Enhancing Teaching through Exam Insights in International GCSE Chemistry

Welcome to this Professional Development Training

- Designed for teachers teaching or who are looking to teach the Pearson Edexcel International GCSE Chemistry Specification.

- Outline the two assessment pathways, and how you can adapt your teaching for the new International GCSE Modular Assessment
- Introduce the writing process of the Pearson Edexcel Examination Papers and Mark Schemes
- Understand how to apply mark schemes to student answers from the 2024 May/June Examination series
- Review the support Pearson offers for teaching the qualification
- Network, discuss best practice and share ideas with other teachers

Getting to know you

Are you new to Pearson Edexcel International GCSE Chemistry?

OR

Have you been teaching the existing specification

1. 1-2 years
2. 3-5 years
3. more than 5 years?

Welcome to Pearson

Welcome to Pearson Edexcel

We are the world's leading learning company and as the **UK's largest awarding organisation**, best placed to provide qualifications aligned to the British

Our international **heritage stretches back over 150 years.**

Today, we partner with schools, universities and employers worldwide, offering world-class, globally-recognized qualifivations to over **3.5 million students a year**.

6,500

Trusted and recognized qualifications partner to 6,500 schools, colleges and employers globally.

10 million

We mark over 10 million exam scripts on behalf of the UK Department for Education each year.

70

We operate in 70 countries worldwide.

The two different routes of Assessment

If you're happy with the linear approach, there is no pressure to move to the modular route; our linear International GCSEs will continue to be offered and taken widely by students around the world.

Modular route

Unit assessments can be taken over multiple exam series.

Grades are calculated on raw marks which are then converted to a UMS (Uniform Mark Scale).

Students can re-sit individual units in any exam series.

Once a student has all their unit results, they can 'cash in' these results for their grade.

A modular route is only offered by Pearson Edexcel at International GCSE

Linear route

Assessments for all units are taken together in one exam series.

Grades are calculated on raw marks only.

Students can re-sit assessments for all units together in one exam series.

The grade students receive are calculated at the end of the exam series in which they sat their assessments.

Specification Content

Principles of Chemistry	Inorganic Chemistry	Physical Chemistry	Organic Chemistry
(a) States of matter (b) Elements, compounds and mixtures (c) Atomic structure (d) The Periodic Table (e) Chemical formulae, equations and calculations (f) Ionic bonding (g) Covalent bonding (h) Metallic bonding (i) Electrolysis	(a) Group 1 (alkali metals) – lithium, sodium and potassium (b) Group 7 (halogens) – chlorine, bromine and iodine (c) Gases in the atmosphere (d) Reactivity series (e) Extraction and uses of metals (f) Acids, alkalis and titrations (g) Acids, bases and salt preparations (h) Chemical tests	(a) Energetics (b) Rates of reaction (c) Reversible reactions and equilibria	a) Introduction (b) Crude oil (c) Alkanes (d) Alkenes (e) Alcohols (f) Carboxylic acids (g) Esters (h) Synthetic polymers

Chemistry: a closer look, Paper 1

The modular and linear approach contact the same content, but the modular approach breaks the journey into two units with an exam at the end of each unit.

<table>
<tr><th colspan="3">Paper 1</th></tr>
<tr><th>Linear</th><th colspan="2">Modular</th></tr>
<tr><td>2-hour written examination.</td><td colspan="2">1-hour-40-minute written examination.</td></tr>
<tr><td>The total number of marks is 110, 61.1% of the total International GCSE.</td><td colspan="2">The total number of marks if 90, 50% of the total International GCSE.</td></tr>
<tr><td>Content summary
Assesses core content that is NOT in bold and does not have a ‘C’ prefix.
Questions may come from any topic area across the specification.
Topic 1. Principles of chemistry
Topic 2. Inorganic chemistry
Topic 3. Physical chemistry
Topic 4. Organic chemistry</td><td>Content summary
Topic 1: Principles of chemistry
a. States of matter
b. Elements, mixtures & compound
c. Atomic structure
d. Periodic table
e. Chemical formulae, equations & calculations
Topic 2: Inorganic chemistry
d. Reactivity series
e. Extraction and uses of metals
f. Acids, alkalis and titrations
g. Acids, bases and salt preparations</td><td>Topic 3: Physical chemistry
a. Energetics
Topic 4: Organic chemistry
a. Introduction
b. Crude oil
c. Alkanes
d. Alkenes</td></tr>
</table>

Chemistry: a closer look, Paper 2

The modular and linear approach contact the same content, but the modular approach breaks the journey into two units with an exam at the end of each unit.

<table>
<tr><th colspan="3">Paper 2</th></tr>
<tr><th>Linear</th><th colspan="2">Modular</th></tr>
<tr><td>1-hour-15-minute written examination.</td><td colspan="2">1-hour-40-minute written examination.</td></tr>
<tr><td>The total number of marks is 70, 38.9% of the total International GCSE.</td><td colspan="2">The total number of marks if 90, 50% of the total International GCSE.</td></tr>
<tr><td>Content summary
Assesses all the content including content that is in bold and has a ‘C’ prefix.

Questions may come from any topic area across the specification. Bold statements cover some topics in greater depth.</td><td>Content summary
Topic 1: Principles of chemistry
e. Chemical formulae, equations & calculations
f. Ionic bonding
g. Covalent bonding
h. Metallic bonding
i. electrolysis
Topic 2: Inorganic chemistry
a. Group 1
b. Group 7
c. Gases in the atmosphere
h. Chemicals tests</td><td>Topic 3: Physical chemistry
b. rates of reaction
c. reversible reactions and equilibrium
Topic 4: Organic chemistry
e. Alcohols
f. Carboxylic acids
g. Esters
h. Synthetic polymers</td></tr>
</table>

Teaching in a Modular Way

You may want to change the way you teach the International GCSE Chemistry Specification Content if you take the Modular route for assessment.

- To support your planning and teaching of the course, we have available **course planners**, **editable schemes of work** and **Getting Started Guide.**

- First teaching for International GCSE Chemistry (Modular) is September 2024
- First assessment of International GCSE Chemistry (Modular) is May/June 2025

Re-sits for Modular International GCSE

- Learners can re-sit any unit irrespective of whether the qualification is to be cashed in.
- If a learner resits a unit more than once, only the better of the two most recent attempts of that unit will be available for aggregation to a qualification grade.
- Results of units will be held in Pearson Edexcel's unit bank for as many years as this specification remains available.
- Once International GCSE in Chemistry (Modular) has been certificated, all unit results are deemed to be used up at that level. These results cannot be used again towards a further award of the same qualification at the same level.

How exam papers are written

Overview of question writing process

There are nine stages involved in producing a question paper:

- **Stage 1 – Preparation and writing**

  The Principal Examiner (PE) produces the first draft of the question paper (QP), mark scheme (MS), assessment objective grid (AOG) and item category grid (ICAT).

- **Stage 2 – Editing**

  The Chair and Chief Examiner (CE) review the documents and the PE produces a second draft in the light of their comments.

- **Stage 3 – Revising**

  A subject expert, known as a Reviser, reviews the documents and the PE produces a third draft in the light of their feedback.

Overview of question writing process

- **Stage 4 – QPEC meeting (Question Paper Evaluation Committee)**

  The Chair, CE, PE and Revisers discuss and amend all the documents.

- **Stage 5 – Typesetting**

  The typesetter produces the First Proof of the QP.

- **Stage 6 – Proofreader**

  A professional proofreader checks all spelling, punctuation and grammar. The Chair, CE and PE check the First Proof to make sure the typesetter has printed the QP as agreed at QPEC and that all diagrams, formulae, equations, etc. are correct. The PE updates the other documents, if necessary.

Overview of question writing process

- **Stage 7 – Scrutiny**

  A subject specialist, known as a Scrutineer, works through the QP as a candidate would, without looking at the MS.

  They then check their answers against the MS and suggest amendments to the QP and MS, if necessary The Chair, CE and PE discuss these suggestions and amend the QP, if necessary The PE amends the MS, if necessary.

- **Stage 8 – Final proof**

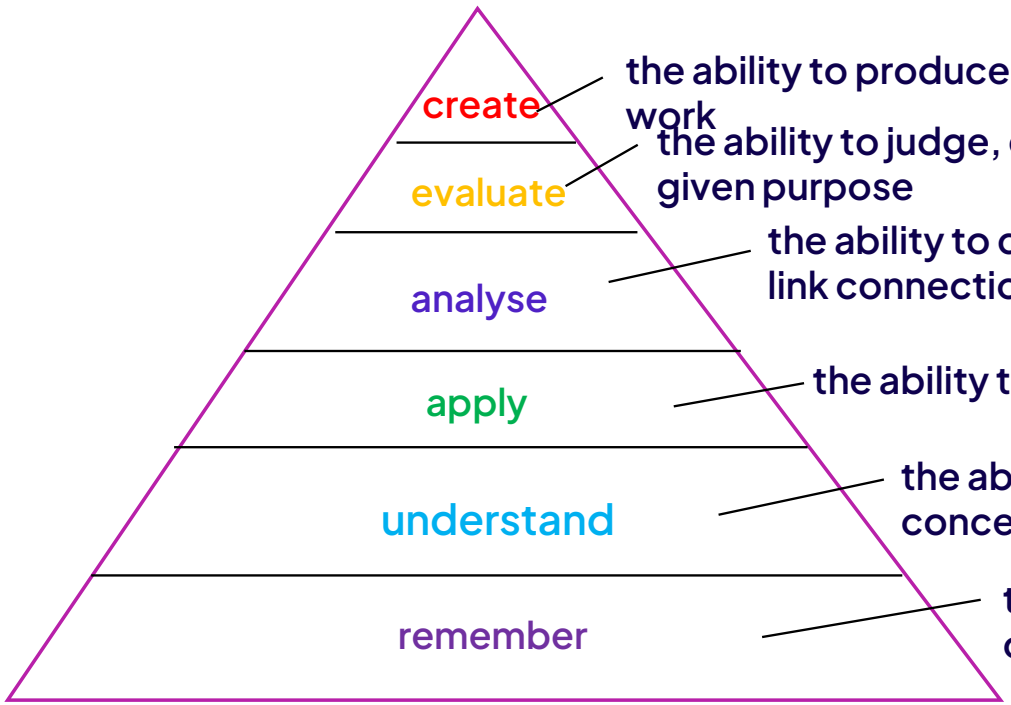
  Once the changes have been made, the final proof is sent to the committee to complete the final check and sign-off the paper.

- **Stage 9 – Printing and ePEN set-up**

  The QP is printed and ePEN is set up ready for marking.

Rules for writing exam papers

Bloom's Taxonomy



the ability to produce a new or original piece of work

the ability to judge, check or critique the value of data for a given purpose

the ability to draw conclusions from data or link connections between ideas

the ability to use information in new situations

the ability to explain ideas or concepts

the ability to recall basic facts and concepts

Assessment Objectives

Every question or part question is linked to a particular assessment objective (AO)

There are three assessment objectives labelled AO1, AO2 and AO3

The assessment objectives are closely lined to Bloom's Taxonomy and are given different weightings in the exam papers

Assessment objectives and weightings

		International GCSE
AO1	Knowledge and understanding of chemistry	38–42%
AO2	Application of knowledge and understanding, analysis and evaluation of chemistry	38 42%
AO3	Experimental skills, analysis and evaluation of data and methods in chemistry	19–21%
		100%

Linking AO1 to command words

- Demonstrate knowledge and understanding of science
- Recall facts and reasons

Example of command words:

Add/Label

Complete/Record

Describe (straightforward known ideas)

Explain (a simple idea or reason)

Give/State/Name

Write (a familiar equation)

Linking AO2 to command words

- Application of knowledge and understanding of science in familiar and unfamiliar contexts
- Apply facts and reasons to contexts

Example of command words:

Calculate

Identity

Deduce

Determine

Predict

Explain (for more complex ideas)

Suggest

Write (an equation)

Linking AO3 to command words

- Experimental skills in science, including analysis and evaluation of data and methods
- Practical skills including recall of some key practical activities
- Explanation for the steps involved may be looked at in both familiar and unfamiliar contexts as will the evaluation of data and methods
- Any of the command words might be used

Assessment objectives and questions

AO1	AO2	AO3
Questions requiring students to recall and use information that you have taught them	Questions requiring students to apply what you have taught them, or to use skills, or to analyse and make judgements	Questions on practical work and associated practical skills, such as planning, drawing graphs, analysing data, evaluating methods

Command words and Bloom's Taxonomy

Bloom's taxonomy	Command word(s)
Remember (Often AO1)	**Add** (e.g. units) **Complete** (e.g. a table or diagram) **Draw** (e.g. diagram of reflux apparatus) **Give / State / Name** (e.g. recall of one or more pieces of information) **Label** (e.g. a diagram) **State what is meant by** (i.e. the meaning of a term when there are different ways of expressing this)
Understand (Often AO1)	**Describe** (i.e. to give an account of something) **Explain** (i.e. the answer requires a point to be made **and** the reason(s) for it, this can include mathematical explanations) **Give a reason / reasons** (e.g. an explanation of a point that is given in the question – e.g. this happens because ….) **Show that** (i.e. verify a statement given in the question, this can include mathematical explanations – e.g. show that hydrochloric acid is in excess)

Command words and Bloom's Taxonomy

Bloom's taxonomy	Command word(s)
Apply (Often AO2)	**Calculate** (used for most calculations) **Determine** (used for some calculations) **Justify** (i.e. give evidence to prove a point made in a question or to prove a prediction that a candidate has made) **Plot** (used for graphs) **Sketch** (used for a freehand graph with axes and labels but no scale) **Write** (used for equations)
Analyse (AO2 or AO3)	**Compare and contrast** (i.e. looking for similarities **and** differences of two or more things) **Deduce** (i.e. use the information provided to draw or reach a conclusion) **Identify** (i.e. use the results of tests / spectra etc to identify an unknown substance) **Predict** (i.e. use the information given to give the expected result – e.g. looking at trends in data or the periodic table)

Command words and Bloom's Taxonomy

Bloom's taxonomy	Command word(s)
Evaluate (AO3)	**Assess** (i.e. consider all the factors that apply and identify which are the most important or relevant, make a judgement or come to a conclusion) **Comment on** (i.e. synthesise a number of variables from data / information to form a judgement) **Criticise** (i.e. inspect a set of data, an experimental plan or a scientific statement – look at the merits and faults of these and back judgements made by giving evidence) **Discuss** (i.e. identify the issue that is being assessed within the question or explore all aspects of it or investigate the issue by reasoning or argument) **Evaluate** (i.e. review information then bring it together to form a conclusion, drawing on evidence including strengths, weaknesses, alternative actions, relevant data or information. Come to a supported judgement of a subject's qualities and relation to it's context.)
Create (AO3)	**Devise** (i.e. plan or invent a procedure from existing principles / ideas)

Activity 1

Activity 1 – Assigning command words and AOs

Your booklet contains some examples of questions

For each question/part question state that command word used and assign an assessment objective

Activity 1 – Assigning command words and AOs

(a) A teacher adds a small piece of sodium to a trough of water.

(i) Give two observations that are made when sodium reacts with water.

(ii) After the reaction has stopped, the teacher adds a few drops of phenolphthalein to the solution in the trough.

Explain the colour of the phenolphthalein after it is added to the solution.

(b) A student does a flame test to see if a white solid contains lithium ions.
They clean a platinum wire before using it for the flame test.

Explain why the student needs to clean the platinum wire.

(c) Potassium aluminium sulfate can be used in baking.

Anhydrous potassium aluminium sulfate has the formula $KAl(SO_4)_2$

(i) Give the formula of each ion in potassium aluminium sulfate.

potassium ion aluminium ion sulfate ion

(ii) Potassium aluminium sulfate is normally found as a hydrated salt, with the formula $KAl(SO_4)_2.xH_2O$

When 23.7 g of the hydrated salt is heated to remove all the water, 12.9 g of the anhydrous salt is formed.

Calculate the value of x. [for $KAl(SO_4)_2$, $M_r = 258$ for H_2O, $M_r = 18$]

Mark Schemes

Mark Schemes

- Mark schemes (MS) are written at the same time as the questions
- They are related to the command word in the question
- Each answer in the MS shows what is needed for each mark
- The expected answer is in the left-hand column headed ‘Acceptable Answers’
- There is more information for the examiners in the right-hand column headed ‘Notes’
- The MS goes through the same checks as the question paper

Hierarchy for marking

Chair or Chief Examiner oversees the paper and ensures mark scheme is of a similar standard to previous years. They also check the marking of the PE

Principal Examiner contacts the team leaders and examiners, provides training for new examiners and team leaders, runs the pre-standardisation meetings, produces the final mark scheme, oversees the day-to-day running of the paper during marking, checks the marking of the TL and / or examiners, writes the reports etc

Team Leaders supervise a team of about 8 examiners and deal with all their initial queries, supervise the standardisation of examiners, check their marking, write a report on each examiner etc

Examiners carry out familiarisation marking, mark the paper, write a report on the items they have marked

Familiarisation marking

- Once candidates have sat the exam paper and their responses have been scanned into ePEN, everyone involved in the marking of the paper (Chair or CE along with the PE, Team Leaders (TL) and examiners) provisionally mark about 15 responses for each item for which they are contracted

This is called ‘familiarisation marking’

- The TL and examiners send their comments and questions on the mark scheme to the PE
- The PE amends the MS to give extra guidance to examiners
- The PE and TL select responses to be used in the Standardisation of examiners and for checking their marking after this

These are called ‘validity items’

Mark schemes are amended

Explain, in terms of electron configuration, why sodium is more reactive than lithium.

(3)

The pre-standardisation mark scheme for this item was:

Answer	Notes
An explanation that links the following three points	
M1 the outer shell is further from the nucleus in sodium	ALLOW a sodium atom is larger than a lithium atom
M2 there is less attraction to the nucleus for the outer electron	
M3 so the outer electron is more easily lost	

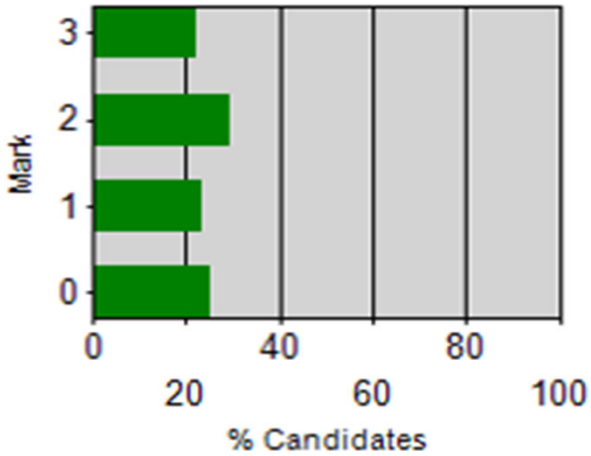
Mark schemes are amended

The final mark scheme was amended to:

Answer	Notes
An explanation that links the following three points	
M1 the outer shell is further from the nucleus in sodium/sodium has more shells/sodium has a larger atomic radius ORA	ALLOW a sodium atom is larger than a lithium atom ALLOW Li 2,1 Na 2,8,1
M2 there is less attraction to the nucleus for the **outer** electron/**outer** shell in sodium ORA	ALLOW there is more shielding in sodium ORA
M3 so the (outer) **electron** is more easily lost ORA	IGNORE electrons (plural) in M1 and M2 but do not allow electrons in M3

Why are mark schemes so strict?

- The purpose of an exam is to separate students into different grades
- This can be done by having questions that are targeted at different levels and / or by mark schemes that differentiate
- A good question and mark scheme may well have a distribution similar to this:



- Mark schemes are also detailed and precise to ensure that all examiners mark to the same standard

Pre-standardisation meeting

- The Chair or Chief examiner, PE and TL meet to decide on the final MS based on the responses they have seen and the comments made by all examiners during familiarisation marking
- They check all the responses that have been proposed for the standardisation of examiners
  - This consists of:
    - 5 Practice responses for each item
    - 10 Qualification responses for each item
- They check all the validity responses that have been proposed to make sure that the quality of examiners' marking does not vary throughout the marking period
- This may take 2 or 3 days, depending on the length of the exam paper and how many items there are
- After the pre-standardisation meeting, all the marks given during the familiarisation marking are removed from ePEN

Standardisation

- Examiners work through the 5 Practice sets for each of the items they are marking
- They contact their TL to discuss any queries they have
- They then work through the 10 Qualification sets by allocating a mark to each response, then they are told the agreed mark
- They need to get at least 8 correct in order to qualify to mark that item
    - If they get less than 8 correct, the PE will produce a second set and they can have another try
    - If they do not get at least 8 correct on the second set, they are stopped from marking that item
- They can continue to mark the items for which they have qualified

Quality control

- After Qualification, examiners are allowed to do **‘live marking’**
- The ePEN system restricts them to marking about 10% of their allocation for each item at a time to ensure they mark evenly across all items
- Their TL has access to all the marking they do and does ‘backreading’ at regular intervals. If the TL disagrees with a mark that an examiner has awarded, they can change this mark and send a message to the examiner to explain why they have done this.
- The validity responses occur randomly within the responses marked by the examiner. The examiner does not know they are there, but their marks are recorded against these
- The TL and PE regularly check the examiner statistics for their progress and how many responses they have marked correctly. The examiner is contacted if their marking falls below a certain level, the TL will explain the MS again and monitor the marking closely. If the marking does not improve, the examiner will be stopped from marking that item

Applying Mark Schemes

Understanding mark schemes

The expected answer is in the Answer column

- Sometimes there is more than one equivalent expected answer for a particular mark and these are shown by ‘or’ between them.
- If two points are needed for 1 mark, there is ‘and’ between them and both must be present

In the Notes column:

- **‘Allow’** indicates answers that are not quite as good as the expected answer, but they can still be given the mark
- **‘Ignore’** statements are other common answers the candidates may give. You just ignore them i.e. you do not award a mark for just that answer alone and you do not deduct a mark if the candidate has already scored that mark from an acceptable answer
- **‘Reject’** – if the candidate included any of those points as well as an acceptable answer, this negates the mark for the acceptable answer

Activity 2

Activity 2 – Your chance to qualify

Your pack contains 5 practice items for the following question taken from Paper 1C.

Assign a mark to each item

Activity 2 – Your chance to qualify

$$Fe_2O_3 + 2Al \rightarrow 2Fe + Al_2O_3$$

Explain why this reaction is a redox reaction.

Answer	Notes
An explanation that links the following two points	
M1 aluminium/Al gains oxygen and iron(III) oxide /Fe_2O_3 loses oxygen	ACCEPT aluminium/Al loses electrons and iron ions/Fe^{3+} gain electrons for M1
M2 (so) aluminium/Al is oxidised and **iron(III) oxide** /Fe_2O_3 is reduced	ACCEPT correct changes in oxidation numbers
OR	
M1 Aluminium/Al gains oxygen so is oxidised	ACCEPT aluminium/Al loses electrons so is oxidised scores for M1 and iron ions/Fe^{3+} gain electrons so is reduced for M2
M2 **Iron(III) oxide/Fe_2O_3** loses oxygen so is reduced	REJECT iron loses oxygen for M2

Activity 2 – Your chance to qualify

Practice Item 1

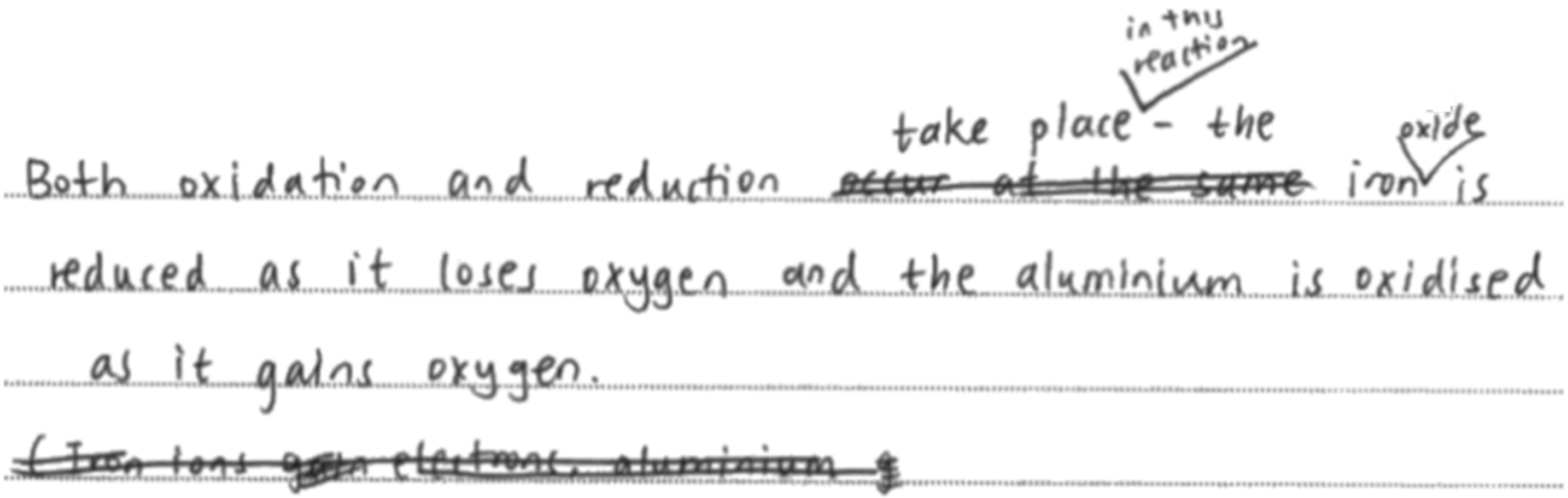
- The equation involves both reduction and oxidation at the same time

- Iron has been reduced as it loses ~~oxygen~~ 3 oxygen atoms

- Aluminium has been oxidised as it gains 3 oxygen atoms

Activity 2 – Your chance to qualify

Practice Item 2



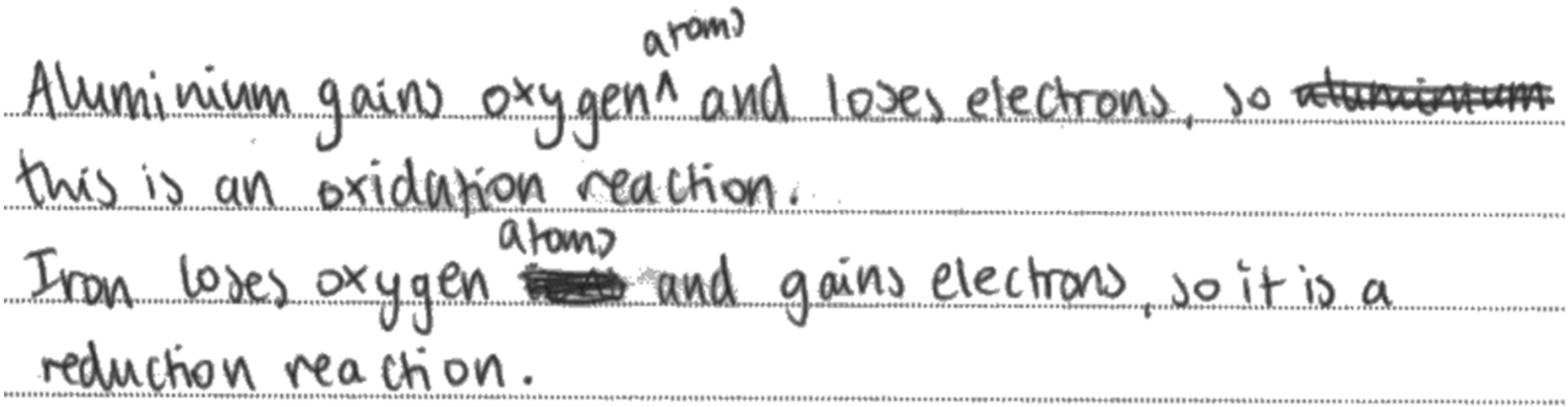
Activity 2 – Your chance to qualify

Practice Item 3

- The iron is reduced and loses oxygen (gains ^{3}electrons)
- The aluminium is oxidised and gains oxygen (loses ^{3}electrons)
- both oxidation and reduction occur.

Activity 2 – Your chance to qualify

Practice Item 4



Activity 2 – Your chance to qualify

Practice Item 5

because both oxidi's ation and reduction take place. Iron (III) oxide ~~loses~~ gains loses electrons and Aluminium ~~gains~~ electrons

Activity 2 – Your chance to qualify

Your pack contains 10 qualification items

Assign a mark to each one

Activity 2 – Your chance to qualify

Qualification Item 1

Both reduction and oxidation are taking place at once

Aluminium gains oxygen, so is oxidised while nonoxicle loses oxygen, so is reduced

Activity 2 – Your chance to qualify

Qualification Item 2

Because iron [redacted] is reduced, and aluminium is oxidised.

Iron [redacted] gains electrons and aluminium loses electrons.

Activity 2 – Your chance to qualify

Qualification Item 3

[redacted] Number of electrons stay the same and oxygen is not lost or gained meaning the reaction stays the same

Activity 2 – Your chance to qualify

Qualification Item 4

It is a redox reaction as both oxidation and reduction occurs. Iron loses electrons as it is oxidised whilst aluminium gains electrons as it is reduced.

Activity 2 – Your chance to qualify

Qualification Item 5

Aluminium gains oxygen^ (atoms) and loses electrons, so this is an oxidation reaction.

Iron loses oxygen (atoms) and gains electrons, so it is a reduction reaction.

Activity 2 – Your chance to qualify

Qualification Item 6

Because the Fe_2O_3 got reduced and the 2Al got oxidised

Activity 2 – Your chance to qualify

Qualification Item 7

Because iron(III) oxide lost oxygen so it is reduced and aliminium gained oxygen so oxidized

Activity 2 – Your chance to qualify

Qualification Item 8

Iron looses oxygen.

Aluminicum gains oxygen.

Activity 2 – Your chance to qualify

Qualification Item 9

Because reduction has occured where Aluminum gained electrons ~~and also oxidation occure~~

Activity 2 – Your chance to qualify

Qualification Item 10

Because Fe_2O_3 loses oxygen and so it become 2 Fe so it's reduction

And 2Al gain oxiygen ~~so it oxidised~~ and become Al_2O_3 so it become oxidised

Student Answers & Examiner Reports

Activity 3

Activity 3 – Student answers and Examiner reports

Your pack contains questions from Papers 1C and 2C, with mark schemes and student answers

Mark the questions using the scheme provided

We will discuss the students answers to each question one by one, but don't let that stop you working on the next question if you are waiting for others to finish

Activity 3 – Student answers and Examiner reports

Question 1

The following question relates to the reaction between marble chips and hydrochloric acid

The student repeats the experiment using the same mass of smaller marble chips.

Explain, using particle collision theory, how using smaller marble chips would affect the rate of this reaction.

Assume that all other conditions are kept the same as in the initial experiment.

(3)

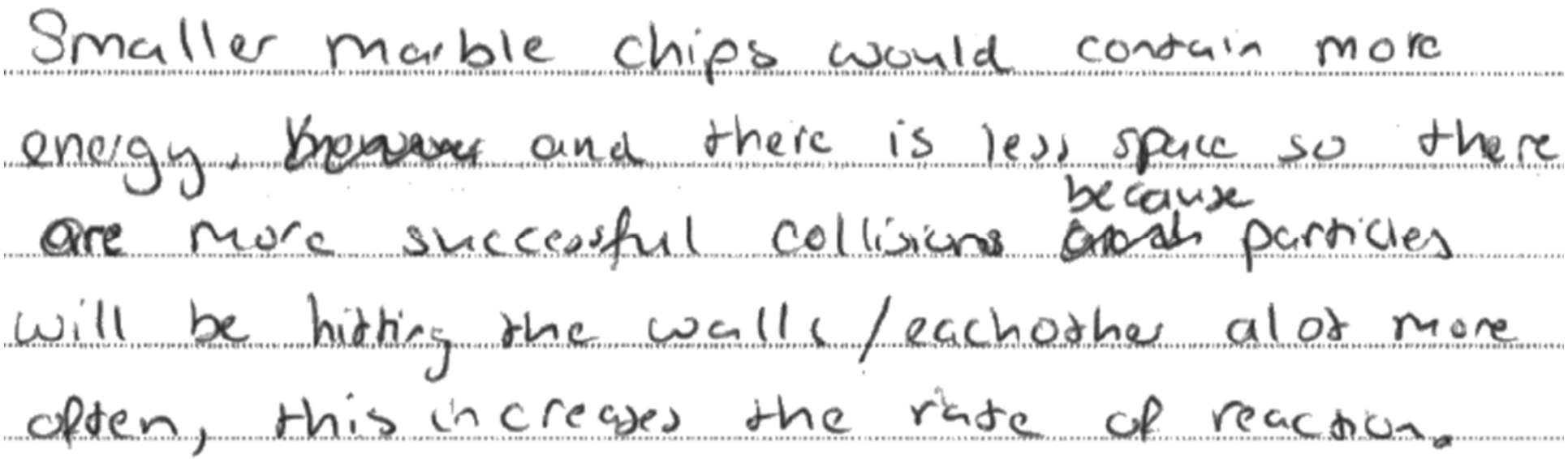
Activity 3 – Student answers and Examiner reports

Question 1

Answer	Notes
An explanation that links the following three points M1 the rate of reaction would increase/be faster M2 (because) the smaller marble chips have a greater surface area M3 (so) there will be more collisions per unit time	 IGNORE less chance of collisions ACCEPT more frequent collisions MAX 1 mark if reference to particles having more energy or moving faster

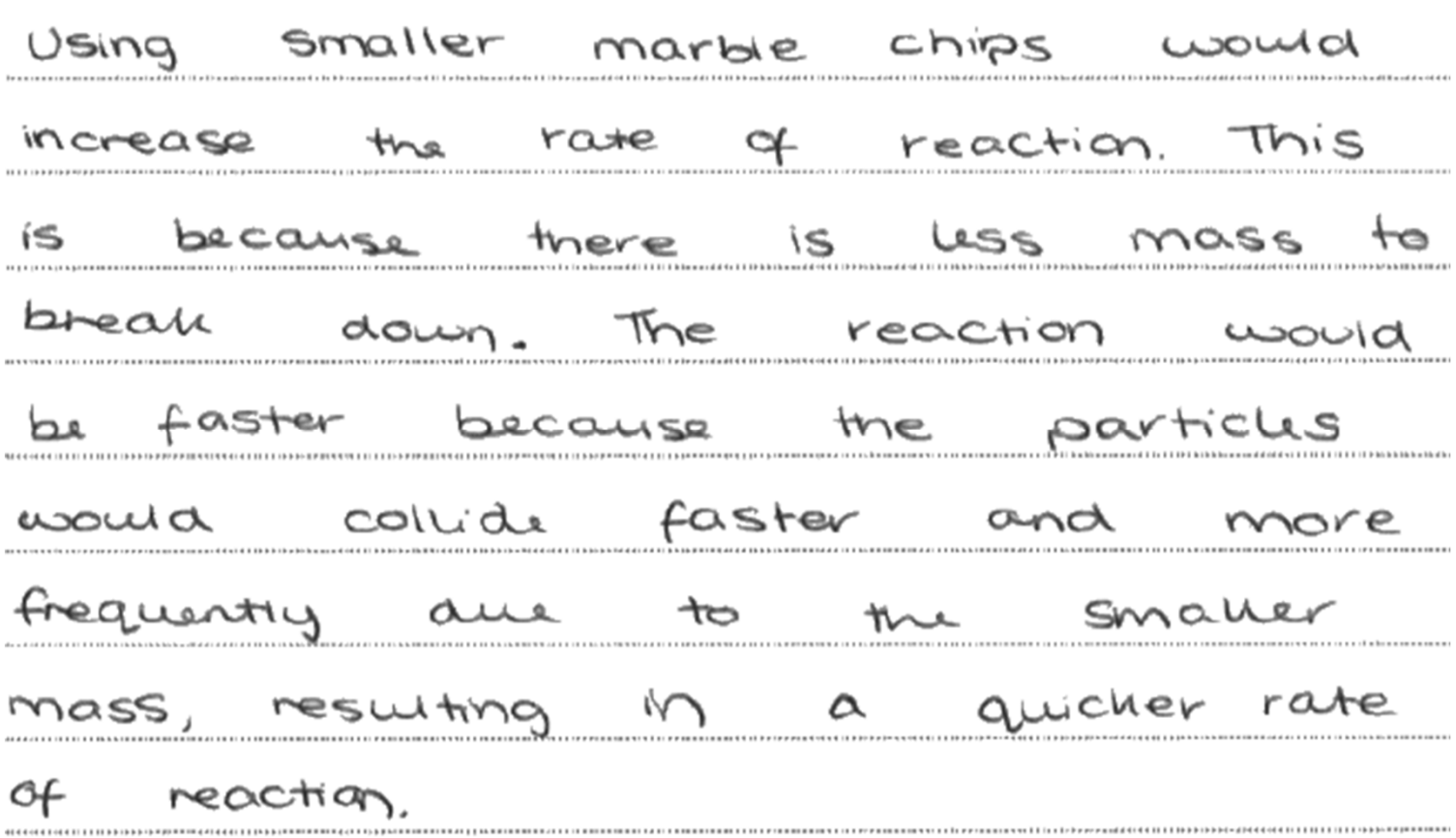
Activity 3 – Student answers and Examiner reports

Student 1



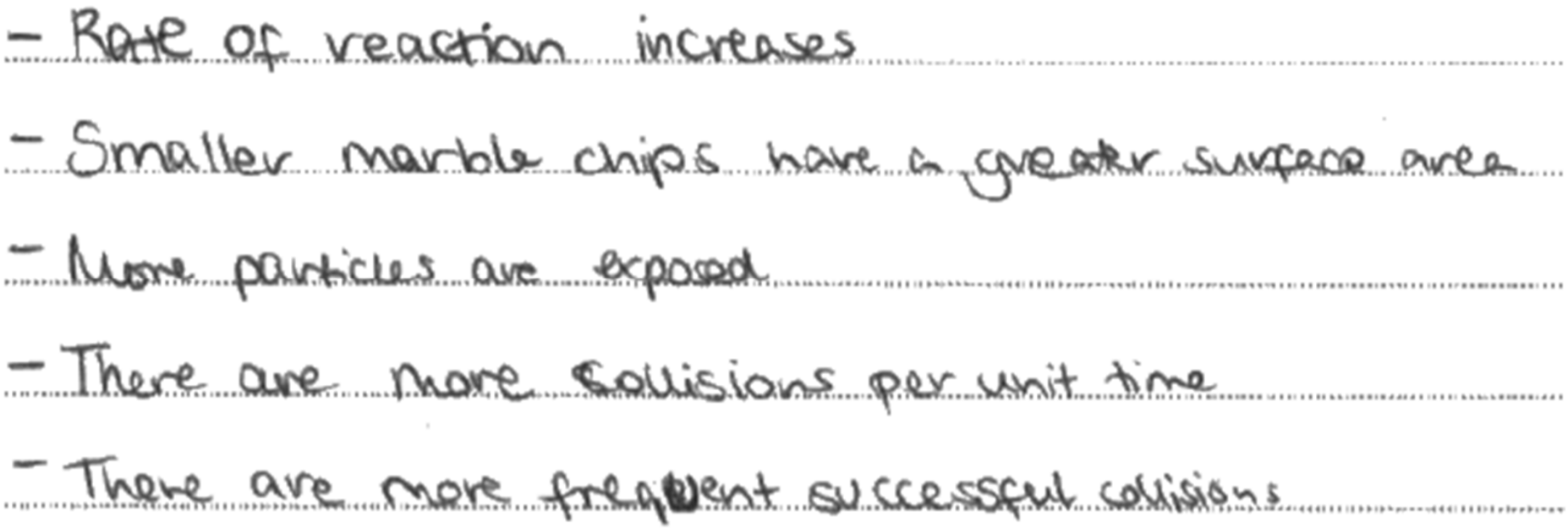
Activity 3 – Student answers and Examiner reports

Student 2


Using smaller marble chips would increase the rate of reaction. This is because there is less mass to break down. The reaction would be faster because the particles would collide faster and more frequently due to the smaller mass, resulting in a quicker rate of reaction.

Activity 3 – Student answers and Examiner reports

Student 3



Activity 3 – Student answers and Examiner reports

Student 4

using smaller marble chips increases the surface area of of the marble chips. This means that it would increase the rate of reaction because the particles will have more succeeful collisions as there is more exposed surface for reactions to take place

Activity 3 – Student answers and Examiner reports

Examiner's report

Most candidates answered this question effectively and demonstrated an understanding of the effect of increased surface area on reaction rate.

Some answers included misconceptions such as the use of energy in their response and also incorrectly suggesting that the surface area had decreased.

Overall, the majority of responses were well-handled with many candidates achieving 3 marks.

The most commonly missed mark was for not specifying that the collisions **per unit time/frequency** of collisions increases with smaller marble chips.

Rates of reaction– Suggestions to enhance teaching

When we collide we come together
If we don't we'll always be apart
I'll take a bruise; I know you're worth it
When you hit me hit me hard

Rates of reaction– Suggestions to enhance teaching

Catalysts and activation energy

Students are used to recalling the definition of a catalyst:

> "A substance that increases the rate of a reaction by **providing an alternative route** with a lower activation energy"

But do they understand?

These are difficult concepts to master, and the idea that catalysts are not used up is often stated by teachers but rarely shown to students

Students need careful guidance if they are to understand the important differences between kinetics (rate) and thermodynamics (energy), and why reactions occur in the first place

Rates of reaction– Suggestions to enhance teaching

Activation energy and understanding energy profile diagrams

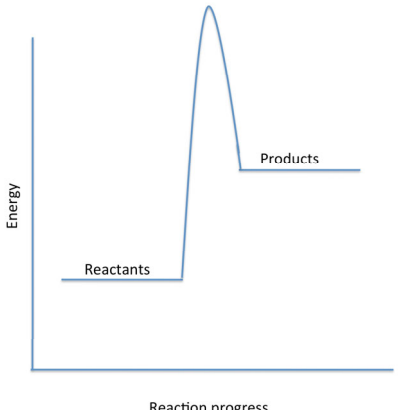
The resource pack contains a worksheet on enthalpy profile diagrams

You could use this as a probe to test their understanding after teaching the topic

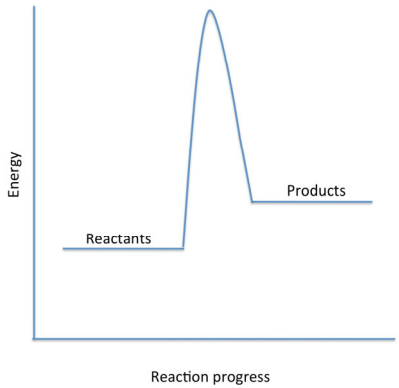
Rates of reaction– Suggestions to enhance teaching

Activation energy and understanding energy profile diagrams

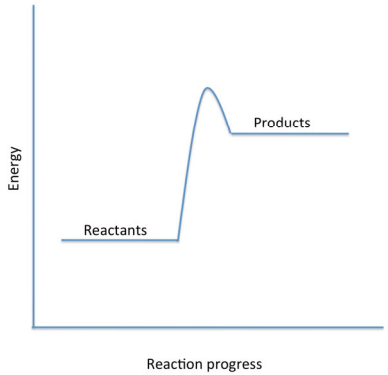
Reaction A



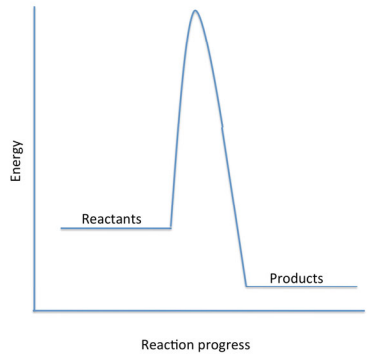
Reaction B



Reaction C



Reaction D



1. Put these reactions in order of how quickly you think they would occur.

2. If the temperature of the reaction was increased would the energy profile for the reactions change?

Explain.

3. Redraw profile B assuming a catalyst had been added.

Rates of reaction– Suggestions to enhance teaching

https://www.youtube.com/watch?v=FBF7auCMy58

Rates of reaction– Suggestions to enhance teaching

The effect of concentration on rate of reaction

https://www.youtube.com/watch?v=vPQPaz8oyPM

Rates of reaction– Suggestions to enhance teaching

The pink catalyst: prove to your students that catalysts are not used up

In this reaction, tartrate ions react with hydrogen peroxide to form bubbles of carbon dioxide

$$C_4H_4O_6^{2-} + 5H_2O_2 \rightarrow 4CO_2 + 6H_2O + 2OH^-$$

Activity 4

Activity 4 – Student answers and Examiner reports

Question 2

Caffeine is a stimulant found in coffee, tea and some soft drinks.

The molecular formula of caffeine is $C_8H_{10}N_4O_2$

Calcium bromide is an ionic compound.

The table shows the formulae and melting points of caffeine and calcium bromide.

Name	Formula	Melting point in °C
caffeine	$C_8H_{10}N_4O_2$	235
calcium bromide	$CaBr_2$	730

The relative formula mass of calcium bromide is similar to the relative formula mass of caffeine.

Explain why calcium bromide has a much higher melting point than caffeine. **(5)**

Activity 4 – Student answers and Examiner reports

Answer	Notes
M1 calcium bromide is a giant (ionic) lattice/structure	
M2 with many/strong electrostatic attractions between (oppositely charged) ions	ALLOW many/strong ionic bonds No M2 if covalent bonds or IMF given here
M3 caffeine has a simple molecular structure	ALLOW simple covalent structure
M4 caffeine has weak intermolecular forces /weak forces between molecules	REJECT weak forces between bonds
M5 more energy is needed to break the electrostatic attractions (in calcium bromide) than to overcome the intermolecular forces (in caffeine) OWTTE	No M5 if reference to breaking covalent bonds No M5 if reference to incorrect bonds

Activity 4 – Student answers and Examiner reports

Student 1

Caffeine is a simple ~~covalent~~ covalent structure. This means that to melt it, enough energy is required to overcome the weak intermolecular forces rather than the strong covalent bonds. This does not require a lot of energy.

Calcium bromide is bonded using ionic bonds. This means that to melt it, the strong intermolecular attraction between the positive and negative ions needs to be overcome. Therefore a high amout of (thermal) energy is required, causing a high melting point.

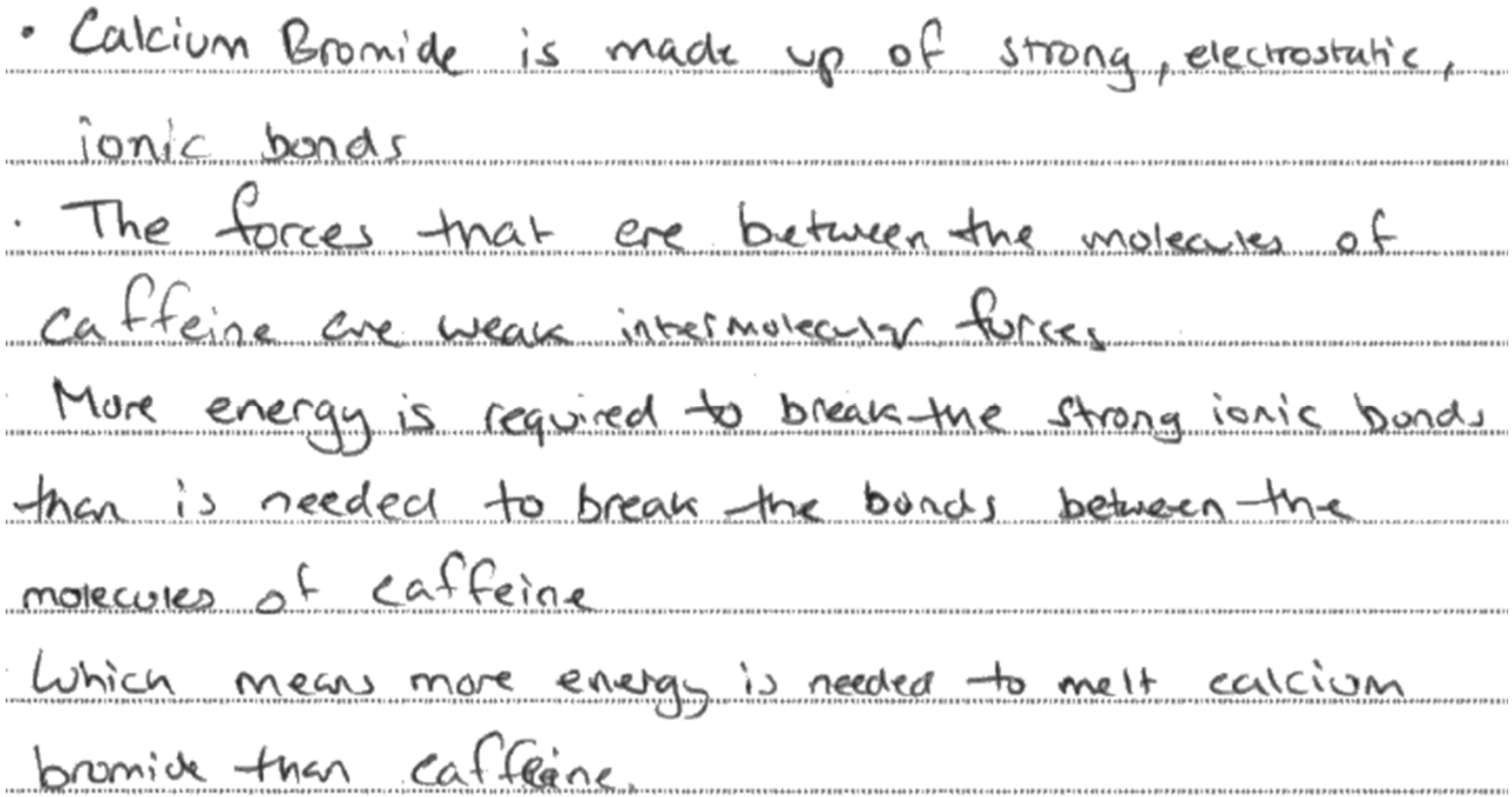
Activity 4 – Student answers and Examiner reports

Student 2

Calcium bromide is a giant ionic structure, therefore, the electrostatic forces of attraction acting between ions is very strong, and they require alot of heat energy to break. $C_8H_{10}N_4O_2$ is however a covalent structure and has weaker covalent bonds which don't require as much heat energy to breaks, therefore, has a lower melting point than calcium bromide.

Activity 4 – Student answers and Examiner reports

Student 3



- Calcium Bromide is made up of strong, electrostatic, ionic bonds
- The forces that are between the molecules of caffeine are weak intermolecular forces.
- More energy is required to break the strong ionic bonds than is needed to break the bonds between the molecules of caffeine
- Which means more energy is needed to melt calcium bromide than caffeine.

Activity 4 – Student answers and Examiner reports

Student 4

Calcium bromide ~~is~~ is a giant ionic lattice therefore there are many strong ~~covalent~~ ionic bonds between the calcium and the ~~bromine~~ bromide ~~ions~~ ions ~~that~~ due because of the strong electrostatic forces of attraction between ~~oppositely charged~~ the ~~positive calcium ions and the~~ calcium cations and the bromide anions. ~~These strong ionic bonds require~~ Lots of energy is needed to ~~over~~ overcome ~~these strong ionic~~ the many strong ionic bonds between the calcium and bromide ions in calcium bromide.

Caffeine ~~is~~ has a simple molecular structure therefore there are weak intermolecular forces of attraction much ~~that~~ require less energy to overcome than the many strong ionic bonds in calcium bromide as the ionic bonds in calcium bromide are ~~much~~ much stronger than the weak intermolecular forces of attraction in caffeine ~~that~~ require little energy to overcome.

(Total for Question 4 = 12 marks)

Activity 4 – Student answers and Examiner reports

Examiner's report

Q04(c) posed challenges for a number of candidates due to their **incorrect** identification of the type of bonding for each substance.

While the type of bonding was often commented upon, many candidates overlooked specifying the giant ionic and simple molecular structures for M1 and M3.

Common issues also included suggesting $CaBr_2$ contained (strong) intermolecular forces, mentioning intermolecular forces between bonds or atoms in caffeine, or incorrectly stating covalent bonds had been broken in caffeine.

A notable number of candidates still struggled with the direct comparison of energy requirements between structures and provided contradictory responses.

Bonding and Structure – Suggestions to enhance teaching

Giant ionic structures have high melting/boiling points because...

- The electrostatic forces between the molecules are strong so lots of energy is needed to overcome them

- The intermolecular forces holding the atoms together are strong so lots of energy is needed to overcome them

Bonding and Structure – Suggestions to enhance teaching

Giant ionic structures have high melting/boiling points because…

…there are **strong electrostatic forces** holding the **oppositely charged ions** together, so it takes a lot of energy to overcome them and pull the ions apart

Bonding and Structure – Suggestions to enhance teaching

Giant ionic structures conduct electricity when…

…solid, because they contain ions which are charged and so allow a current to pass through them

- … in any state, because they contain delocalised electrons that can carry a current

Why are these statements wrong?

Bonding and Structure – Suggestions to enhance teaching

Giant ionic structures conduct electricity when molten/in solution but not when solid because…

…in the **solid** the **ions are fixed in position** in the lattice, but when an ionic compound is **molten or in solution** the **ions are free to move**, so a current can flow.

Bonding and Structure – Suggestions to enhance teaching

Simple molecular structures have low melting/boiling points because...

- The intermolecular forces between the atoms are weak so it does not take much energy to overcome them

- The covalent bonds in the molecules are weak

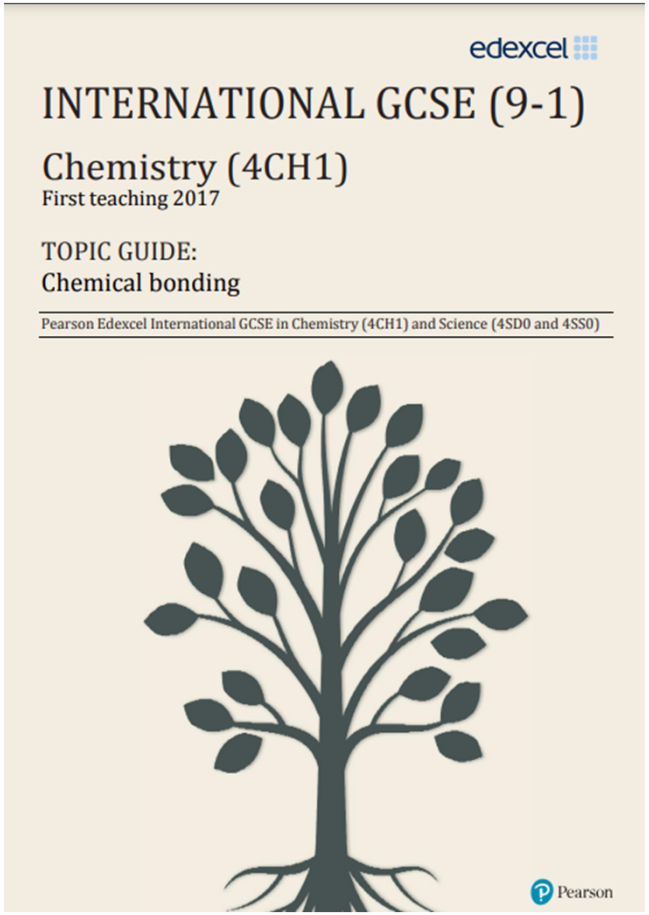
Bonding and Structure – Suggestions to enhance teaching

Simple molecular structures have low boiling points because...

...although there are strong covalent bonds holding the atoms together in the molecule, there are only weak forces between the molecules, so it does not take much energy to overcome these intermolecular forces to boil the substance

Topic Guide – Chemical Bonding

- Chemical bonding (and related ideas about chemical stability/reactivity) is acknowledged as being a ‘tricky to teach’ topic, and with good reason.
- It involves abstract, theoretical ideas that require students to develop and apply increasingly sophisticated ideas in order to make sense of their observations of the macroscopic properties of different substances.
- Research has shown that students commonly acquire misconceptions about chemical bonding.
- Some of these can be persistent and may present significant barriers to students’ progression and understanding of more complex ideas in chemistry.



Activity 5

Activity 5 – Student answers and Examiner reports

Question 3

Methane reacts with steam to form carbon monoxide and hydrogen.

This is the equation for the reaction.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \qquad \Delta H = +206\ kJ/mol$$

(a) Explain the effect, if any, on the yield of hydrogen at equilibrium when a nickel catalyst is used. **(2)**

(b) The reaction conditions for this reaction are a temperature of 700 °C and a pressure of 5 atmospheres.

(i) The temperature of the reaction mixture is reduced to 600 °C, but the pressure is kept at 5 atmospheres.

Explain the effect on the yield of hydrogen at equilibrium. **(2)**

(ii) The pressure of the reaction mixture is reduced to 4 atmospheres, but the temperature is kept at 700 °C.

Explain the effect on the yield of hydrogen at equilibrium. **(2)**

Activity 5 – Student answers and Examiner reports

Question number	Answer	Notes	Marks
(a)	An explanation that links the following two points M1 no effect M2 as increases rate of forward reaction and rate of backward reaction **equally**	 M2 dep on M1 or missing	2
(b) (i)	An explanation that links the following two points M1 yield decreases M2 as (forward) reaction is endothermic (so equilibrium shifts to the LHS / reactants side)	 **ALLOW** backward /reverse reaction is exothermic M2 dep on M1 or missing **IGNORE** references to Le Chatelier	2
(ii)	An explanation that links the following two points M1 yield increases M2 as there are fewer moles / molecules (of gas) on the left-hand side / there are 2 mol on LHS and 4 mol on RHS (so equilibrium shifts to the RHS / products side) ORA	 M2 dep on M1 or missing **IGNORE** references to Le Chatelier	2

Activity 5 – Student answers and Examiner reports

Student 1

(a) there's no change of yield in the product or the reactant as the both are the same under a closed condition in an equilibrium reaction, the catalyst would only speed up the reaction.

Student 2

(a) it does not have an effect because it is already at equilibrium

- ~~it~~ ~~does~~ the rate of the forward and backward reaction will stay the same

Activity 5 – Student answers and Examiner reports

Student 3

(a) The yield will not be affected. The catalyst simply provides an alternate pathway with a lower activation energy, increasing the rate of the forward and back reaction equally, thus yield is unaffected, only the rate is affected.

Student 4

(a) The yield would increase as the rate of reaction increases as the catalyst lowers activation energy by providing an alternate pathway

Activity 5 – Student answers and Examiner reports

Student 1

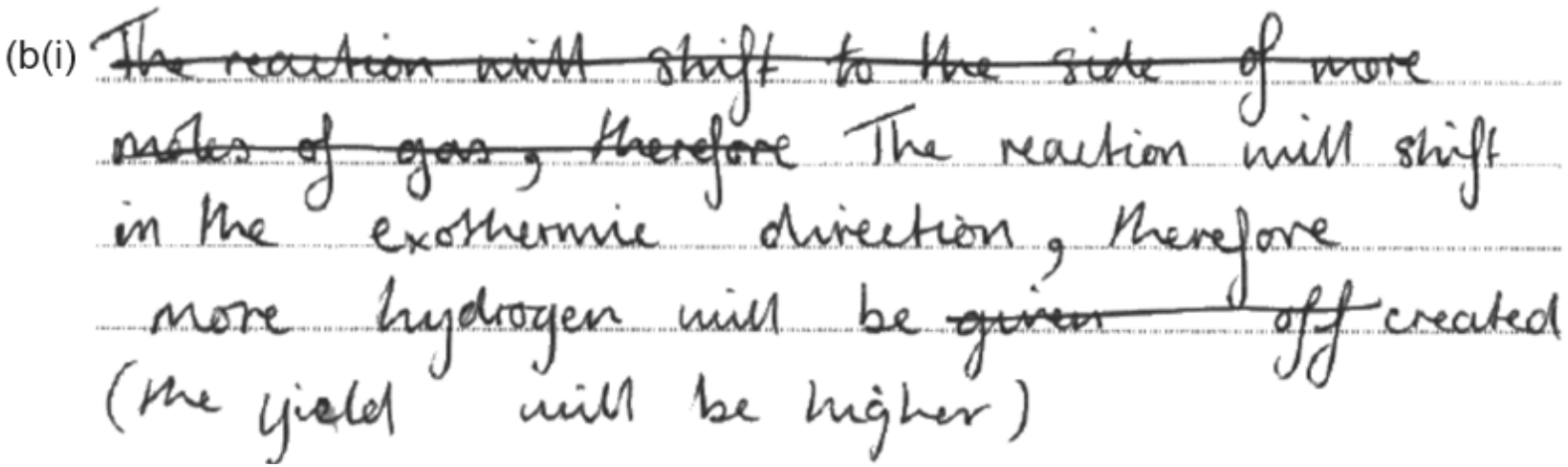
(b(i) decreases as the temperature ↓ decreases because rate there is less activation energy so there are less successful collisions.

Student 2

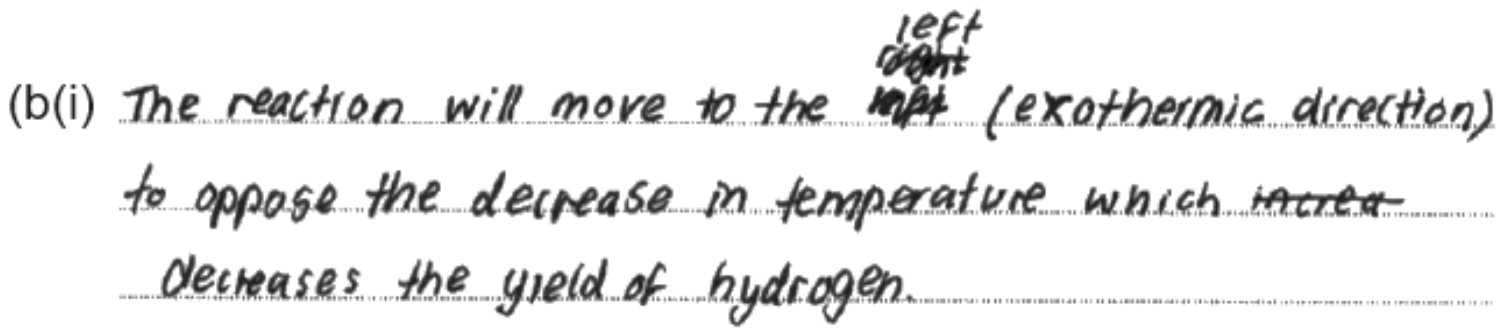
(b(i) The yield of hydrogen will ~~increase~~ decrease to oppose the ~~increase~~ decrease in temperature as the equilibrium will shift to the ~~right~~ left in the ~~endothermic~~ exothermic direction.

Activity 5 – Student answers and Examiner reports

Student 3



Student 4



Activity 5 – Student answers and Examiner reports

Student 1

(b)(ii) There will be a lower yeild of hydrogen because the reaction will move to the left where less hydrogen is produced.

Student 2

(b)(ii) The yield of hydrogen will increase as the equilibrium will shift to the direction that produces more moles (right side).

Activity 5 – Student answers and Examiner reports

Student 3

(b)(ii) Yield of hydrogen increases as equilibrium position shifts to the right (forwards) as it has the most (more) molecules, to oppose the change and increase the pressure.

Student 4

(b)(ii) the yield of hydrogen decreases and the equillibrium moves to the side of the reaction with more moles which is the right hand side.

Activity 5 – Student answers and Examiner reports

Examiner's report

(a) The majority of candidates gained the first marking point as they knew that the catalyst did not affect the yield, but only the minority explained adequately why the yield was not affected. A few thought that as the reaction speeded up that the yield would increase.

(b)(i) This question gave a range of marks with most scoring at least 1 mark for knowing that the yield decreases.

(b)(ii) The majority scored at least 1 mark for stating that the yield increased, although many did not refer to the numbers of moles so did not gain the second marking point.

Chemical Equilibrium – Suggestions to enhance teaching

What students need to know

- Chemical reactions involve the rearrangement of atoms and the breaking and forming of bonds
- Changes of state in molecular substances involve changes in the bonding between the molecules, but not within them
- Chemical reactions can be exothermic or endothermic, and temperature affects how reactions progress
- Concentration is a measure of the amount of substance in a set volume
- Reactions are observed macroscopically, but changes occur sub-microscopically

Chemical Equilibrium – Suggestions to enhance teaching

Some misconceptions and difficulties

- Students mainly experience chemical reactions that appear to go to completion
- When they meet a reaction that does not go to completion, but which has a reverse reaction occurring they may find the concept difficult to understand
- One major misconception students have about equilibria is that they think equilibria positions are fixed and once achieved there is no movement of particles between the two 'sides'
- That is, they believe that equilibria are static not dynamic

Chemical Equilibrium – Suggestions to enhance teaching

Some misconceptions and difficulties

- Rate and equilibria are often confused because students think that the rate of one reaction may change while the other slows or remains constant
- They have not grasped that rate applies to the system as a whole
- It is important to use a wide range of reversible reactions to help get these ideas across to the students

Chemical Equilibrium – Suggestions to enhance teaching

- When introducing equilibrium to students, start with familiar examples
- Ask questions such as: what happens when we leave an open glass of water in a room?
- Most students will be able to tell you that, over time, the level of the water in the glass will decrease as the water evaporates into the atmosphere
- We can then ask: what happens when we have the same glass, but with a lid on it?
- Students may suggest that the water level will remain constant (a macroscopic observation) because the rate of evaporation and condensation are equal (a sub-microscopic explanation)
- Writing out the equation of these reactions explicitly (symbolically) can help develop their understanding of the different ways we view chemical change:
  - **Evaporation:** $H_2O(l) \rightarrow H_2O(g)$
  - **Condensation:** $H_2O(g) \rightarrow H_2O(l)$
  - **Overall:** $H_2O(l) \rightleftharpoons H_2O(g)$

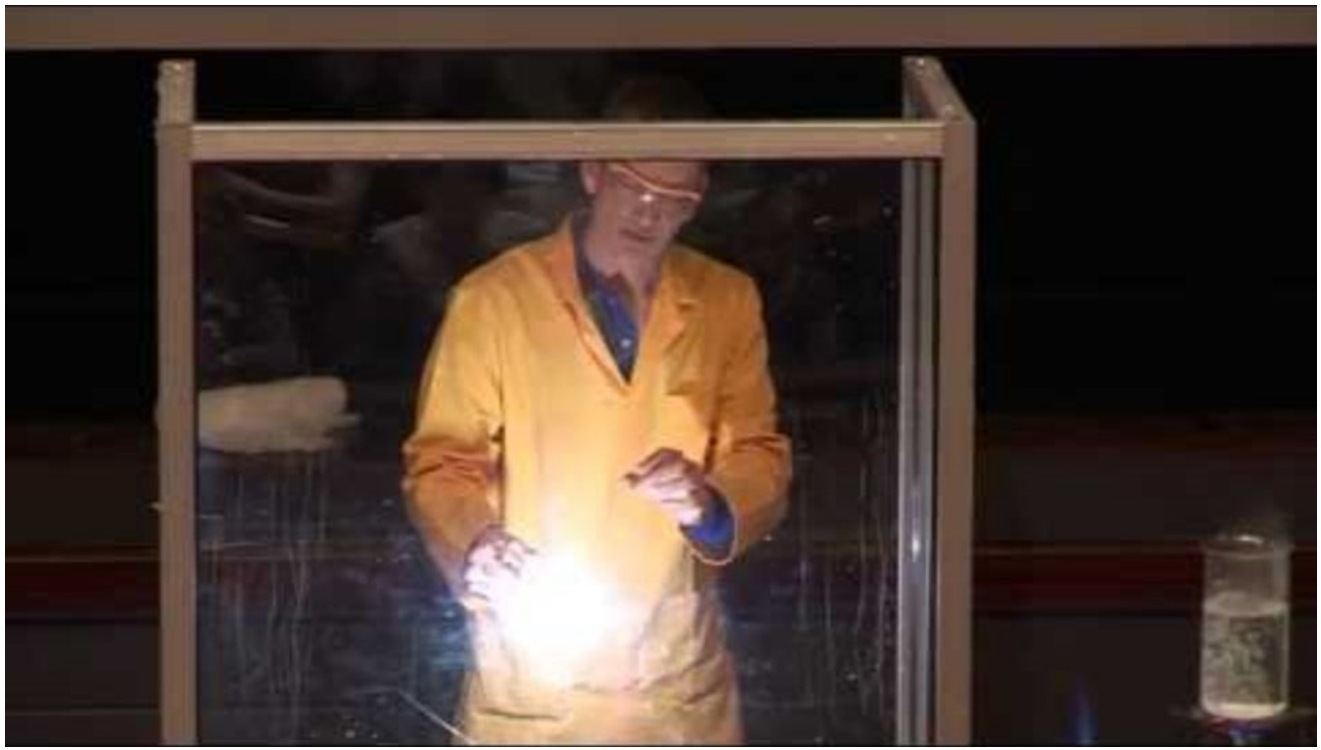
Chemical Equilibrium – Suggestions to enhance teaching

- Another way to show students the progression towards the idea of equilibria, is to demonstrate the irreversible reaction of burning magnesium ribbon **(taking care that no one looks directly at the flame and the teacher takes appropriate safety precautions)**

- If this is not possible the link below has video of magnesium burning in oxygen
  https://www.youtube.com/watch?v=lqOrCiOquRI

- It is worth revising the observations such as shiny metal to white powder plus, of course, heat

Chemical Equilibrium – Suggestions to enhance teaching



Chemical Equilibrium – Suggestions to enhance teaching

- The next stage would then be to look at a reversible reaction and a good class practical is the heating of ammonium chloride
- Another common example of a reversible reaction is the (de)hydration of copper(II) sulfate
- You could also look at cobalt complexes to help students develop an understanding of how the position of equilibrium can change with a change in temperature:

$$[Co(H_2O)_6]^{2+} + 4Cl^- \rightleftharpoons [CoCl_4]^{2-} + 6H_2O$$

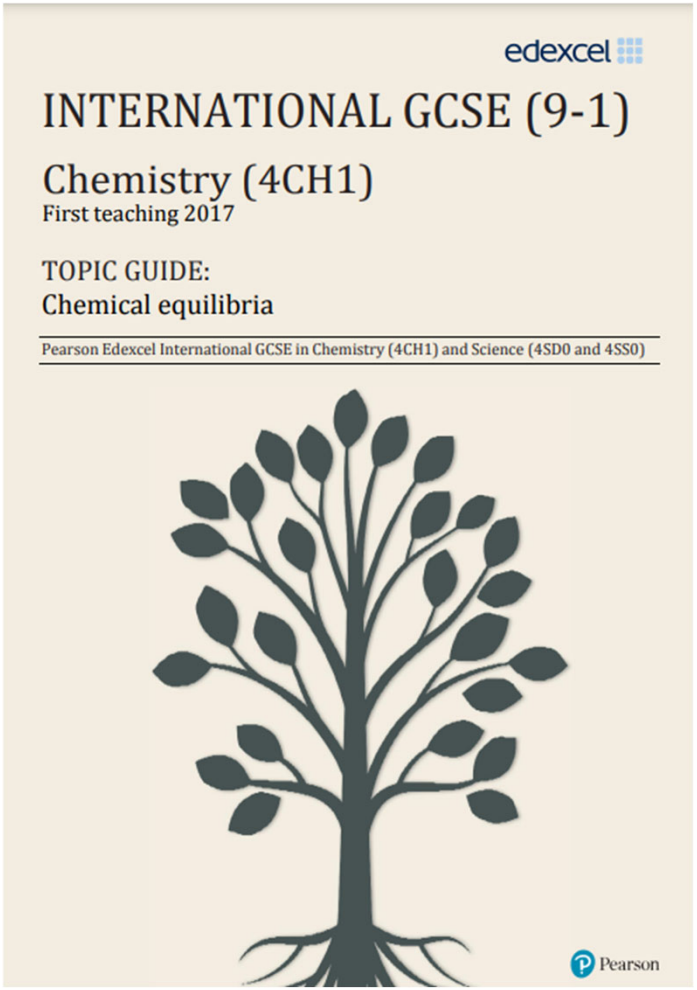
- Move a tube of the mixture between hot and cold-water baths and watch as the colour changes back and forth
- This experiment also shows that an equilibrium can be approached from either direction

Topic Guide – Chemical Equilibrium

In 1984 R.T. Allsop and N.H. George wrote an article, published in Education in Chemistry, entitled 'Le Châtelier – A Redundant Principle?' in which they argued that the use of the principle was counterproductive to the understanding of chemical equilibrium

Despite the compelling arguments put forward in this article, and the evidence from a number of research papers published within the last twenty years showing that reliance on Le Châtelier to explain the qualitative effects of external changes on the position of equilibrium leads to many misconceptions in both students and teachers alike, the principle has remained a prominent a feature of many Chemistry specifications in both England and worldwide

Although Le Châtelier's Principle is not required for teaching the International GCSE Chemistry specification, a number of students refer to it in answers



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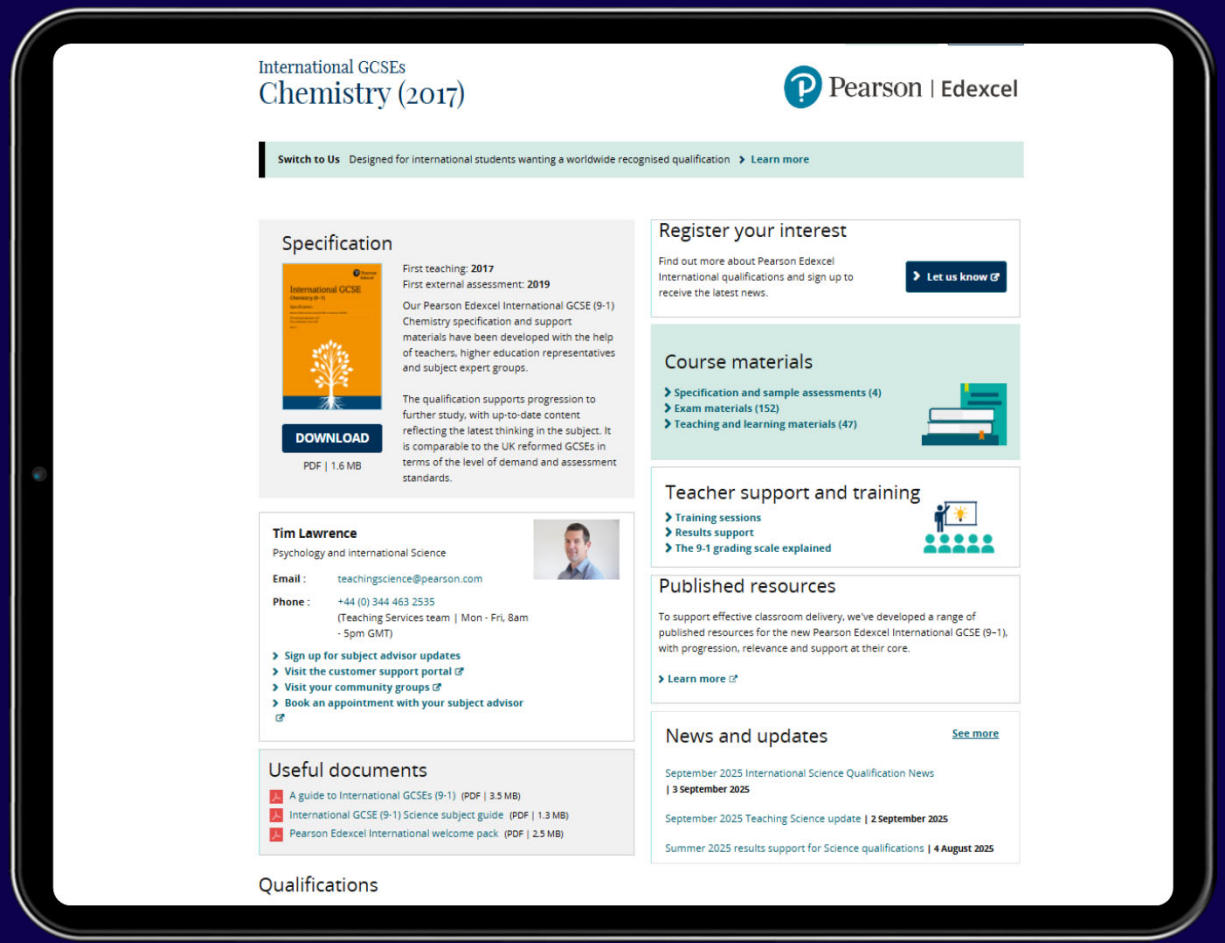
Support for you at every Stage



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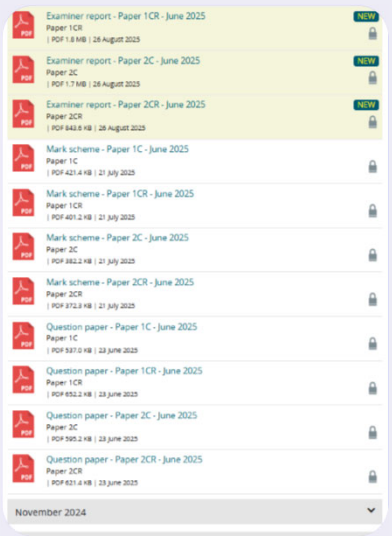

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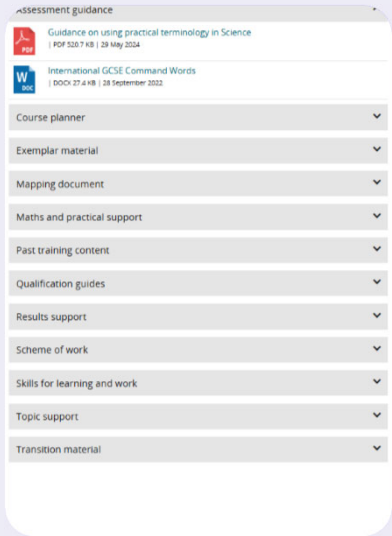
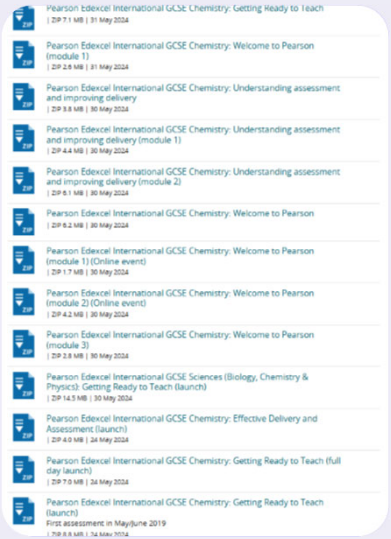


Teaching and Learning Materials



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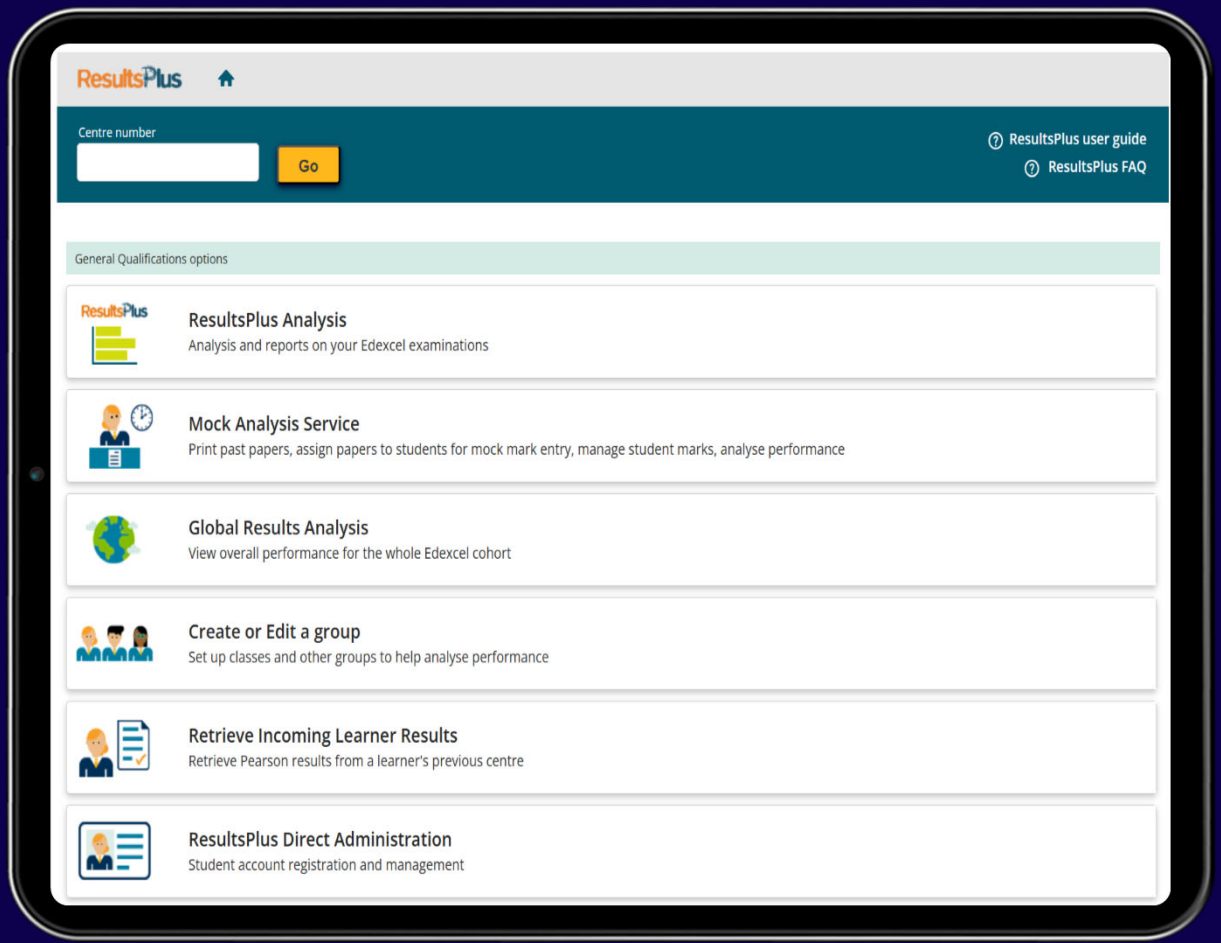

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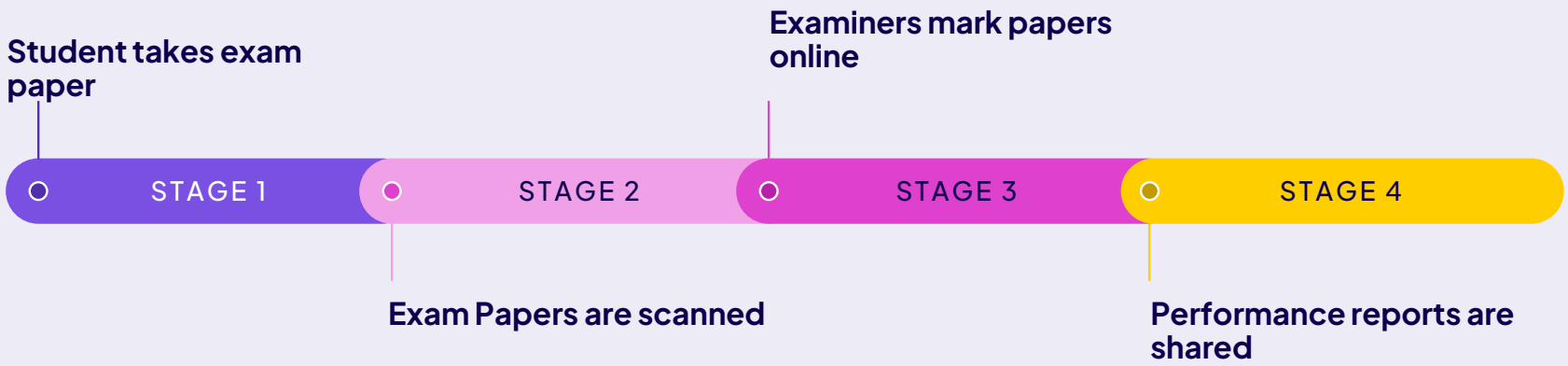

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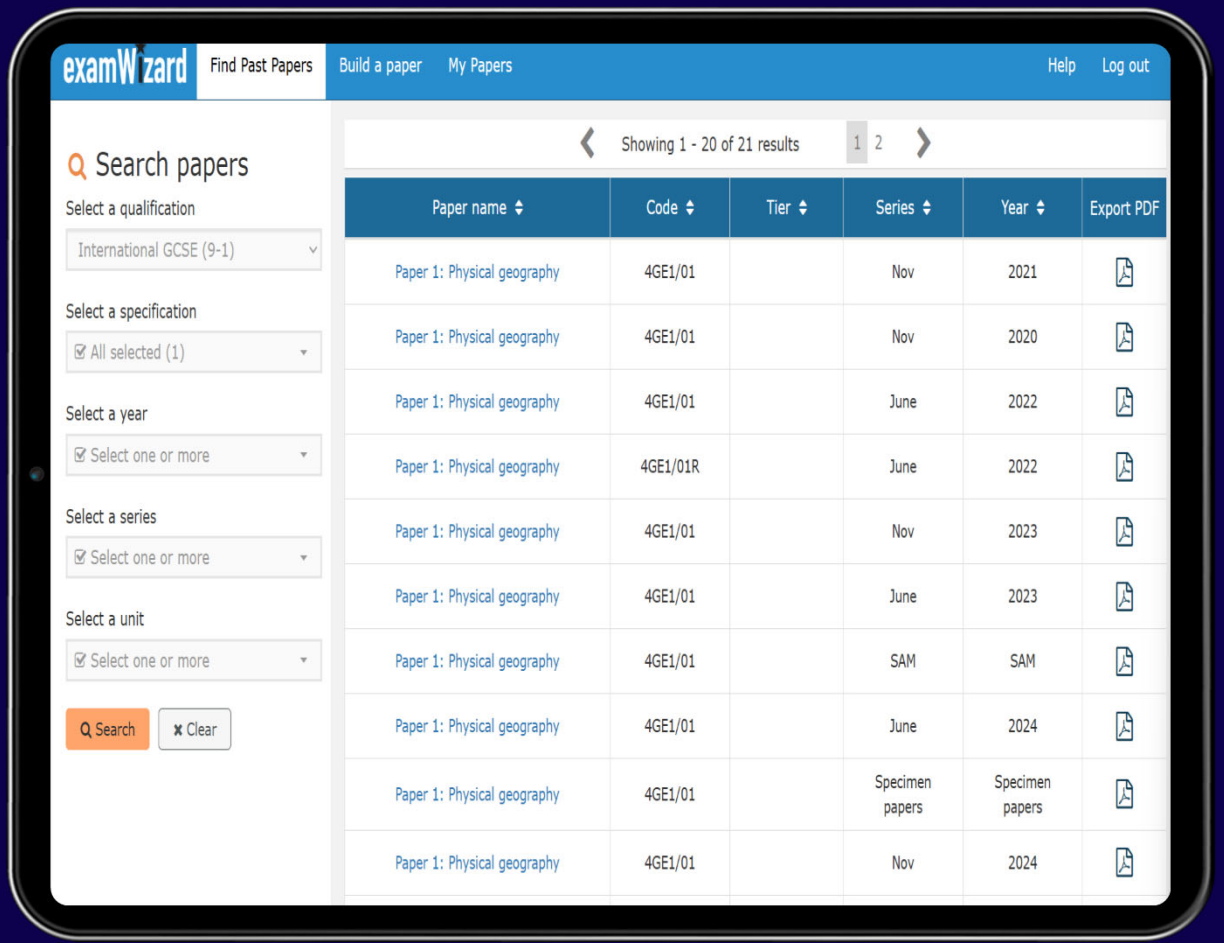

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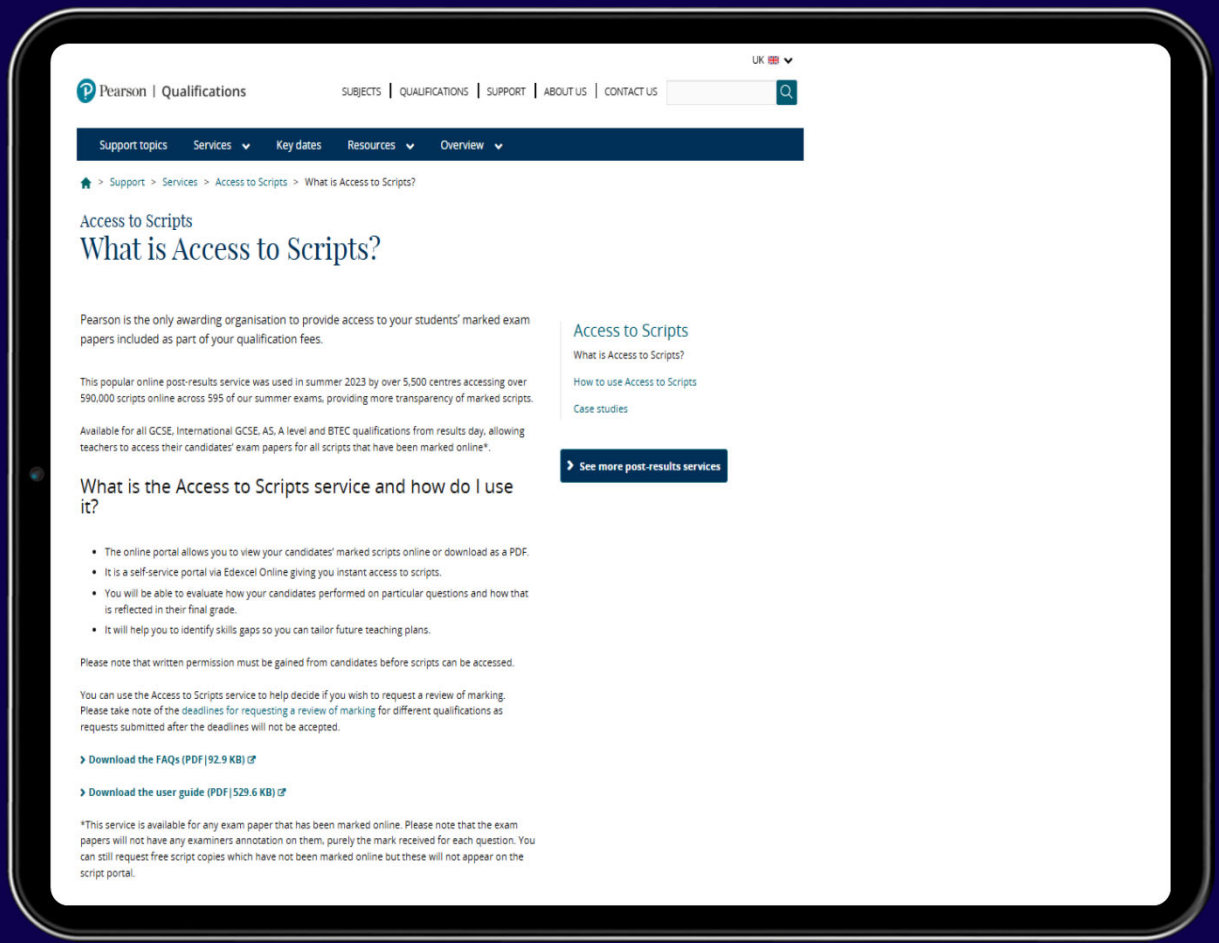

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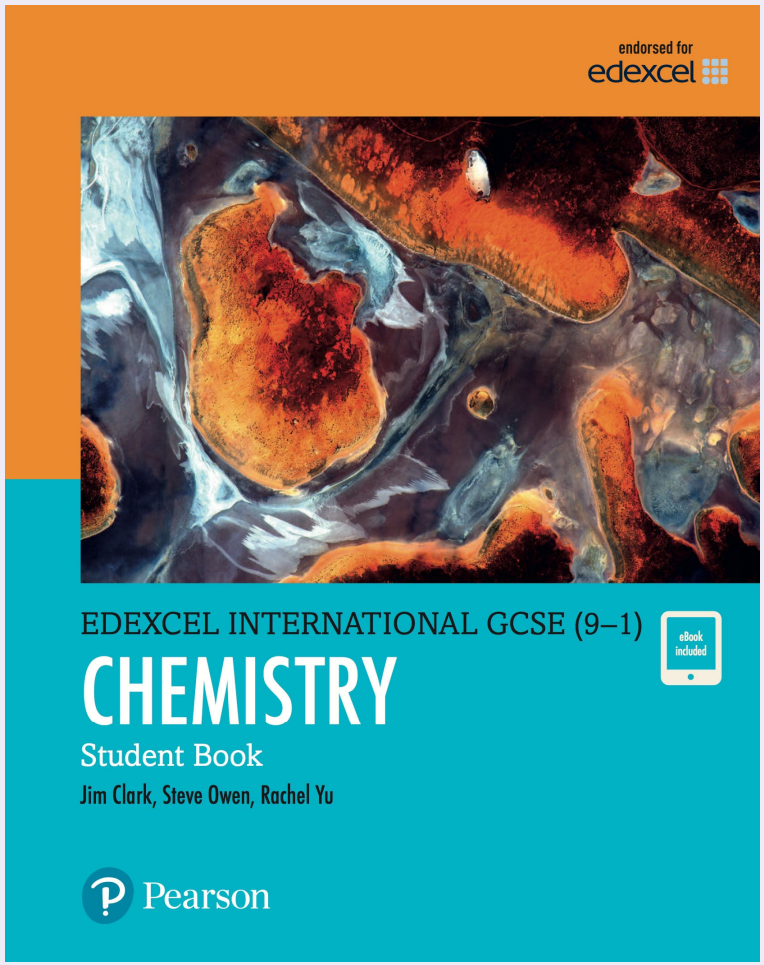

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