Unit title: Polymer Chemistry

Unit code: **L/601/0415**

QCF level: **5**

Credit value: **15**

Aim

This unit enables learners to gain an understanding of aspects of the structure, reaction mechanisms and polymer preparations. The properties, performance, behaviour and breakdown of types of polymer under a variety of conditions are also examined.

Unit abstract

The commercial uses of polymers and composite polymers are limitless and are an essential aspect of everyday life. Supermarket plastic bags, contact lenses, packaging and insulation materials are just a few examples of polymers that are used almost daily.

The development of polymer science provides a classic example of systematic chemical innovation and progress. This unit builds on the knowledge and understanding of functional group chemistry and mechanisms and expands these to give an understanding of polymer science.

Polymerisation mechanisms are used to support different types of polymerisation techniques. This leads to an examination of structural features of polymers related to their polymeric properties and characteristics. The unit concludes by examining polymer performance together with conditions likely to cause failure in behaviour when polymers are used in extreme environments.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand polymerisation mechanisms and techniques

2 Understand the basic properties of polymers from their structural features

3 Understand the service performance and environmental behaviour of polymers.

Unit content

1 **Understand polymerisation mechanisms and techniques**

Free radical mechanisms: initiator types; propagation; termination reactions e.g. vinyl polymers

Reaction rates and degree of polymerisation: deduction of general rate equations using the chemical equations generated for free radical mechanisms

Step polymerisations: uncatalysed and catalysed systems; degree of polymerisation; extent of reaction

Ionic processes: cationic; anionic; living polymer systems; Ziegler-Natta catalysts

Ring opening processes: lactams; epoxy systems

Co-polymerisation technique: reactivity ratios; Mayo-Lewis equation for determination of reaction rates

Polymerisation techniques: bulk solution; suspension; emulsion systems; kinetics of emulsion free radical systems e.g. bulk polymerisation of methyl methacrylate, suspension polymerisation of styrene, emulsion polymerisation of methyl methacrylate, preparation of polyesters, preparation of polyurethane

2 **Understand the basic properties of polymers from their structural features**

Glass transition temperature: relationship between polymer structure and glass transition temperature; tacticity; geometrical isomerism; branching; transparency; relationship between polymer properties and glass transition temperature; strength; stiffness; impact strength; ability to crystallise

Crystal structure of polymers and their relation to properties and uses: single crystal; spherulites; strain-induced crystallisation

Creep strain and stress relaxation: Maxwell and Kelvin-Voigt models

Molecular mass: number and weight averages; molecular mass distribution; effect on processing properties; calculations and determinations

Mechanical properties: strength; rigidity; moulding ability

3 **Understand the service performance and environmental behaviour of polymers**

Factors responsible for the degradation of polymers on processing and in service: thermodynamic depolymerisation; oxygen uptake; free radical autocatalytic mechanisms; heat; ozone; fatigue; chemical attack; apply to appropriate examples e.g. natural rubber, polypropylene

Common antidegradants: theories of antidegradant action; chain breaking donor and chain breaking acceptor mechanisms

Environmental stress cracking: mechanisms; surface energy

Structure of polymers related to attack by common inorganic and organic chemicals: discussion of polar and non-polar polymers; use of solubility parameter data

Environment: effects of e.g. heat, light, chemical attack by water, oil, petrol, disinfectants

Learning outcomes and assessment criteria

Learning outcomes On successful completion of this unit a learner will:	**Assessment criteria for pass** The learner can:
LO1 Understand polymerisation mechanisms and techniques	1.1 explain the mechanisms of free radical polymerisation and step polymerisations employing functional groups 1.2 deduce rate of equation for free radical and step polymerisations 1.3 explain the importance of ionic, step and ring opening polymerisation techniques in the development of new polymers 1.4 explain the importance of co-polymerisation techniques 1.5 use polymerisation techniques safely to produce small quantities of free radical and step polymers using standard laboratory apparatus
LO2 Understand the basic properties of polymers from their structural features	2.1 relate the crystal structures and properties of polymers to their glass transition temperature 2.2 deduce the ability of a polymer to crystallise from its structural features 2.3 relate crystal structure to the properties and uses of polymers 2.4 use literature data to calculate creep strain and stress employing Maxwell and Kelvin-Voigt equations 2.5 calculate molecular mass averages and molecular mass distribution 2.6 relate molecular mass averages and molecular mass distributions to mechanical properties and processing behaviour

Learning outcomes On successful completion of this unit a learner will:	**Assessment criteria for pass** The learner can:
LO3 Understand the service performance and environmental behaviour of polymers	3.1 discuss the factors responsible for the degradation of polymers on processing and in service 3.2 explain the action of common antidegradants 3.3 explain potential environmental stress cracking of polymers 3.4 explain the relation of polymer structure to attack by common inorganic and organic chemicals 3.5 perform experiments safely to investigate the influence of the environment on polymers

Guidance

Links

This unit has particular links with the following units within this qualification:

- *Unit reference number R/601/0352: Organic Chemistry*
- *Unit reference number Y/601/0353: Physical Chemistry*
- *Unit reference number J/601/0364: Physical Chemistry of Spectroscopy, Surfaces and Chemical and Phase Equilibria.*
- *Unit reference number A/601/0362: Organic Chemistry of Aromatic and Carbonyl Compounds*

Essential requirements

Delivery

Polymerisation mechanisms must be discussed alongside typical techniques employed. Wherever possible, practical investigations must be undertaken.

Emphasis must be placed on relating structural features to the properties of polymers and to conditions relating to polymer failure.

Assessment

Learners must prepare polymers using a variety of techniques, for example bulk polymerisation of methyl methacrylate, suspension polymerisation of styrene, emulsion polymerisation of methyl methacrylate, preparation of polyesters and preparation of polyurethane. These may all be prepared using standard laboratory equipment.

Learners must demonstrate their understanding of the basic properties of polymers from their structural features.

Published data can be used to calculate stress and strains from Maxwell and Kelvin-Voigt equations that describe creep strain and stress relaxation. Molecular mass averages must also be calculated.

Learners must undertake a practical investigation into the influence of the environment on stressed mouldings of polyethene and polycarbonate. (The term environment includes any gas, liquid or solid that may come into contact with the moulding.)

Learners must investigate the reactivity of common inorganic and organic chemicals on polar and non-polar polymers. Solubility parameter data must be used to predict the reactivity of inorganic and organic chemicals.

Resources

Learners require access to a chemical laboratory. The use of typical rubber and plastics products would help to illustrate the effects of glass transition and crystallinity.

Employer engagement and vocational contexts

Learners will benefit from visits to industrial laboratories particularly in the polymer sector. They should have the opportunity to gain experience of processing behaviour and the use of antidegradant systems and to see pilot scale and manufacturing scale plant in operation.

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