
    - protects fragile products which are easily broken or damaged such as eggs, fruit or cakes
    - can hold multiple items together such as bagged fruit, multi-can packs
  - limitations:
    - large amounts of waste which is not always recyclable
  - uses:
    - used to pack multiple items such as eggs in trays and multipack products.
- Flexible packaging: shape of the packaging can be easily changed; this includes bags, pouches, shrink films, tubes, sleeves and carded packaging
  - advantages:
    - lightweight bags or pouches which can be modified or customised with ease
    - the packaging life will exceed the product shelf life
    - it will remain functional until consumption
    - barrier properties prevent product change
    - maintains food safety and preserves product quality
    - shape can match the product and/or function
  - limitations:
    - chemical release from packaging into food may occur (mass transfer migration)
  - uses:
    - leafy vegetables
    - frozen vegetables
    - frozen flash-fried meat products.

1.87	<p><b>Packing techniques used in the food and drink industry:</b></p> <ul style="list-style-type: none"> <li>• Engineered packing: <ul style="list-style-type: none"> <li>○ advantages: <ul style="list-style-type: none"> <li>– depending on the type of automation and the number of products to be packaged, this can increase productivity time and ensure a faster production line</li> </ul> </li> <li>○ limitations: <ul style="list-style-type: none"> <li>– requires engineering know-how</li> <li>– susceptible to breakdowns and downtimes</li> <li>– requires expertise</li> <li>– increased foreign body contaminant risk</li> </ul> </li> <li>○ uses: <ul style="list-style-type: none"> <li>– wide range of uses across food manufacturing for example, leafy salad packaging lines</li> <li>– sophisticated and self-learning automated packaging and sorting units</li> </ul> </li> </ul> </li> <li>• Hand packing: <ul style="list-style-type: none"> <li>○ advantages: <ul style="list-style-type: none"> <li>– suitable for products with greater variables, such as size or shape</li> <li>– used for more specialised (for example, handmade, handpicked) food products or food products with greater fragility (for example, sandwiches)</li> </ul> </li> <li>○ limitations: <ul style="list-style-type: none"> <li>– lower productivity; focus on quality rather than production volumes</li> </ul> </li> <li>○ uses: <ul style="list-style-type: none"> <li>– sandwiches and certain fruits (for example, mangoes).</li> </ul> </li> </ul> </li> </ul>
1.88	<p><b>The information included on packaging for pre-packed and non-pre-packed products:</b></p> <ul style="list-style-type: none"> <li>• Name of food.</li> <li>• List of ingredients (including alcohol and strength).</li> <li>• Allergen information (in bold).</li> <li>• Quantity of ingredients.</li> <li>• Weight.</li> <li>• Use by, best before and display until dates.</li> <li>• Origin of raw materials (where origin is claimed).</li> <li>• Origin of product.</li> <li>• Nutritional information.</li> <li>• Specialist storage conditions.</li> <li>• Specific instructions for use (for example, cooking times, mixing instructions).</li> <li>• Additional information that must be obvious to consumers (for example, packed in a protective atmosphere, contains raw milk).</li> <li>• Position of labels on product (for example, front of pack, back of pack, side of pack).</li> <li>• Contact address of the seller (for example, retailer, farm, brand).</li> </ul>

1.89	<p><b>The information included on packaging for pre-packed and non-pre-packed products:</b></p> <ul style="list-style-type: none"> <li>• Name of food.</li> <li>• List of ingredients (including alcohol and strength).</li> <li>• Allergen information (in bold).</li> <li>• Quantity of ingredients.</li> <li>• Weight.</li> <li>• Use by, best before and display until dates.</li> <li>• Origin of raw materials (where origin is claimed).</li> <li>• Origin of product.</li> <li>• Nutritional information.</li> <li>• Specialist storage conditions.</li> <li>• Specific instructions for use (for example, cooking times, mixing instructions).</li> <li>• Additional information that must be obvious to consumers (for example, packed in a protective atmosphere, contains raw milk).</li> <li>• Position of labels on product (for example, front of pack, back of pack, side of pack).</li> <li>• Contact address of the seller (for example, retailer, farm, brand).</li> </ul>
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**What skills do students need to demonstrate?**

**S1.22 Assess, using VACCP, when food adulteration could be taking place (E1, E4, E5, M1, M2, M4, M5, M6, M7, M8, D1, D2, D3, D4)**

**What underpinning knowledge do students need?**

**Food supply chain from end to end and relationships within it**

1.90	<p><b>How food fraud could occur within the food supply chain:</b></p> <ul style="list-style-type: none"> <li>• Adulteration</li> <li>• Substitution</li> <li>• Illegal processing</li> <li>• Waste diversion</li> <li>• Falsifying documentation</li> </ul>
1.91	<p><b>Where, within the food supply chain, food fraud could occur:</b></p> <ul style="list-style-type: none"> <li>• Suppliers</li> <li>• During transportation</li> <li>• Manufacturing plant</li> <li>• During storage</li> <li>• At point of sale</li> </ul>

1.92	<p><b>Why food fraud may occur within the food supply chain:</b></p> <ul style="list-style-type: none"> <li>• Criminal activity (for example, by manufacturer, consumer)</li> <li>• Profit (for example, by manufacturer, consumer)</li> <li>• Increased demand (for example, by manufacturers)</li> <li>• Shortages of product and/or ingredients (for example, by suppliers)</li> </ul>
1.93	<p><b>How Vulnerability Assessment and Critical Control Points (VACCP) can be used for the systematic prevention of any adulteration of food, particularly in relation to economically motivated adulteration:</b></p> <ul style="list-style-type: none"> <li>• By identifying possible areas of weakness and, therefore, implementing additional checks to reduce likelihood of occurrence</li> </ul>
1.94	<p><b>How to assess, using VACCP, when food adulteration could be taking place:</b></p> <ul style="list-style-type: none"> <li>• How it has occurred (for example, adulteration)</li> <li>• Where, within the food supply chain, it has occurred (for example, suppliers)</li> <li>• Why it has occurred (for example, criminal activity)</li> <li>• Who to escalate the issue to (for example, local concerns would be escalated to the police; global and national concerns would be escalated to the FSA)</li> </ul>
1.95	<p><b>Food and drink organisations' responsibilities in confirming the traceability of products, one step forward and one step back, within the food supply chain:</b></p> <ul style="list-style-type: none"> <li>• Provide batch numbers</li> <li>• Documented systems in place for traceability</li> <li>• Record-keeping</li> </ul>
1.96	<p><b>Food and drink organisations' responsibilities in confirming the quality of products within the food supply chain:</b></p> <ul style="list-style-type: none"> <li>• Quality assurance procedures</li> <li>• Quality control procedures</li> <li>• Certificate of conformance/analysis</li> </ul>
1.97	<p><b>Food and drink organisations' responsibilities in highlighting potential concerns within the food supply chain:</b></p> <ul style="list-style-type: none"> <li>• Recall procedures</li> <li>• Crisis management procedures</li> <li>• Escalation process: <ul style="list-style-type: none"> <li>○ notify external agencies when appropriate: <ul style="list-style-type: none"> <li>– local concerns must be escalated to the police</li> <li>– global and national concerns must be escalated to the FSA</li> </ul> </li> </ul> </li> </ul>

## Performance Outcome 2: Develop new food and food related products to support the food supply chain

<b>What skills do students need to demonstrate?</b>
<b>S2.1 Perform an impact assessment of consumer trends on the design of both a new product development and an existing product development (E1, E2, E3, E4, E5, M2, M4, M5, M6, M7, M8, M9, M10, D1, D2, D3, D4)</b>

<b>What underpinning knowledge do students need?</b>	
<b>Product development process</b>	
2.1	<p><b>The stages and principles of the product development process, from concept to launch:</b></p> <ul style="list-style-type: none"> <li>• Product brief: <ul style="list-style-type: none"> <li>○ what the product is</li> <li>○ why it is being developed</li> <li>○ intended market</li> <li>○ specific information about the product (for example, raw/cooked/ready to eat/ready to cook/starter/main/dessert)</li> <li>○ total weight of final product</li> <li>○ cost to sell to consumer.</li> </ul> </li> <li>• Idea generation: <ul style="list-style-type: none"> <li>○ research and development on trends</li> <li>○ innovation</li> <li>○ viability.</li> </ul> </li> <li>• Review meeting (for example, with sales, customer service, promotions departments) to discuss: <ul style="list-style-type: none"> <li>○ initial idea</li> <li>○ viability of product</li> <li>○ margins and profitability</li> <li>○ cost (for example, production, raw materials, packaging, staff).</li> </ul> </li> <li>• Feasibility study: <ul style="list-style-type: none"> <li>○ legal checks</li> <li>○ production (for example, pilot plant or scaled factory production)</li> <li>○ technical (for example, food safety)</li> <li>○ procurement</li> <li>○ planning</li> <li>○ resource</li> <li>○ raw materials</li> <li>○ sales/marketing</li> <li>○ engineering</li> <li>○ process development.</li> </ul> </li> </ul>

- Customer (for example, retailer) review of product:
  - taste panel (for example, colour/texture/viscosity/consistency)
  - discuss costs
  - suitable alternatives (for example, to ingredients or packaging).
- Concept approval and handover to production:
  - labelling
  - total weight of product
  - total ingredients for the trial run
  - breakdown of costings at each stage
  - packaging, including format and artwork
  - allergens in product
  - raw material specification (for example, raw materials, ingredients by weight, process, image of product, image of packaging).
- Trial run of product:
  - ingredient procurement
  - process development
  - label sign-off, including nutritional information, allergens and shelf life of food
  - confirm costings are accurate
  - required Standard Operating Procedures (SOPs) created (for example, mixing, sieving, cooking, allergen and integrity controls)
  - Hazard Analysis and Critical Control Points (HACCP) flow diagram
  - supplier approval
  - undertake nutritional analysis
  - primary packaging sealing and closure testing
  - secondary packaging review – physical fit and text review
  - identify number of trials required to ensure product meets requirements
  - potential external testing to confirm product is well received/fit for purpose
  - customer (retailer or brand) approval.
- Review trial of product:
  - variables (for example, cooking times, HACCP flow diagram, production environment, required additional skills and training)
  - yields (for example, issues with raw materials and packaging, volume, cooking process, batch sizes).
- Pre-production:
  - to confirm process.
- Launch product:
  - marketing to end point consumers
  - taste panels of end point consumers.

	<ul style="list-style-type: none"> <li>• Post launch review of product: <ul style="list-style-type: none"> <li>○ rate of sell, rate of waste in store</li> <li>○ customer (for example, retailer) feedback</li> <li>○ complaints</li> <li>○ issues from taste panels</li> <li>○ microbiology testing and results</li> <li>○ issues with production of raw materials</li> <li>○ any changes required.</li> </ul> </li> </ul>
2.2	<p><b>Why an existing product may need to be changed:</b></p> <ul style="list-style-type: none"> <li>• Cost.</li> <li>• Improve sales.</li> <li>• Scarcity of raw materials.</li> <li>• Customer request.</li> <li>• Change of packaging.</li> <li>• Change in the law.</li> <li>• Improve quality.</li> <li>• Issue with food safety.</li> </ul>
2.3	<p><b>How the process for changing an existing product would differ to that of a new product development process:</b></p> <ul style="list-style-type: none"> <li>• Reduction in number of stages (for example, may not include feasibility study or taste panels).</li> </ul>
2.4	<p><b>Different consumer trends that may drive the design of a new product:</b></p> <ul style="list-style-type: none"> <li>• Health (for example, low fat, high protein, vegan).</li> <li>• Environmental (for example, palm oil).</li> <li>• Ethical (for example, fair trade).</li> <li>• Economic factors (for example, low cost).</li> <li>• Influence of media and peers (for example, celebrity endorsement, social media).</li> </ul>
2.5	<p><b>How to perform an impact assessment of consumer trends on the design of both a new product development and an existing product development:</b></p> <ul style="list-style-type: none"> <li>• Using different sources of information to gather evidence.</li> <li>• Reading, understanding and synthesising the information for the intended purpose, taking into consideration any potential bias.</li> <li>• Presenting the information to suit the audience and purpose in a professional format (for example, presentation, written report, graphs, tables), ensuring the information is organised logically and coherently.</li> </ul>
2.6	<p><b>How impact assessments are used to investigate the viability of a new product:</b></p> <ul style="list-style-type: none"> <li>• Costs of people, process, equipment, raw materials and packaging.</li> <li>• Feasibility of production.</li> <li>• Brand reputation.</li> </ul>

<b>What skills do students need to demonstrate?</b>
<b>S2.2 Formulate a recipe from first principles, taking into consideration customer requirements</b> (E1, E2, E4, E5, M1, M2, M3, M4, M5, M8, D1, D2, D3, D4)
<b>K7 Enhance an existing recipe, selecting the correct ingredients based on their functionality, to improve the flavour of the product</b> (E1, E2, E4, E5, M1, M2, M3, M4, M5, M8, D1, D2, D3, D4)
<b>S2.4 Develop a new food product to meet customer requirements</b> (E1, E2, E4, E5, M1, M2, M3, M4, M5, M8, D1, D2, D3, D4)

<b>What underpinning knowledge do students need?</b>	
<b>Advanced recipe formulation</b>	
2.7	<p><b>The first principles of recipe balance:</b></p> <ul style="list-style-type: none"> <li>• Proportionality: ratio of each individual ingredient within a recipe.</li> <li>• Nutrient balance: ensuring the correct nutrients are included, dependent on the consumer requirements (for example, low sugar, high protein).</li> <li>• Organoleptic properties: ensuring acceptable colour, taste, odour and texture, dependent on customer specification (for example, requirement for low salt).</li> <li>• Ingredient substitution where appropriate: the substitution of ingredients, dependent on the functionality and cost of the product (for example, requirement for gluten free).</li> </ul>
2.8	<p><b>Why ingredients may need to be substituted:</b></p> <ul style="list-style-type: none"> <li>• Seasonality.</li> <li>• Environmental.</li> <li>• Media influence.</li> <li>• Allergens.</li> <li>• Cost.</li> <li>• Availability.</li> <li>• Religion/culture.</li> <li>• Organoleptic properties.</li> </ul>
2.9	<p><b>How the functionality of ingredients can be used to enhance a recipe:</b></p> <ul style="list-style-type: none"> <li>• Emulsifiers: makes two incompatible components compatible, such as water and oil (for example, lecithin).</li> <li>• Raising agents: causes expansion by release of gases (for example, yeast).</li> <li>• Stabilisers: preserves structure (for example, gelatin).</li> <li>• Flavourings/seasoning: used to enhance taste (for example, spices, salt).</li> </ul>

	<ul style="list-style-type: none"> <li>• Preservatives: used to reduce available water and enhance shelf life (for example, sugar, salt, potassium sorbate).</li> <li>• Colour enhancers: used to enhance organoleptic properties (for example, caramel, beetroot powder).</li> <li>• Firming agents: strengthens the structure of food to keep firm or crisp (for example, calcium chloride).</li> <li>• Sweeteners: used to reduce sugar content (for example, aspartame).</li> <li>• Anti-caking agents: used to stop powdered or granulated foods sticking together (for example, silicon dioxide).</li> <li>• Foaming agents: helps make foam by dispersing a gas in a liquid or solid (for example, quillaia extract).</li> </ul>
2.10	<p><b>How to enhance an existing recipe, selecting the correct ingredients based on their functionality, to improve the flavour of the product:</b></p> <ul style="list-style-type: none"> <li>• Taste: <ul style="list-style-type: none"> <li>○ sweet (for example, sucrose, fructose, glucose, maltose, dextrose)</li> <li>○ sour (for example, citric, acetic, lactic, malic and tartaric acid)</li> <li>○ salt (for example, sodium chloride, potassium chloride)</li> <li>○ bitter (for example, quinine sulfate, caffeine)</li> <li>○ umami (for example, monosodium glutamate (MSG)).</li> </ul> </li> <li>• Aroma: <ul style="list-style-type: none"> <li>○ odour of food which can be affected by mastication and air intake (for example, fruit flavours).</li> </ul> </li> <li>• Trigeminal response: <ul style="list-style-type: none"> <li>○ burning (for example, mustard, chilli, horseradish)</li> <li>○ cooling (for example, mint, menthol)</li> <li>○ tingling (for example, citric, acidic).</li> </ul> </li> </ul>
2.11	<p><b>The reasons for selecting ingredients for specific applications:</b></p> <ul style="list-style-type: none"> <li>• Reasons for selecting ingredients: <ul style="list-style-type: none"> <li>○ functionality</li> <li>○ physical properties of the ingredient (for example, whether it can withstand the processing requirements)</li> <li>○ suitability for specific applications.</li> </ul> </li> <li>• Specific applications: <ul style="list-style-type: none"> <li>○ age of consumer</li> <li>○ nutritional requirements (for example, increase protein, low fat)</li> <li>○ allergenic (for example, free-from)</li> <li>○ social/religion/culture/lifestyle (for example, vegetarian).</li> </ul> </li> </ul>

2.12	<p><b>A range of raw material alternatives that can be used when formulating a recipe:</b></p> <ul style="list-style-type: none"> <li>• Soya protein instead of meat protein.</li> <li>• Sweeteners instead of sugar.</li> <li>• Vegetable fats instead of animal fats.</li> <li>• Cashew/almond milk instead of dairy.</li> </ul>
2.13	<p><b>How to develop a new food product to meet customer requirements, taking into account:</b></p> <ul style="list-style-type: none"> <li>• The suitability of all raw materials.</li> <li>• Substituting raw materials, dependent on consumer need and seasonality.</li> </ul>

**What skills do students need to demonstrate?**

**S2.5 Carry out a product costing on a new product and on a modification to an existing product**

**(E1, E4, E5, M1, M2, M3, M4, M5, M8, D1, D2, D3, D4)**

**What underpinning knowledge do students need?**

**Costing the production of products**

2.14	<p><b>How individual costs of different components contribute to the overall product cost:</b></p> <ul style="list-style-type: none"> <li>• Premium ingredients versus cheaper substitutions (for example, Sicilian lemons versus non-Sicilian lemons).</li> <li>• Handmade versus machine produced (for example, labour-intensive versus automated).</li> <li>• Low volume versus high volume (for example, small batches versus mass produced).</li> <li>• Types of packaging (for example, boxed versus unboxed).</li> <li>• Recyclable waste versus non-recyclable waste (for example, collecting excess dusting flour and reusing for other dusting).</li> </ul>
2.15	<p><b>How to calculate total production run costs:</b></p> <ul style="list-style-type: none"> <li>• Raw material cost (recipe ingredients and packaging × number of products).</li> <li>• Labour cost (number of people × hourly rate × number of hours).</li> <li>• Utility costs (hourly rate × number of hours).</li> <li>• Equipment (hourly rate × number of hours).</li> <li>• Distribution and transportation costs (batch size × number of vehicles required).</li> </ul>

2.16	<p><b>Carry out a product costing on a new product and on a modification to an existing product, by:</b></p> <ul style="list-style-type: none"> <li>• Calculating individual component costs and production run costs to give a total cost: <ul style="list-style-type: none"> <li>○ individual component costs: <ul style="list-style-type: none"> <li>– ingredients</li> <li>– process</li> <li>– batch size</li> <li>– packaging</li> <li>– re-use of waste.</li> </ul> </li> <li>○ production run costs: <ul style="list-style-type: none"> <li>– raw material costs</li> <li>– labour costs</li> <li>– utility costs</li> <li>– equipment costs</li> <li>– distribution and transportation costs.</li> </ul> </li> </ul> </li> <li>• Undertaking cost-comparison in order to reduce costs where appropriate (for example, premium ingredients versus cheaper substitutions).</li> </ul>
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<b>What skills do students need to demonstrate?</b>
<p><b>S2.6 Recommend packaging when developing a new food product, considering innovations in packaging, to reduce plastic waste and increase opportunities for recycling</b></p> <p style="text-align: right;">(E1, E4, E5, M2, M4, M5, M6, M8, D1, D3, D4)</p>
<p><b>S2.7 Carry out a sustainability analysis on a new product, by identifying the social, environmental and economic implications</b></p> <p style="text-align: right;">(E1, E4, E5, M2, M4, M5, M6, M8, D1, D3, D4)</p>
<p><b>S2.8 Present information on a sustainability analysis of a new product (for example, using a presentation, written report, graphs, tables)</b></p> <p style="text-align: right;">(E1, E2, E3, E4, E5, E6, M2, M3, M4, M5, M6, M7, M8, M10, D1, D2, D3, D4)</p>

<b>What underpinning knowledge do students need?</b>	
<b>Packaging innovation and sustainability</b>	
2.17	<p><b>A range of packaging innovations used to reduce plastic waste/increase opportunities for recycling:</b></p> <ul style="list-style-type: none"> <li>• Use of innovative materials (for example, bamboo).</li> <li>• Package free (for example, fill your own containers).</li> <li>• Compostable packaging (for example, made from plant-based materials).</li> <li>• Single-layer packaging.</li> </ul>

2.18	<p><b>The importance of procuring raw materials from sustainable sources (for example, sustainable palm oil):</b></p> <ul style="list-style-type: none"> <li>• To ensure traceability of the raw materials.</li> <li>• To minimise harm to the environment.</li> <li>• To maintain reputation and integrity.</li> <li>• To demonstrate accreditation of particular raw materials/ingredients (for example, Marine Stewardship Council, Roundtable on Sustainable Palm Oil (RSPO)).</li> </ul>
2.19	<p><b>Ways in which the use of plastic (particularly black plastic) can be reduced in the packaging of food and drink, whilst ensuring the packaging remains fit for purpose:</b></p> <ul style="list-style-type: none"> <li>• Reducing plastics wherever possible: <ul style="list-style-type: none"> <li>○ boxes instead of bottles</li> <li>○ paper bags instead of plastic.</li> </ul> </li> <li>• Re-use plastics wherever possible: <ul style="list-style-type: none"> <li>○ re-usable bags and containers.</li> </ul> </li> <li>• Recycle plastics wherever possible: <ul style="list-style-type: none"> <li>○ polyethylene terephthalate (PET)</li> <li>○ high density polyethylene (HDPE)</li> <li>○ plastics with On-Pack Recycling Label (OPRL).</li> </ul> </li> </ul>
2.20	<p><b>Ways in which to re-use waste:</b></p> <ul style="list-style-type: none"> <li>• Composting.</li> <li>• Anaerobic digestion.</li> <li>• Food waste recycling.</li> <li>• Biomass products.</li> <li>• Thermal treatment with energy recovery.</li> </ul>
.21	<p><b>Ways in which to reduce energy usage when developing a new product:</b></p> <ul style="list-style-type: none"> <li>• Use of energy efficient equipment (for example, insulated refrigeration).</li> <li>• Efficient use of existing equipment and resources (for example, turning down thermostats, use of LED light bulbs).</li> <li>• Good manufacturing processes (for example, keeping areas clean and minimising movement/transportation).</li> </ul>
2.22	<p><b>How to reduce the effect of transportation on the environment:</b></p> <ul style="list-style-type: none"> <li>• Consider type of fuel used for transport.</li> <li>• Change from 'food miles' to 'green food miles'</li> <li>• Minimise packaging and containers.</li> <li>• Consider transport method (for example, aerodynamic vehicles, rail versus road).</li> </ul>

2.23	<p><b>How to carry out a sustainability analysis on a new product, by identifying the social, environmental and economic implications:</b></p> <ul style="list-style-type: none"> <li>• Implications of the following: <ul style="list-style-type: none"> <li>○ raw materials</li> <li>○ packaging</li> <li>○ re-use of waste</li> <li>○ energy usage</li> <li>○ transportation.</li> </ul> </li> <li>• Social, environmental and economic impact may include: <ul style="list-style-type: none"> <li>○ use of natural resources and stewardship of natural resource, global and local</li> <li>○ energy efficiency and use of natural resource/recycling</li> <li>○ business ethics, fair trade, human rights and employment rights.</li> </ul> </li> </ul>
2.24	<p><b>How to present information on a sustainability analysis of a new product (for example, using a presentation, written report, graphs, tables):</b></p> <ul style="list-style-type: none"> <li>• Summarising information concisely.</li> <li>• Selecting fact from opinion.</li> <li>• Using technical terms where appropriate.</li> <li>• Organising information logically and coherently.</li> <li>• Using appropriate grammar.</li> <li>• Listening actively, recording information accurately and concisely, and requesting clarification where appropriate (for example, requesting additional information from support functions/specialists such as the maintenance team regarding energy usage).</li> <li>• Responding to questions/feedback from colleagues/customers.</li> </ul>

**What skills do students need to demonstrate?**

**S2.9 Contribute to continuous improvement to drive down costs and drive up quality by following the Deming cycle**

**(E5, M1, M2, M4, M5, M6, M8, M10, D3)**

**What underpinning knowledge do students need?**

**Continuous improvement (CI) management in the food industry**

2.25	<p><b>How to use workplace organisational techniques for continuous improvement:</b></p> <ul style="list-style-type: none"> <li>• Lean approach: <ul style="list-style-type: none"> <li>○ determine value (for example, establishing who the customer is and their exact requirements)</li> <li>○ map the value stream (for example, the activities or processes required to deliver the product to the customer)</li> </ul> </li> </ul>
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	<ul style="list-style-type: none"> <li>○ enable the flow (for example, eliminate queuing and waiting times)</li> <li>○ pull (for example, pulling the product through to the customer as and when they need it)</li> <li>○ seek perfection (for example, embedding new ways of working and improving customer experience).</li> <li>● The Deming cycle: <ul style="list-style-type: none"> <li>○ plan</li> <li>○ do</li> <li>○ check</li> <li>○ act.</li> </ul> </li> <li>● 5 Ss: <ul style="list-style-type: none"> <li>○ sort: keeping what you need and getting rid of what you do not</li> <li>○ set in order: having a place for everything and everything in its place</li> <li>○ shine: keeping everything clean</li> <li>○ standardise: everything is the same (for example, use of colour coding)</li> <li>○ sustain: maintaining a consistent standard.</li> </ul> </li> </ul>
2.26	<p><b>How to contribute to continuous improvement to drive down costs and drive up quality by following the Deming cycle:</b></p> <ul style="list-style-type: none"> <li>● Plan: <ul style="list-style-type: none"> <li>○ identify where improvements may be made, using IT systems to analyse and interpret data to identify trends (for example, volumes, run times)</li> <li>○ identify key stakeholders to gain agreement on proposed changes (internal or external).</li> </ul> </li> <li>● Do: <ul style="list-style-type: none"> <li>○ apply the lean approach to implement identified improvements.</li> </ul> </li> <li>● Check: <ul style="list-style-type: none"> <li>○ use IT systems to analyse and interpret data to measure effectiveness of implemented improvements.</li> </ul> </li> <li>● Act: <ul style="list-style-type: none"> <li>○ recommend improvements and agree with key stakeholders (for example, improvements to the product, process, people management)</li> <li>○ use IT systems to demonstrate before and after results</li> <li>○ review results to maintain improvements.</li> </ul> </li> </ul>
2.27	<p><b>Ways to maximise equipment efficiency:</b></p> <ul style="list-style-type: none"> <li>● Using equipment at optimum speed (for example, overall equipment efficiency).</li> <li>● Reducing stoppage time (for example, single-minute exchange of dies).</li> <li>● Reviewing what has gone wrong to reduce future failure (for example, failure mode and effect analysis).</li> </ul>

2.28	<p><b>The considerations of process limitations (for example, bottlenecks):</b></p> <ul style="list-style-type: none"> <li>• Ensuring consistent quality of product (for example, if machine is not being used at optimum speed, it may affect output).</li> <li>• Batch size.</li> <li>• Machine capacity and capability.</li> <li>• Resources (for example, labour, raw materials).</li> <li>• Environment (for example, other processes that may affect each other).</li> <li>• Production planning.</li> </ul>
2.29	<p><b>How to manage the 8 types of waste within a food and drink manufacturing process:</b></p> <ul style="list-style-type: none"> <li>• Transportation: <ul style="list-style-type: none"> <li>○ reducing transportation both external (from supplier) and internal (within manufacturing plant).</li> </ul> </li> <li>• Inventory: <ul style="list-style-type: none"> <li>○ minimising the amount of raw materials on-site.</li> </ul> </li> <li>• Motion: <ul style="list-style-type: none"> <li>○ minimising the amount of movement within the production facility.</li> </ul> </li> <li>• Waiting: <ul style="list-style-type: none"> <li>○ reducing the time that is spent between each stage in the process.</li> </ul> </li> <li>• Over-production: <ul style="list-style-type: none"> <li>○ avoiding making more than is required.</li> </ul> </li> <li>• Over-processing: <ul style="list-style-type: none"> <li>○ avoiding adding unnecessary value</li> <li>○ avoiding finished products being over or under weight.</li> </ul> </li> <li>• Defects: <ul style="list-style-type: none"> <li>○ avoiding mistakes through effective quality assurance, quality rejections, machinery breakdowns.</li> </ul> </li> <li>• Skills: <ul style="list-style-type: none"> <li>○ ensuring staff are trained appropriately for their role.</li> </ul> </li> </ul>
2.30	<p><b>The relationship between the drivers for cost and quality and improving value:</b></p> <ul style="list-style-type: none"> <li>• Drivers for cost and quality: <ul style="list-style-type: none"> <li>○ increased productivity</li> <li>○ improved quality</li> <li>○ lowered costs</li> <li>○ decreased delivery times</li> <li>○ improved staff morale</li> <li>○ understanding the market and competitors</li> <li>○ understanding internal and external failure costs</li> <li>○ continuous review of business requirements.</li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>• Improving value: <ul style="list-style-type: none"> <li>○ value-creating (for example, improve or increase)</li> <li>○ non-value-creating but necessary (for example, reduce)</li> <li>○ pure waste (for example, eliminate).</li> </ul> </li> </ul>
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<b>What skills do students need to demonstrate?</b>	
<b>S2.10 Follow procedural requirements to collect samples</b>	<b>(E5, M1, M2, M3, M4, M6)</b>
<b>S2.11 Select a suitable test method, depending on the purpose of the test</b>	<b>(E1, E5, M6)</b>
<b>S2.12 Analyse test results to confirm nutritional requirements and ensure product safety</b>	<b>(E1, E2, E4, M2, M4, M5, M6, M7, M8, D3, D4)</b>

<b>What underpinning knowledge do students need?</b>	
<b>Selecting suitable sampling and test methods and analysing results</b>	
2.31	<p><b>How the sample size, sample numbers per batch and frequency of sampling are determined for the procedural requirements:</b></p> <ul style="list-style-type: none"> <li>• Type of product (high risk/low risk).</li> <li>• Type of process (high care/low care).</li> <li>• Volume of product.</li> <li>• Any known associated risks with the product.</li> </ul>
2.32	<p><b>How to follow procedural requirements to collect samples:</b></p> <ul style="list-style-type: none"> <li>• Collecting the correct sample size.</li> <li>• Collecting the correct numbers per batch.</li> <li>• Collecting the sample at the correct frequency.</li> </ul>
2.33	<p><b>The purpose of different test methods that can be used to test new food products and/or identify and resolve issues in the food supply chain:</b></p> <ul style="list-style-type: none"> <li>• Ensure compliance with product specification: <ul style="list-style-type: none"> <li>○ nutritional analysis meets requirements</li> <li>○ taste/sensory panels; comparing against customer quality assurance sheets, including types and quantity of raw materials; photographic representation of plated, finished product and sample of approved packaging.</li> </ul> </li> <li>• Ensure product quality: <ul style="list-style-type: none"> <li>○ taste/sensory panels, through the use of organoleptic and physiological testing.</li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>• Ensure product safety: <ul style="list-style-type: none"> <li>○ microbiological</li> <li>○ food allergen testing</li> <li>○ food contaminant testing.</li> </ul> </li> </ul>
2.34	<p><b>How to analyse test results to confirm nutritional requirements and ensure product safety:</b></p> <ul style="list-style-type: none"> <li>• Quantitative results (for example, presence/absence and type of pathogens (causative agents), allergens or contaminants).</li> <li>• Qualitative results (for example, numbers of pathogens (causative agents) present or percentage of nutrients).</li> </ul>

## Performance Outcome 3: Identify and resolve issues in the food supply chain

<b>What skills do students need to demonstrate?</b>
<b>S3.1 Identify and resolve problems relating to quality issues and/or customer complaints using appropriate problem solving techniques</b> (E1, E4, E6, M6, M7, M10, D1, D3)
<b>S3.2 Apply the 8 stages of root cause analysis to investigate problems and/or customer complaint and recommend suggestions for improvement</b> (E1, E4, E5, E6, M6, M7, M10, D1, D3)

<b>What underpinning knowledge do students need?</b>	
<b>Solving technical and quality problems in the food supply chain</b>	
3.1	<p><b>The purpose of using problem solving techniques (for example, root cause analysis) when investigating and resolving problems within the food and drink industry:</b></p> <ul style="list-style-type: none"> <li>• To identify the cause, rather than the symptoms, of the problem.</li> <li>• To generate possible solutions.</li> <li>• To evaluate and identify the most appropriate solution.</li> <li>• To fully resolve and prevent reoccurrence.</li> </ul>
3.2	<p><b>The importance of identifying and resolving problems relating to customer complaints and quality issues:</b></p> <ul style="list-style-type: none"> <li>• Prevents re-work.</li> <li>• Reduces waste.</li> <li>• Maintains brand reputation.</li> <li>• Reduces customer complaints.</li> <li>• Increases customer satisfaction.</li> </ul>
3.3	<p><b>Identify and resolve problems relating to quality issues and/or customer complaints using appropriate problem solving techniques:</b></p> <ul style="list-style-type: none"> <li>• Receiving feedback and evidence from customer.</li> <li>• Establishing if complaint is valid.</li> <li>• Identifying the batch.</li> <li>• Reviewing taste panel results: <ul style="list-style-type: none"> <li>○ identifying if it is a one-off incident or whether it affects a whole batch</li> <li>○ considering the risks associated with the incident</li> <li>○ considering whether the batch needs to be recalled.</li> </ul> </li> <li>• Reviewing retained samples of the same batch against complaint.</li> <li>• Sharing results of investigation, including proposed solution.</li> </ul>

3.4	<p><b>Apply the 8 stages of root cause analysis to investigate problems and/or customer complaint and recommend suggestions for improvement:</b></p> <ul style="list-style-type: none"> <li>• Stage 1: defining the incident through the use of open questions to ensure a thorough understanding of the problem/customer complaint.</li> <li>• Stage 2: identifying initial corrective action to contain and address the immediate consequence.</li> <li>• Stage 3: categorising the incident by drawing up a fish bone diagram, focusing on the key factors that need to be taken into account, including packaging, ingredients, process, procedures and people.</li> <li>• Stage 4: determining the root causes by utilising the 5 whys (for example, risks, probabilities and other factors).</li> <li>• Stage 5: identifying management procedures that have failed.</li> <li>• Stage 6: defining preventative actions and implementing solutions to resolve problem/customer complaint.</li> <li>• Stage 7: reviewing effectiveness of preventative actions, including validity of the solution.</li> <li>• Stage 8: sustaining and maintaining improvements, sharing outcomes and best practice where appropriate.</li> </ul>
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<b>What skills do students need to demonstrate?</b>	
<b>S3.3</b>	<b>Carry out procedures for quality control testing and sensory analysis (E1, E4, M1, M2, M3, M4, M5, M6, M7, M8, D1, D3)</b>
<b>S3.4</b>	<b>Carry out a taste panel and evaluate results (E1, E4, M1, M2, M3, M4, M5, M6, M7, M8, D1, D3)</b>

<b>What underpinning knowledge do students need?</b>	
<b>Testing and evaluation in the food supply chain</b>	
3.5	<p><b>The principles of sensory evaluation used in food operations:</b></p> <ul style="list-style-type: none"> <li>• Using the 5 senses (sight, odour, taste, texture, sound) to evaluate the quality of the product to ensure it meets the specification.</li> <li>• To gain qualitative and quantitative data to maintain the consistency of product quality.</li> </ul>
3.6	<p><b>How to carry out sensory evaluation:</b></p> <ul style="list-style-type: none"> <li>• At specified times.</li> <li>• Controlled by trained staff.</li> <li>• Using screened participants.</li> </ul>

3.7	<p><b>How to determine the sampling required as part of the sensory analysis panels:</b></p> <ul style="list-style-type: none"> <li>• Batch size.</li> <li>• Specification requirements.</li> <li>• Outcomes of previous panels.</li> </ul>
3.8	<p><b>How different procedures are used to measure quality control and sensory analysis in food operations:</b></p> <ul style="list-style-type: none"> <li>• Following customer specifications: <ul style="list-style-type: none"> <li>○ following pack instructions (for example, cooking or mixing) to ensure customer requirements are met</li> <li>○ checking visible ingredients</li> <li>○ checking finished product against photo image</li> <li>○ checking packaging against photo image.</li> </ul> </li> <li>• On-line tasting (for example, on the production line): <ul style="list-style-type: none"> <li>○ checking that the flavour, aroma and texture meet customer specifications.</li> </ul> </li> <li>• Finished product tasting: <ul style="list-style-type: none"> <li>○ carrying out a formal taste panel with screened participants.</li> </ul> </li> </ul>
3.9	<p><b>The importance of maintaining specifications when carrying out sensory evaluation in food operations:</b></p> <ul style="list-style-type: none"> <li>• To ensure updates are factored into evaluation.</li> <li>• To avoid traceability issues (for example, taste panel participant has an allergic reaction).</li> </ul>
3.10	<p><b>Procedures for quality control testing and sensory analysis:</b></p> <ul style="list-style-type: none"> <li>• Step 1: screening all taste panel participants to check for: <ul style="list-style-type: none"> <li>○ colour blindness</li> <li>○ ability to taste salt, sweet, sour, bitter and umami</li> <li>○ ability to describe a product objectively</li> <li>○ ability to detect odour.</li> </ul> </li> <li>• Step 2: ensuring facilities and resources are appropriate: <ul style="list-style-type: none"> <li>○ separated, designated tasting area</li> <li>○ minimal décor</li> <li>○ neutral work surfaces</li> <li>○ well lit</li> <li>○ good ventilation</li> <li>○ access to bottled or filtered water and palate cleansers</li> <li>○ access to white crockery, clear glasses and white plastic cutlery</li> <li>○ adequate cooking sample preparation facilities</li> <li>○ copies of the product specification available</li> <li>○ questionnaires to record results.</li> </ul> </li> </ul>

3.11	<p><b>How to carry out a taste panel and evaluate results:</b></p> <ul style="list-style-type: none"><li>• Step 3: leading the taste panel:<ul style="list-style-type: none"><li>○ ensuring sample is in place prior to participants' arrival</li><li>○ clarifying the process and responding to any questions that arise</li><li>○ ensuring participants do not influence each other's opinion</li><li>○ ensuring there is no communication during the taste panel</li><li>○ ensuring all participants are facing away from each other</li><li>○ ensuring participants undertake the tasting and grading of the product.</li></ul></li><li>• Step 4: collect, collate and analyse data from the taste panels using digital devices and applications<ul style="list-style-type: none"><li>○ ensure all participant data is considered</li><li>○ ensure the product is graded (for example, red, amber, green or numerical values)</li><li>○ make recommendations based on analysis of trends.</li></ul></li></ul>
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## Performance Outcome 4: Collect, analyse and interpret food production data

<b>What skills do students need to demonstrate?</b>
<b>S4.1 Create a spreadsheet to track production trends</b> (E1, E3, E4, E5, M2, M4, M5, M6, M7, M8, D1, D2, D3, D4)
<b>S4.2 Input management data to track production trends, demonstrating digital critical literacy by ensuring confidentiality processes are followed to ensure safety, security and privacy (for example, when using screens to input data)</b> (E1, E3, E4, E5, M2, M4, M5, M6, M7, M8, D1, D2, D3, D4)
<b>S4.3 Systematically organise data in order to track production trends</b> (E1, E2, E3, E4, E5, M2, M4, M5, M6, M7, M8, D1, D2, D3, D4)
<b>S4.4 Critically interpret the data, considering process and scale, and any out-of-tolerance results that breach the critical limits</b> (E5, M1, M2, M4, M5, M6, M7, M8, D2, D3, D4)
<b>S4.5 Present information</b> (E1, E2, E3, E4, E5, M5, M6, M7, M8, D1, D2, D3, D4)

<b>What underpinning knowledge do students need?</b>	
<b>Food production data</b>	
4.1	<p><b>Where to collect food production data from in relation to:</b></p> <ul style="list-style-type: none"> <li>• Food safety: <ul style="list-style-type: none"> <li>○ Hazard Analysis and Critical Control Points (HACCP) records</li> <li>○ cleaning records (for example, good hygiene practices (GHP))</li> <li>○ product recalls/withdrawals</li> <li>○ customer complaints</li> <li>○ consumer complaints</li> <li>○ audit results (for example, good manufacturing practice (GMP), supplier assurance, external)</li> <li>○ risk assessments (for example, vulnerability, traceability, allergen, integrity)</li> <li>○ laboratory testing (for example, microbiology, allergen and nutritional).</li> </ul> </li> <li>• Food quality: <ul style="list-style-type: none"> <li>○ taste panels</li> <li>○ audit results (for example, GMP, supplier assurance, external)</li> <li>○ customer feedback (for example, customer complaints or compliments)</li> <li>○ risk assessments (for example, vulnerability, traceability, allergen, integrity)</li> <li>○ cleaning records (for example, GHP).</li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>● Customer requirements: <ul style="list-style-type: none"> <li>○ trend analysis</li> <li>○ changes to specifications</li> <li>○ customer feedback.</li> </ul> </li> </ul>
4.2	<p><b>How to interpret and analyse food production data:</b></p> <ul style="list-style-type: none"> <li>● Identifying out-of-tolerance results in relation to process and scale.</li> <li>● Identifying trends.</li> <li>● Identifying root cause.</li> <li>● Identifying corrective actions required.</li> <li>● Providing recommended preventative actions.</li> </ul>
4.3	<p><b>How different applications, including spreadsheets, databases and data loggers, can be used to support the interpretation and analysis of food production data:</b></p> <ul style="list-style-type: none"> <li>● Storage of large amounts of data, over long periods of time.</li> <li>● Organisation of data.</li> <li>● Presentation of data.</li> </ul>
4.4	<p><b>Why electronic resource planning systems (management information system) are used within the food and drink industry:</b></p> <ul style="list-style-type: none"> <li>● To support all business transactions within the food production facility by providing a central integrated system.</li> <li>● To store different types of data (for example, supplier information, quantity of raw material, specification requirements, batch numbers).</li> <li>● To retrieve food production data (for example, sales and trends, test analysis results).</li> </ul>
4.5	<p><b>How trends in food production data can be used for continuous improvement within the food and drink industry:</b></p> <ul style="list-style-type: none"> <li>● To make improvements to product (for example, making the nutritional value of the product healthier, such as sugar or salt reduction, or reducing the yeast levels in a product by perfecting the cooking process to reduce microorganisms to a safe level, while preserving quality).</li> <li>● To make improvements to processes (for example, meeting exact weight tolerances to improve consistency of filling weight).</li> <li>● To make improvements to people management (for example, utilising skills to maintain quality and safety levels).</li> <li>● To make improvements to packaging (for example, improving the seal integrity of a piece of packaging).</li> <li>● To make improvements to raw materials (for example, using cheaper raw materials whilst maintaining recipe functionality).</li> <li>● To make cost savings.</li> <li>● To identify training needs and skills gaps.</li> <li>● To make changes within the supply chain (for example, shortening the route to market and improving the product shelf life).</li> </ul>

4.6	<p><b>How to present information:</b></p> <ul style="list-style-type: none"><li>• In a written and visual format and/or presentation (for example, in a variety of texts).</li><li>• In a clear and unambiguous way.</li><li>• Using technical language correctly.</li><li>• Using mathematical processes to support technical arguments (for example, deviation from acceptable microbiology results).</li><li>• Using images and other tools (for example, graphs as appropriate).</li><li>• Organising information logically and coherently.</li><li>• Proofreading information to ensure appropriate use of grammar, vocabulary, spelling and punctuation.</li></ul>
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# Scheme of Assessment

There is a single synoptic assessment for this Occupational Specialism, which is an extended project. The synoptic element of the project is important to ensure students can demonstrate threshold competence and are able to evidence all the skills required by the Performance Outcomes.

The project consists of several activities grouped into six substantive tasks.

Each task is completed during a window set by Pearson, during which Providers schedule supervised assessment sessions.

<b>Occupational Specialism project – Food Sciences</b>
<b>Internally assessed project: 24.5 hours</b> <b>298 marks</b>
<b>Performance Outcomes</b> In this project students will: <b>PO1</b> – Perform appropriate activities to support the food supply chain complying with regulatory requirements <b>PO2</b> – Develop new food and food related products to support the food supply chain <b>PO3</b> – Identify and resolve issues in the food supply chain <b>PO4</b> – Collect, analyse and interpret food production data
<b>Assessment overview</b> There are seventeen parts to the assessment. Task 1: Plan a new food product <ul style="list-style-type: none"><li>• Activity A: Develop a product brief</li><li>• Activity B: Define the product brief objectives</li></ul> Task 2: Carry out risk assessment and prepare for sample production <ul style="list-style-type: none"><li>• Activity A: Food safety and quality management</li><li>• Activity B: Health and safety risk assessment</li><li>• Activity C: Product specification and analysis</li></ul> Task 3: Practical – kitchen samples and taste panel <ul style="list-style-type: none"><li>• Activity A: Kitchen samples</li><li>• Activity B: Production data</li><li>• Activity C: Taste panel</li></ul> Task 4: Prepare for product launch <ul style="list-style-type: none"><li>• Activity A: Rationale</li><li>• Activity B: Product packaging</li><li>• Activity C: Sustainability report</li><li>• Activity D: Testing and monitoring plan</li><li>• Activity E: Evaluation</li></ul>

Task 5: Identify and resolve issues in the food supply chain

- Activity A: Risk assessment
- Activity B: Customer complaints analysis

Task 6: Collect, analyse and interpret food production data

- Activity A: Data report
- Activity B: Continuous improvement.

Students respond to given scenarios to complete the project. They are assessed on their application of the skills listed for the Performance Outcomes.

Students are not assessed against specific 'knowledge' outcomes but are expected to draw on and apply related knowledge to ensure appropriate outcomes when applying the skills in response to an assessment scenario.

Students undertake the project under a combination of supervised and controlled conditions.

The assessment takes place over multiple sessions, up to a combined duration of 24.5 hours.

The project outcomes consist of the student's responses to tasks submitted electronically.

Tasks 1, 2, 4, 5 and 6 of this project will be externally set and marked by Pearson. Task 3 (practical) will be externally set and internally marked with moderation by Pearson.

### Administration

Providers must follow the guidance in the following:

- General Administrative Support Guide
- Administration Support Guide for the specific Technical Qualification Employer Set Project (if applicable).

These are located on the [Training and Admin Support webpage](#).

Performance Outcome		Weighting	
		Raw marks	% of total marks
PO1	Perform appropriate activities to support the food supply chain complying with regulatory requirements	105	35.2
PO2	Develop new food and food related products to support the food supply chain	106	35.6
PO3	Identify and resolve issues in the food supply chain	36	12.1
PO4	Collect, analyse and interpret food production data	51	17.1

## Resources for the delivery of Occupational Specialism: Supporting Food Sciences

Providers would benefit from a good IT suite with access to Office software and the internet and for students to have regular access to this.

Teachers must have qualifications and/or experience in the science sector.

Teaching will need to be shared across a curriculum team which together will have the experience and knowledge that spans the breadth of the qualification content and some experience of teaching to external assessments.

Assessment Task	Resource required
1	<ul style="list-style-type: none"> <li>• Microsoft Office 365 package</li> <li>• Internet</li> </ul>
2	<ul style="list-style-type: none"> <li>• Microsoft Office 365 package</li> </ul>
3	<ul style="list-style-type: none"> <li>• Microsoft Office 365 package</li> <li>• Activity A: a kitchen equipped with oven, microwave, mixer/blender, bag/carton sealer, fridge/freezer and selection of basic utensils</li> <li>• Activity C: appropriate preparation tools (e.g. oven); serving container and utensils; palate cleansers e.g. water, cucumber; quiet room with neutral lighting and minimal distractions</li> </ul>
4	<ul style="list-style-type: none"> <li>• Microsoft Office 365 package</li> <li>• Activity B: sample food-safe packaging materials, cutting and folding tools, glue/adhesive tape, labels, and functional components e.g. tamper-proof seals, clear windows</li> </ul>
5	<ul style="list-style-type: none"> <li>• Microsoft Office 365 package</li> </ul>
6	<ul style="list-style-type: none"> <li>• Microsoft Office 365 package</li> </ul>

# 5 Command word taxonomy list

## Command word taxonomy list

The following table shows the command words that will be used consistently in the Core Examinations to ensure students are rewarded for demonstrating the necessary skills.

The list below will not necessarily be used in every paper and is provided for guidance only.

Command word	Definition	Mark tariffs
Which (MCQ)	MCQ instructions – select one correct answer from a choice of four options.	1 mark per item
Add/label	Label or add to a stimulus material given in the question (e.g. labelling a diagram, adding units on a table, adding points or line to a graph).	1 to 2 marks per item
Complete	Provide the missing information for a diagram or table so that it is complete (contains all the necessary information).	1 to 2 marks per item
Draw	Produce a diagram using information from a given context or scenario.	1 to 2 marks per item
Give/state/ name	Provide a response generally requiring the recall of information (e.g. a feature, a characteristic, a use of, or a justification for something).	1 to 2 marks per item
Identify	Select the correct answer from the given context or stimulus.	1 to 2 marks per item
Suggest	Propose a likely solution or application in a given context.	2 marks per item
Describe	Give an account of something. Statements in the response need to be developed as they are often linked but do not need to include a justification or reason.	2 or 4 marks per item Max 2 marks per response
Explain	Requires identification of a point and linked justification of that point. For a 3-mark question a further linked justification is required. For a 4-mark question, the identification of 2 points and 2 linked justifications are required.	2 marks – point (1) + justification (1) 3 marks – point (1) + justification (1) + additional justification (1)

		4 mark – point (1) + justification (1) used twice
Calculate/ determine	Obtain a numerical answer showing relevant working. The number of marks indicates the number of stages in the calculation.	2 or 4 marks per item
Discuss	Consider the factors that apply in relation to a specific context. Give consideration to the aspects of an issue, situation, or a problem. Does not require a conclusion.	6 mark EOR. LBMS descriptors provided – must use these
Evaluate	Consider various aspects of a subject's qualities in relation to its context (e.g. strengths and weaknesses, advantages and disadvantages, pros and cons). Come to a judgment supported by evidence which will often be in the form of a conclusion.	9 mark EOR LBMS descriptors provided – must use these

# 6 General Competency Frameworks for T Levels

## English, maths and digital competencies

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The General Competency Framework for T Levels articulates English, maths and digital competencies that students are required to develop over the course of the qualification. The tables below list the competencies from the framework that are relevant to the *T Level Technical Qualification in Science*.

Competencies that can be developed in relation to a specification element of content are referenced in the Occupational Specialism. These competencies should be able to be delivered through the content of this qualification and tutors should be able to seek opportunities to allow students to develop the relevant skills to enable them to reach threshold competence in the specialism.

The English, maths and digital competencies are embedded in both the Core component and the Occupational Specialist component of the *T Level Technical Qualification in Science*. This is so that students can demonstrate their knowledge and understanding of these skills over the course of the qualification.

### General English competencies

E1	Convey technical information to different audiences
E2	Present information and ideas
E3	Create texts for different purposes and audiences
E4	Summarise information/ideas
E5	Synthesise information
E6	Take part in/leading discussions

### General maths competencies

M1	Measure with precision
M2	Estimate, calculate and spot errors
M3	Work with proportion
M4	Use rules and formulae
M5	Process data
M6	Understand data and risk
M7	Interpret and represent with mathematical diagrams
M8	Communicate using mathematics

M9	Cost a project
M10	Optimise work processes

## General digital competencies

Students should be supported to develop the digital knowledge and skills needed in order to:

D1	Use digital technology and media effectively
D2	Design, create and edit documents and digital media
D3	Communicate and collaborate
D4	Process and analyse numerical data
D5	Be safe and responsible online





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