edexcel

INTERNATIONAL ADVANCED LEVEL

CHEMISTRY

SPECIFICATION

Pearson Edexcel International Advanced Subsidiary in Chemistry (XCH11)
Pearson Edexcel International Advanced Level in Chemistry (YCH11)
First teaching September 2018
First examination from January 2019
First certification from August 2019 (International Advanced Subsidiary) and August 2020 (International Advanced Level)

Pearson

Edexcel, BTEC and LCCI qualifications

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Acknowledgements

This specification has been produced by Pearson on the basis of consultation with teachers, examiners, consultants and other interested parties. Pearson would like to thank all those who contributed their time and expertise to the specification's development.

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ISBN 978 1 446 94996 2

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About this specification

The Pearson Edexcel International Advanced Subsidiary in Chemistry and the Pearson Edexcel International Advanced Level in Chemistry are part of a suite of International Advanced Level qualifications offered by Pearson.

These qualifications are not accredited or regulated by any UK regulatory body.

Key features

This specification includes the following key features.

Structure

The Pearson Edexcel International Advanced Subsidiary in Chemistry and the Pearson Edexcel International Advanced Level in Chemistry are modular qualifications. The Advanced Subsidiary can be claimed on completion of the International Advanced Subsidiary (IAS) units.

The International Advanced Level can be claimed on completion of all the units (IAS and IA2 units).

Content

The content is relevant for students who have achieved a GCSE in Chemistry and who want to study the subject at a higher level. The content has been updated from the previous Pearson Edexcel International Advanced Subsidiary in Chemistry and Pearson Edexcel International Advanced Level in Chemistry qualifications. It covers the major topics in chemistry, including molar calculations, structure and bonding, energetics, rates, equilibria, Group chemistry, transition metals and a range of organic chemistry; as well as associated experimental skills.

Assessment

Assessment consists of three written papers at IAS level that are externally assessed. The International A level consists of three further written papers that are externally assessed.

Approach

Students will develop their knowledge and understanding of chemistry by applying the concepts in this specification to a range of different problems, set in a variety of contexts. Students will need to apply mathematical skills to the problems.

Students will also develop their practical skills. This specification includes 16 core practical activities, which is the minimum number of practical activities that students will carry out. Centres are encouraged to include additional practical activities to develop students' practical skills further.

Specification updates

This specification is Issue 1 and is valid for first teaching from September 2018. If there are any significant changes to the specification, we will inform centres in writing. Changes will also be posted on our website.

For more information please visit qualifications.pearson.com

Using this specification

This specification gives teachers guidance and encourages effective delivery of these qualifications. The following information will help you get the most out of the content and guidance.

Compulsory content: as a minimum, all the topics in the content must be taught. The word 'including' in content specifies the detail of what must be covered.

Assessments: use a range of material and are not limited to the examples given. Teachers should deliver these qualifications using a good range of examples to support the assessment of the content.

Depth and breadth of content: teachers should use the full range of content and all the assessment objectives given in the subject content section.

Qualification aims and objectives

The aims and objectives of these qualifications are to enable students to develop:

- essential knowledge and understanding of different areas of the subject and how they relate to each other
- a deep appreciation of the skills, knowledge and understanding of scientific methods
- competence and confidence in a variety of practical, mathematical and problem-solving skills
- their interest in and enthusiasm for the subject, including developing an interest in further study and careers associated with the subject.

Qualification abbreviations used in this specification

The following abbreviations appear in this specification:

International Advanced Subsidiary – IAS

International A2 – IA2 (the additional content required for an IAL)

International Advanced Level – IAL.

Why choose Edexcel qualifications?

Pearson – the world's largest education company

All Edexcel's academic qualifications, including our new International AS and A level suite, are produced by Pearson, the UK's largest awarding organisation. With over 3.4 million students studying our academic and vocational qualifications worldwide, we offer internationally recognised qualifications to schools, colleges and employers globally.

Pearson is recognised as the world's largest education company, allowing us to drive innovation and provide comprehensive support for Edexcel students to acquire the knowledge and skills they need for progression in study, work and life.

A heritage you can trust

The background to Pearson becoming the UK's largest awarding organisation began in 1836, when a royal charter gave the University of London its first powers to conduct exams and confer degrees on its students. Edexcel qualifications build on experience of over 150 years in international education, and have a firm academic foundation, built on the traditions and rigour associated with Britain's educational system.

To find out more about our Edexcel heritage please visit our website: qualifications.pearson.com/en/about-us/about-pearson/our-history

Results you can trust

Pearson's leading online marking technology has been shown to produce exceptionally reliable results, demonstrating that at every stage, Edexcel qualifications maintain the highest standards.

Developed to Pearson's world-class qualifications standards

Pearson's world-class standards mean that all Edexcel qualifications are developed to be rigorous, demanding, inclusive and empowering. We work collaboratively with a panel of educational thought-leaders and assessment experts to ensure that Edexcel qualifications are globally relevant, represent world-class best practice and maintain a consistent standard.

For more information on the world-class qualification process and principles please go to *Appendix 2: Pearson World Class Qualification design principles* or visit our website: uk.pearson.com/world-class-qualifications.

Why choose Pearson Edexcel International Advanced Subsidiary / Advanced Level qualifications in Chemistry?

We have listened to feedback from all parts of the international school education community, including a large number of teachers. Our International Advanced Subsidiary and Advanced Levels have been developed to be engaging for international learners and to give them the necessary skills to support progression to further study in chemistry, as well as to a wide range of other subjects.

Key qualification features – using feedback from teachers, we have retained several key features which we know you value. These include:

- modular assessment, offered at different times of year to suit your delivery model
- practical skills assessed through a dedicated examination unit both at AS (Unit 3) and at A Level (Unit 6)
- comparable content with the UK GCE A Level – giving confidence to students, teachers and universities on comparability between specifications
- a range of types of questions in exams – testing breadth of knowledge, as well as allowing depth of understanding to be examined.

Clear and straightforward question papers – our question papers are clear and accessible for students of all ability ranges, and use a series of well-defined command words. Our mark schemes are straightforward so that the assessment requirements are clear.

Broad and deep development of learners' skills – we designed the International Advanced Subsidiary and International Advanced Level qualifications to extend learners' knowledge by broadening and deepening skills. For example learners will:

- develop and use a range of mathematical skills which support their knowledge and understanding of chemistry
- gain experience in a variety of practical techniques and procedures, which will be assessed separately in Units 3 and 6
- widen their learning through a number of key transferable skills, which may be cognitive, intrapersonal or interpersonal (see *Appendix 3: Transferable skills*)

Progression – these qualifications enable successful progression to further education courses in chemical sciences. Through our world-class qualification development process we have consulted with a number of universities in the UK, as well as internationally, to validate the appropriateness of these qualifications, including content, skills and assessment structure.

Our International Advanced Subsidiary and Advanced Levels in Chemistry sit within our wider subject offer for sciences. We also offer International Advanced Subsidiary and Advanced Levels in Biology, Physics and Psychology, and in Mathematics and Further Mathematics.

More information can be found on our website (qualifications.pearson.com) on the Edexcel International Advanced Level pages.

Supporting you in planning and implementing these qualifications

Planning

- Our *Getting Started Guide* gives you an overview of the Pearson Edexcel International Advanced Subsidiary and Advanced Levels in Chemistry to help you understand the changes to content and assessment, and what these changes mean for you and your students.
- We will provide you with an editable course planner and scheme of work to save you time in planning and help you to put together teaching strategies for delivering the specification content.
- Our mapping documents highlight key differences between the new and legacy qualifications to help you understand the changes made to the new specifications.

Teaching and learning

- Course planners and schemes of work – to help you to put together teaching strategies for delivering the specification content.
- Practical Skills Guides and Mathematical Skills Guides – to help you ensure that students are developing these skills, both of which form a key part of the assessment for the new International Advanced Subsidiary and Advanced Levels.
- Getting Ready to Teach and other training events – available locally and online.
- Printed textbooks and digital teaching resources – promote ‘any time, any place’ learning to improve student motivation and encourage new ways of working.

Preparing for exams

We will also provide a range of resources to help you prepare your students for the assessments, including:

- specimen papers to support formative assessments and mock exams
- examiner commentaries on questions, following each examination series.

ResultsPlus

ResultsPlus provides the most detailed analysis available of your students’ examination performance. It can help you identify the topics and skills where further learning would benefit your students.

examWizard

A free online resource, containing a bank of past paper questions, designed to support students and teachers with examination preparation and assessment.

Training events

In addition to online training, we host a series of training events each year for teachers to deepen their understanding of our qualifications.

Get help and support

Our Subject Advisor service will ensure that you receive help and guidance from us. You can sign up to receive our Science newsletter, containing qualification updates and product and service news. You can contact our Science Advisor team through the science pages of the Pearson Qualifications homepage (qualifications.pearson.com), or by emailing TeachingScience@pearson.com.

Qualification at a glance

Qualification overview

Pearson Edexcel International Advanced Subsidiary in Chemistry

This qualification consists of three externally-examined units.

The International Advanced Subsidiary (IAS) is the first half of the International Advanced Level qualification and consists of three IAS units – Units 1, 2 and 3. This qualification can be awarded as a discrete qualification or can contribute 50% towards the International Advanced Level qualification.

The qualification will include questions that target mathematics at Level 2 or above (see *Appendix 6: Mathematical skills and exemplifications*). Overall, a minimum of 20% of the marks across the papers will be awarded for mathematics at Level 2 or above.

Pearson Edexcel International Advanced Level in Chemistry

This qualification consists of six externally-examined units.

The International Advanced Level consists of the three IAS units (Units 1, 2 and 3) plus three IA2 units (Units 4, 5 and 6). Students wishing to take the International Advanced Level must, therefore, complete all six units.

The qualification will include questions that target mathematics at Level 2 or above (see *Appendix 6: Mathematical skills and exemplifications*). Overall, a minimum of 20% of the marks across the papers will be awarded for mathematics at Level 2 or above.

Course of study

The structure of these qualifications allows teachers to construct a course of study that can be taught and assessed as either:

- distinct modules of teaching and learning with related units of assessment taken at appropriate stages during the course; or
- a linear course assessed in its entirety at the end.

Content and assessment overview

IAS **Unit 1: Structure, Bonding and Introduction to Organic Chemistry**	***Unit code:** **WCH11/01**	
Externally assessed Written examination: 1 hour and 30 minutes Availability: January, June and October First assessment: January 2019 80 marks	40% of the total IAS	20% of the total IAL

Content overview

- Formulae, Equations and Amount of Substance
- Atomic Structure and the Periodic Table
- Bonding and Structure
- Introductory Organic Chemistry and Alkanes
- Alkenes

Assessment overview

- This paper has two sections:
  - Section A: multiple choice questions
  - Section B: mixture of short-open, open-response and calculation questions.
- This paper will include a minimum of 18 marks that target mathematics at Level 2 or above (see *Appendix 6: Mathematical skills and exemplifications*).
- Students will be expected to apply their knowledge and understanding of experimental methods in familiar and unfamiliar contexts.

IAS

Unit 2: Energetics, Group Chemistry, Halogenoalkanes and Alcohols

***Unit code: WCH12/01**

Externally assessed Written examination: 1 hour and 30 minutes Availability: January, June and October First assessment: June 2019 80 marks	40% of the total IAS	20% of the total IAL

Content overview

- Energetics
- Intermolecular Forces
- Redox Chemistry and Groups 1, 2 and 7
- Introduction to Kinetics and Equilibria
- Organic Chemistry: Alcohols, Halogenoalkanes and Spectra

Assessment overview

- This paper has three sections:
  - Section A: multiple choice questions
  - Section B: mixture of short-open, open-response, calculations and extended-writing questions
  - Section C: contemporary context question.
- This paper will contain questions that require information from the Data Booklet (see *Appendix 9*).
- This paper will include a minimum of 18 marks that target mathematics at Level 2 or above (see *Appendix 6: Mathematical skills and exemplifications*).
- Students will be expected to apply their knowledge and understanding of experimental methods in familiar and unfamiliar contexts.
- This paper may contain some synoptic questions which require knowledge and understanding from Unit 1.

IAS

Unit 3: Practical Skills in Chemistry I

***Unit code: WCH13/01**

Externally assessed Written examination: 1 hour and 20 minutes Availability: January, June and October First assessment: June 2019 50 marks	20% of the total IAS	10% of the total IAL

Content overview

Students are expected to develop experimental skills, and a knowledge and understanding of experimental techniques, by carrying out a range of practical experiments and investigations while they study Units 1 and 2.

This unit will assess students’ knowledge and understanding of experimental procedures and techniques that were developed in Units 1 and 2.

Assessment overview

- This paper may include short-open, open-response and calculation questions.
- This paper will include a minimum of 6 marks that target mathematics at Level 2 or above (see *Appendix 6: Mathematical skills and exemplifications*).
- Students will be expected to apply their knowledge and understanding of practical skills to familiar and unfamiliar situations.

IA2 **Unit 4: Rates, Equilibria and Further Organic Chemistry**	***Unit code: WCH14/01**	
Externally assessed Written examination: 1 hour and 45 minutes Availability: January, June and October First assessment: January 2020 90 marks	40% of the total IA2	20% of the total IAL

Content overview

- Kinetics
- Entropy and Energetics
- Chemical Equilibria
- Acid-base Equilibria
- Organic Chemistry: Carbonyls, Carboxylic Acids and Chirality

Assessment overview

- This paper has three sections:
  - Section A: multiple choice questions
  - Section B: mixture of short-open, open-response, calculations and extended-writing questions
  - Section C: data or calculation question.
- This paper will contain questions that require information from the Data Booklet (see *Appendix 9*).
- This paper will include a minimum of 22 marks that target mathematics at Level 2 or above (see *Appendix 6: Mathematical skills and exemplifications*).
- Students will be expected to apply their knowledge and understanding of experimental methods in familiar and unfamiliar contexts.
- This paper may contain some synoptic questions which require knowledge and understanding from Units 1 and 2.

IA2

Unit 5: Transition Metals and Organic Nitrogen Chemistry

***Unit code: WCH15/01**

Externally assessed

Written examination: 1 hour and 45 minutes

Availability: January, June and October

First assessment: June 2020

90 marks

40% of the total IA2

20% of the total IAL

Content overview

- Redox Equilibria
- Transition Metals and their Chemistry
- Organic Chemistry: Arenes
- Organic Nitrogen Compounds: Amines, Amides, Amino Acids and Proteins
- Organic Synthesis

Assessment overview

- This paper has three sections:
  - Section A: multiple choice questions
  - Section B: mixture of short-open, open-response, calculations and extended-writing questions
  - Section C: contemporary context question.
- This paper will contain questions that require information from the Data Booklet (see *Appendix 9*).
- This paper will include a minimum of 18 marks that target mathematics at Level 2 or above (see *Appendix 6: Mathematical skills and exemplifications*).
- Students will be expected to apply their knowledge and understanding of experimental methods in familiar and unfamiliar contexts.
- This paper may contain some synoptic questions which require knowledge and understanding from Units 1, 2 and 4.

IA2 **Unit 6: Practical Skills in Chemistry II**	***Unit code: WCH16/01**	
Externally assessed Written examination: 1 hour and 20 minutes Availability: January, June and October First assessment: June 2020 50 marks	20% of the total IA2	10% of the total IAL

Content overview

Students are expected to develop further the experimental skills and the knowledge and understanding of experimental techniques that they acquired in Units 1 and 2 (tests for anions and cations, gases and organic functional groups) by carrying out a range of practical experiments and investigations while they study Units 4 and 5.

This unit will assess students' knowledge and understanding of the experimental procedures and techniques that were developed in Units 4 and 5.

Assessment overview

- This paper may include short-open, open-response and calculation questions.
- This paper will include a minimum of 6 marks that target mathematics at Level 2 or above (see *Appendix 6: Mathematical skills and exemplifications*).
- Students will be expected to apply their knowledge and understanding of practical skills to familiar and unfamiliar situations.

*See *Appendix 1: Codes* for a description of this code and all other codes relevant to these qualifications.

Calculators

Calculators may be used in the examination. Please see *Appendix 8: Use of calculators*.

Chemistry content

Content overview

Students are expected to demonstrate and apply the knowledge, understanding and skills described in the content. They are also expected to analyse, interpret and evaluate a range of scientific information, ideas and evidence using their knowledge, understanding and skills.

To demonstrate their knowledge, students should be able to undertake a range of activities, including the ability to recall, describe and define, as appropriate.

To demonstrate their understanding, students should be able to explain ideas and use their knowledge to apply, analyse, interpret and evaluate, as appropriate.

Students should develop their ability to apply mathematical skills to chemistry throughout the course. These skills include the ability to change the subject of an equation, substitute numerical values and solve algebraic equations using decimal and standard form, ratios, fractions and percentages. Further details of the skills that should be developed are given in *Appendix 6: Mathematical skills and exemplifications*. Students should also be familiar with *Système Internationale d'Unités* (SI) units and their prefixes, be able to estimate physical quantities and know the limits of physical measurements.

Practical work is central to any study of chemistry. For this reason, the specification includes 16 core practical activities and further suggested practicals, which form a thread linking theoretical knowledge and understanding to practical scenarios. In following this thread, students will build on practical skills learned at GCSE (or equivalent), becoming confident practical chemists, handling apparatus competently and safely. Using a variety of apparatus and techniques, they should be able to design and carry out both the core practical activities and their own investigations, collecting data which can be analysed and used to draw valid conclusions.

Questions in examination papers will aim to assess the knowledge and understanding that students gain while carrying out practical activities, within the context of the 16 core practical activities, as well as in novel practical scenarios. Success in questions that indirectly assess practical skills will come more naturally to those candidates who have a solid foundation of laboratory practice and who, having carried them out, have a thorough understanding of practical techniques. Therefore, where possible, teachers should consider adding additional experiments to the core practical activities.

Students will be assessed on their practical skills in papers 3 and 6. These papers will include testing the skills of students in planning practical work – both in familiar and unfamiliar applications – including risk management and the selection of apparatus, with reasons.

When data handling, students will be expected to use significant figures appropriately, to process data and to plot graphs.

Students should be encouraged to use information technology throughout the course.

Units

Unit 1: Structure, Bonding and Introduction to Organic Chemistry

IAS compulsory unit

Externally assessed

Unit description

Introduction

This unit gives students opportunities to develop the basic chemical skills of writing formulae and equations, and calculating chemical quantities.

The study of atomic structure includes a description of *s*, *p*, and *d* orbitals and shows how electronic configurations can account for the arrangement of elements in the Periodic Table. This leads to an appreciation of one of the central features of chemistry: the explanation of the properties of elements and the patterns in the Periodic Table in terms of atomic structure.

An understanding of the electronic structure of atoms leads to an appreciation of the three types of strong chemical bonding: ionic, covalent and metallic. Following from this, shapes of molecules can then be considered.

The basic principles of organic chemistry are covered and students study alkanes and alkenes, and will begin to develop a mechanistic approach to organic chemistry.

Chemistry in action

The study of atomic structure gives some insight into the methods that scientists use to study the structure of atoms. This leads to the introduction of the mass spectrometer and its importance in sensitive methods of analysis in areas such as space research, medical research and diagnosis, in detecting drugs in sport and in environmental monitoring.

Chemists set up theoretical models and gain insight by comparing real and theoretical properties of chemicals. This is illustrated in the unit by considering the evidence for the different kinds of chemical bonding.

Electron-pair repulsion theory is also used to show how chemists can develop theories and use them to make predictions.

Students start to use the conventions for mechanisms in organic chemistry as a way to represent the movement of electrons in reactions.

Practical skills

Students can start with simple test-tube reactions to illustrate a range of chemical equations. They can then build up to carrying out practical work that can be used to find reaction quantities, covered in the first core practical on molar volume.

Simple practical work can be used to investigate the properties of substances with different types of bonding.

The introduction to organic chemistry shows how chemists work safely with hazardous chemicals by managing risks. A number of possible practicals can be used to explore the chemistry of alkenes.

Mathematical skills

There are opportunities for the development of mathematical skills in this unit. This includes converting between units such as cm^3 and dm^3, using standard form with the Avogadro constant, rearranging formulae for calculating moles in solids and in solutions and the ideal gas equation, calculating atom economy, dealing with percentage errors, calculating a relative atomic mass from isotopic composition data, using simple probability to calculate the peak heights for the mass spectrum of molecules such as chlorine, using logarithms to compare successive ionisation energies for an element, representing shapes of molecules with suitable sketches, plotting data to investigate trends in boiling temperatures of alkanes and calculating the yield of a reaction. (Please see *Appendix 6: Mathematical skills and exemplifications* for more detail.)

Assessment information

- First assessment: January 2019.
- The assessment is 1 hour and 30 minutes.
- The assessment is out of 80 marks.
- Students must answer all questions.
- This paper has two sections:
    - Section A: multiple choice questions
    - Section B: mixture of short-open, open-response and calculation questions.
- This paper will include a minimum of 18 marks that target mathematics at Level 2 or above.
- Students will be expected to apply their knowledge and understanding of experimental methods in familiar and unfamiliar contexts.
- Calculators may be used in the examination (see *Appendix 8: Use of calculators*).

Topic 1: Formulae, Equations and Amount of Substance

Application of ideas from this topic will be applied to all other units.

Students will be assessed on their ability to:

1.1	know the terms 'atom', 'element', 'ion', 'molecule', 'compound', 'empirical formula' and 'molecular formula'
1.2	know that the mole (mol) is the unit for the amount of a substance and be able to perform calculations using the Avogadro constant L (6.02×10^{23} mol^{-1})
1.3	write balanced full and ionic equations, including state symbols, for chemical reactions
1.4	understand the terms: i 'relative atomic mass' based on the ^{12}C scale ii 'relative molecular mass' and 'relative formula mass', including calculating these values from relative atomic masses *The term 'relative formula mass' should be used for compounds with giant structures.* iii 'molar mass' as the mass per mole of a substance in g mol^{-1} iv parts per million (ppm), including gases in the atmosphere
1.5	calculate the concentration of a solution in mol dm^{-3} and g dm^{-3} *Titration calculations are not required at this stage.*
1.6	be able to use experimental data to calculate empirical and molecular formulae
1.7	be able to use chemical equations to calculate reacting masses and vice versa, using the concepts of amount of substance and molar mass
1.8	be able to use chemical equations to calculate volumes of gases and vice versa, using: i the concepts of amount of substance ii the molar volume of gases iii the expression $pV = nRT$ for gases and volatile liquids
1.9	be able to calculate percentage yields and percentage atom economies (by mass) in laboratory and industrial processes, using chemical equations and experimental results Atom economy = $\frac{\text{molar mass of the desired product}}{\text{sum of the molar masses of all products}} \times 100\%$
1.10	be able to determine a formula or confirm an equation by experiment, including evaluation of the data
1.11	**CORE PRACTICAL 1** **Measurement of the molar volume of a gas.**
1.12	be able to relate ionic and full equations, with state symbols, to observations from simple test-tube experiments, to include: i displacement reactions ii typical reactions of acids iii precipitation reactions

	Further suggested practicals: i preparation of a salt and calculating the percentage yield of product, including the preparation of a double salt, such as ammonium iron(II) sulfate from iron, ammonia and sulfuric acid ii determine a chemical formula by experiment, such as the formula of copper(II) oxide by reduction iii determine a chemical equation by experiment, such as the reaction between lithium and water, or the reaction between magnesium and an acid iv carry out and interpret the results of simple test-tube reactions, as outlined in 1.12

Topic 2: Atomic Structure and the Periodic Table

Students will be assessed on their ability to:

2.1	know the structure of an atom in terms of electrons, protons and neutrons
2.2	know the relative mass and charge of protons, neutrons and electrons
2.3	know what is meant by the terms ‘atomic (proton) number’ and ‘mass number’
2.4	be able to use the atomic number and the mass number to determine the number of each type of subatomic particle in an atom or ion
2.5	understand the term ‘isotope’
2.6	understand the basic principles of a mass spectrometer and be able to analyse and interpret mass spectra to: i deduce the isotopic composition of a sample of an element ii calculate the relative atomic mass of an element from relative abundances of isotopes and vice versa iii determine the relative molecular mass of a molecule, and hence identify molecules in a sample iv understand that ions in a mass spectrometer may have a 2+ charge
2.7	be able to predict mass spectra, including relative peak heights, for diatomic molecules, including chlorine, given the isotopic abundances
2.8	be able to define first, second and third ionisation energies and understand that all ionisation energies are endothermic
2.9	know that an orbital is a region within an atom that can hold up to two electrons with opposite spins
2.10	understand how ionisation energies are influenced by the number of protons in the nucleus, the electron shielding and the sub-shell from which the electron is removed
2.11	know that ideas about electronic structure developed from: i an understanding that successive ionisation energies provide evidence for the existence of quantum shells and the group to which the element belongs ii an understanding that the first ionisation energy of successive elements provides evidence for electron sub-shells
2.12	be able to describe the shapes of *s* and *p* orbitals
2.13	know that orbitals in sub-shells: i each take a single electron before pairing up ii pair up with two electrons of opposite spin
2.14	be able to predict the electronic configuration of atoms of the elements from hydrogen to krypton inclusive and their ions, using *s, p, d* notation and electron-in-boxes notation
2.15	understand that electronic configuration determines the chemical properties of an element
2.16	know that the Periodic Table is divided into blocks, such as *s, p* and *d,* and know the number of electrons that can occupy *s, p* and *d* sub-shells in the first four quantum shells

2.17	be able to represent data, in a graphical form (including the use of logarithms of first ionisation energies on a graph) for elements 1 to 36 and hence explain the meaning of the term ‘periodic property’
2.18	be able to explain: i the trends in melting and boiling temperatures of the elements of Periods 2 and 3 of the Periodic Table in terms of the structure of the element and the bonding between its atoms or molecules ii the general increase and the specific trends in ionisation energy of the elements across Periods 2 and 3 of the Periodic Table iii the decrease in first ionisation energy down a group

Topic 3: Bonding and Structure

3A: Ionic bonding

Students will be assessed on their ability to:

3.1	know and be able to interpret evidence for the existence of ions, limited to physical properties of ionic compounds, electron density maps and the migration of ions
3.2	be able to describe the formation of ions in terms of loss or gain of electrons
3.3	be able to draw dot-and-cross diagrams to show electrons in cations and anions
3.4	be able to describe ionic crystals as giant lattices of ions
3.5	know that ionic bonding is the result of strong net electrostatic attraction between ions
3.6	understand the effects of ionic radius and ionic charge on the strength of ionic bonding
3.7	understand reasons for the trends in ionic radii down a group in the Periodic Table, and for a set of isoelectronic ions, including N^{3-} to Al^{3+}
3.8	understand the meaning of the term 'polarisation' as applied to ions
3.9	understand that the polarising power of a cation depends on its radius and charge, and the polarisability of an anion also depends on its radius and charge
	Further suggested practical The migration of ions in a U-tube using copper(II) chromate solution or on a microscope slide using potassium manganate(VII) crystals

3B: Covalent bonding

Students will be assessed on their ability to:

3.10	understand that covalent bonding is the strong electrostatic attraction between two nuclei and the shared pair of electrons between them, based on the evidence: i the physical properties of giant atomic structures ii electron density maps for simple molecules
3.11	be able to draw dot-and-cross diagrams to show electrons in covalent substances, including: i molecules with single, double and triple bonds ii species with dative covalent (coordinate) bonds, including Al_2Cl_6 and the ammonium ion
3.12	be able to describe the different structures formed by giant lattices of carbon atoms, including graphite, diamond and graphene, and discuss the applications of each
3.13	understand the meaning of the term 'electronegativity' as applied to atoms in a covalent bond

3.14	know that ionic and covalent bonding are the extremes of a continuum of bonding type and be able to explain this in terms of electronegativity differences, leading to bond polarity in bonds and molecules, and to ionic bonding if the electronegativity is large enough
3.15	be able to distinguish between polar bonds and polar molecules and predict whether or not a given molecule is likely to be polar
	Further suggested practical Determine the effect of an electrostatic force on jets of liquids (water, ethanol and cyclohexane) and use the results to determine whether the molecules are polar or non-polar

3C: Shapes of molecules

Students will be assessed on their ability to:

3.16	understand the principles of the electron-pair repulsion theory, used to interpret and predict the shapes of simple molecules and ions
3.17	understand the terms ‘bond length’ and ‘bond angle’
3.18	know and be able to explain the shapes of, and bond angles in, $BeCl_2$, BCl_3, CH_4, NH_3, NH_4^+, H_2O, CO_2, gaseous PCl_5 , SF_6 and C_2H_4
3.19	be able to apply the electron-pair repulsion theory to predict the shapes of, and bond angles in, molecules and ions analogous to those in 3.18

3D: Metallic bonding

Students will be assessed on their ability to:

3.20	understand that metals consist of giant lattices of metal ions in a sea of delocalised electrons
3.21	know that metallic bonding is the strong electrostatic attraction between metal ions and the delocalised electrons
3.22	be able to use the models in 3.20 and 3.21 to interpret simple properties of metals, including electrical conductivity and high melting temperature

Topic 4: Introductory Organic Chemistry and Alkanes

Related topics in Units 2, 4 and 5 will assume knowledge of this material.

4A: Introduction

Students will be assessed on their ability to:

4.1	understand the difference between hazard and risk
4.2	understand the hazards associated with organic compounds and why it is necessary to carry out risk assessments when dealing with potentially hazardous materials
4.3	be able to suggest ways in which risks can be reduced and reactions carried out safely, for example: i working on a smaller scale ii taking precautions specific to the hazard iii using an alternative method that involves less hazardous substances
4.4	understand the concepts of homologous series and functional group
4.5	be able to apply the rules of International Union of Pure and Applied Chemistry (IUPAC) nomenclature to: i name compounds relevant to this specification ii draw these compounds, as they are encountered in the specification, using structural, displayed and skeletal formulae *Students will be expected to know prefixes for compounds up to* C_{10}
4.6	be able to classify reactions as addition, substitution, oxidation, reduction or polymerisation
4.7	understand that bond breaking can be: i homolytic, to produce free radicals ii heterolytic, to produce ions
4.8	know definitions of the terms ‘free radical’ and ‘electrophile’

4B: Alkanes

Students will be assessed on their ability to:

4.9	know the general formula of alkanes and cycloalkanes, and understand that they are hydrocarbons (compounds of carbon and hydrogen only) which are saturated (contain single bonds only)
4.10	understand the term ‘structural isomerism’ and be able to draw the structural isomers of organic molecules, given their molecular formula
4.11	be able to draw and name the structural isomers of alkanes and cycloalkanes with up to six carbon atoms
4.12	know that alkanes are used as fuels and obtained from the fractional distillation, cracking and reforming of crude oil, and be able to write equations for these reactions
4.13	know that pollutants, including carbon monoxide, oxides of nitrogen and sulfur, carbon particulates and unburned hydrocarbons, are emitted during the combustion of alkane fuels
4.14	understand the problems arising from pollutants from the combustion of alkane fuels, limited to the toxicity of carbon monoxide and why it is toxic, and the acidity of oxides of nitrogen and sulfur
4.15	be able to discuss the reasons for developing alternative fuels in terms of sustainability and reducing emissions, including the emission of CO_2 and its relationship to climate change
4.16	be able to apply the concept of carbon neutrality to different fuels, such as petrol, bioethanol and hydrogen
4.17	understand the reactions of alkanes with: i oxygen in the air (combustion) ii halogens
4.18	understand the mechanism of the free radical substitution reaction between an alkane and a halogen: i using free radicals, which are species with an unpaired electron, represented by a single dot ii showing the initiation step of the mechanism, with curly half-arrows for free radical formation iii showing the propagation and termination steps of the mechanism iv having limited use in synthesis because of further substitution reactions
	Further suggested practical Cracking alkanes by thermal decomposition, including liquid paraffin using aluminium oxide as a catalyst

Topic 5: Alkenes

Related topics in Units 2, 4 and 5 will assume knowledge of this material.

Students will be assessed on their ability to:

5.1	know the general formula of alkenes and understand that alkenes and cycloalkenes are hydrocarbons which are unsaturated (have a carbon-carbon double bond which consists of a σ bond and a π bond)
5.2	be able to explain geometric isomerism in terms of restricted rotation around a C=C double bond and the nature of the substituents on the carbon atoms
5.3	understand the *E–Z* naming system for geometric isomers and why it is necessary to use this when the *cis*- and *trans*- naming system breaks down
5.4	be able to describe the reactions of alkenes, limited to: i the addition of hydrogen, using a nickel catalyst, to form an alkane ii the addition of halogens to produce a di-substituted halogenoalkane iii the addition of hydrogen halides to produce mono-substituted halogenoalkanes iv the addition of steam, in the presence of an acid catalyst, to produce alcohols v oxidation of the double bond by acidified potassium manganate(VII) to produce a diol
5.5	know the qualitative test for a C=C double bond using bromine or bromine water
5.6	be able to describe the mechanism (including diagrams), giving evidence where possible, of: i the electrophilic addition of bromine and hydrogen bromide to ethene ii the electrophilic addition of hydrogen bromide to propene *Use of the curly arrow notation is expected – the curly arrows should start from either a bond or from a lone pair of electrons.* *Knowledge of the relative stability of primary, secondary and tertiary carbocation intermediates is expected.*
5.7	be able to describe the addition polymerisation of alkenes and draw the repeat unit given the monomer, and vice versa
5.8	understand how chemists limit the problems caused by polymer disposal by: i developing biodegradable polymers ii removing toxic waste gases produced by the incineration of polymers
	Further suggested practicals: i investigating the difference in reactivity of alkanes and alkenes, including combustion, reaction with bromine water, reaction with acidified potassium manganate(VII) ii preparation of cyclohexene from cyclohexanol iii preparation of limonene from orange peel by steam distillation iv preparation of Perspex® from methyl 2-methylpropenoate

Unit 2: Energetics, Group Chemistry, Halogenoalkanes and Alcohols

IAS compulsory unit

Externally assessed

Unit description

Introduction

This unit develops the treatment of chemical bonding by introducing intermediate types of bonding and by exploring the nature and effects of intermolecular forces.

Study of the Periodic Table is extended to cover the chemistry of Groups 1, 2 and 7, where ideas about redox reactions are applied to the reactions of halogens and their compounds.

The study of energetics in chemistry is of theoretical and practical importance. In this unit, students learn how to define, measure and calculate enthalpy changes. They will see how a study of enthalpy changes helps chemists to understand chemical bonding.

The unit also develops an understanding – mostly at a qualitative level – of the ways in which chemists can control the rate, direction and extent of chemical change in reactions.

The organic chemistry in this unit covers halogenoalkanes and alcohols, and explores the mechanisms of selected reactions.

The study of spectroscopy gives further examples of the importance of accurate and sensitive methods of analysis, which can be applied to study chemical changes but also to detect drugs such as ethanol.

Chemistry in action

The use of models in chemistry is illustrated by the way in which the Maxwell-Boltzmann distribution and collision theory can account for the effects of temperature on the rates of chemical reactions.

The unit shows how chemists can study chemical changes at an atomic level and propose mechanisms to account for their observations.

The study of rates and equilibria shows the contribution that chemistry can make to a more sustainable economy by redeveloping manufacturing processes to make them more efficient, less hazardous and less polluting.

Practical skills	Again, students can begin their practical work for this unit with simple reactions, in polystyrene cups, to investigate energy changes in chemical reactions. This leads to the first core practical in this unit. Inorganic chemistry and basic redox reactions can also be explored with simple test-tube reactions. The techniques of volumetric analysis are introduced in this unit, with two core practicals to develop competence in this key skill. The effect of temperature, concentration and surface area on the rate of a reaction can be explored through a variety of reactions, and also forms part of the first core practical in organic chemistry. Further core practicals in organic chemistry are used to develop students' skills in using glassware and techniques such as reflux, use of a separating funnel and distillation. The final core practical considers qualitative analysis for ions and organic functional groups.
Mathematical skills	There are opportunities for the development of mathematical skills in this unit. This includes plotting and extrapolating graphs of temperature rise against time for displacement reactions, calculating enthalpy changes in J and kJ mol^{-1}, using algebra to solve Hess's Law problems, calculating enthalpy changes using bond enthalpies and evaluating experimental results in terms of measurement uncertainties and systematic errors in the context of measuring energy changes and in titrations. Also, calculating oxidation numbers within a complex system, balancing equations for redox reactions by combining ionic half-equations, calculating rates from reaction time, plotting graphs and having an appreciation of the graph for a Maxwell-Boltzmann distribution, and deriving an algebraic expression for the equilibrium constant. Further mathematical skills can be developed in analysing mass and infrared spectra. (Please see *Appendix 6: Mathematical skills and exemplifications* for more details.)

Assessment information

- First assessment: June 2019.
- The assessment is 1 hour and 30 minutes.
- The assessment is out of 80 marks.
- Students must answer all questions.
- This paper has three sections:
  - Section A: multiple choice questions
  - Section B: mixture of short-open, open-response, calculations and extended-writing questions
  - Section C: contemporary context question.
- This paper will contain questions that require information from the Data Booklet (see *Appendix 9*).
- This paper will include a minimum of 18 marks that target mathematics at Level 2 or above.
- Students will be expected to apply their knowledge and understanding of experimental methods in familiar and unfamiliar contexts.
- This paper may contain some synoptic questions which require knowledge and understanding from Unit 1.
- Calculators may be used in the examination (see *Appendix 8: Use of calculators*).

Topic 6: Energetics

Students will be assessed on their ability to:

6.1	know that the enthalpy change, ΔH, is the heat energy change measured at constant pressure and that standard conditions are 100 kPa and a specified temperature, usually 298 K
6.2	know that, by convention, exothermic reactions have a negative enthalpy change and endothermic reactions have a positive enthalpy change
6.3	be able to construct and interpret enthalpy level diagrams, showing exothermic and endothermic enthalpy changes
6.4	know the definition of standard enthalpy change of: i reaction, $\Delta_r H$ ii formation, $\Delta_f H$ iii combustion, $\Delta_c H$ iv neutralisation, $\Delta_{neut} H$ v atomisation, $\Delta_{at} H$
6.5	be able to use experimental data to calculate: i energy transferred in a reaction recalling and using the expression: energy transferred (J) = mass (g) × specific heat capacity (J g^{-1} °C^{-1}) × temperature change (°C) ii enthalpy change of the reaction in kJ mol^{-1} *This will be limited to experiments where substances are mixed in an insulated container and combustion experiments using a suitable calorimeter.*
6.6	know Hess's Law and be able to apply it to: i constructing enthalpy cycles ii calculating enthalpy changes of reaction using data provided, or data selected from a table or obtained from experiments
6.7	**CORE PRACTICAL 2** **Determination of the enthalpy change of a reaction using Hess's Law.**
6.8	be able to evaluate the results obtained from experiments and comment on sources of error and uncertainty and any assumptions made in the experiments *Students will need to consider experiments where substances are mixed in an insulated container and combustion experiments using, for example, a spirit burner and be able to draw suitable graphs and use cooling curve corrections.*
6.9	understand the terms 'bond enthalpy' and 'mean bond enthalpy', and be able to use bond enthalpies to calculate enthalpy changes, understanding the limitations of this method
6.10	be able to calculate mean bond enthalpies from enthalpy changes of reaction
6.11	understand that bond enthalpy data gives some indication about which bond will break first in a reaction, how easy or difficult it is and therefore how rapidly a reaction will take place at room temperature

	Further suggested practicals: i the enthalpy change for the decomposition of calcium carbonate using the enthalpy changes of reaction of calcium carbonate and calcium oxide with hydrochloric acid ii the enthalpy change of combustion of an alcohol iii the enthalpy change of the reaction between zinc and copper(II) sulfate solution iv the enthalpy of hydration of anhydrous copper(II) sulfate

Topic 7: Intermolecular Forces

Students will be assessed on their ability to:

7.1	understand the nature of the following intermolecular forces: i London forces (instantaneous dipole-induced dipole) ii permanent dipole-permanent dipole interactions iii hydrogen bonds
7.2	understand the interactions in molecules, such as H_2O, liquid NH_3 and liquid HF, which give rise to hydrogen bonding
7.3	understand the following anomalous properties of water resulting from hydrogen bonding: i its high melting and boiling temperature when compared with similar molecules ii the density of ice compared to that of water
7.4	be able to predict the presence of hydrogen bonding in molecules analogous to those mentioned in 7.2
7.5	understand, in terms of intermolecular forces, physical properties shown by substances, including: i the trends in boiling temperatures of alkanes with increasing chain length ii the effect of branching in the carbon chain on the boiling temperatures of alkanes iii the relatively low volatility (higher boiling temperatures) of alcohols compared to alkanes with a similar number of electrons iv the trends in boiling temperatures of the hydrogen halides HF to HI
7.6	understand factors that influence the choice of solvents, including: i water, to dissolve some ionic compounds, in terms of the hydration of the ions ii water, to dissolve simple alcohols, in terms of hydrogen bonding iii water, as a poor solvent for compounds (to include polar molecules such as halogenoalkane), in terms of inability to form hydrogen bonds iv non-aqueous solvents, for compounds that have similar intermolecular forces to those in the solvent
	Further suggested practicals: i the solubility of simple molecules in different solvents ii measuring the enthalpy change of vaporisation of water iii measuring temperature changes when substances dissolve

Topic 8: Redox Chemistry and Groups 1, 2 and 7

8A: Redox chemistry

Students will be assessed on their ability to:

8.1	know what is meant by the term ‘oxidation number’ and understand the rules for assigning oxidation numbers
8.2	be able to calculate the oxidation number of elements in compounds and ions, including in peroxides and metal hydrides
8.3	be able to indicate the oxidation number of an element in a compound or an ion, using a Roman numeral
8.4	be able to write formulae given oxidation numbers
8.5	understand oxidation and reduction in terms of electron transfer and changes in oxidation number, and the application of these ideas to reactions of *s*-block and *p*-block elements
8.6	know that oxidising agents gain electrons and reducing agents lose electrons
8.7	understand that a disproportionation reaction involves an element in a single species being simultaneously oxidised and reduced
8.8	know that oxidation number is a useful concept in terms of the classification of reactions as redox and as disproportionation
8.9	understand that metals, in general, form positive ions by loss of electrons with an increase in oxidation number whereas non-metals, in general, form negative ions by gain of electrons with a decrease in oxidation number
8.10	be able to write ionic half-equations and use them to construct full ionic equations

8B: The elements of Groups 1 and 2

Students will be assessed on their ability to:

8.11	understand reasons for the trend in ionisation energy down Groups 1 and 2
8.12	understand reasons for the trend in reactivity of the elements down Group 1 (Li to K) and Group 2 (Mg to Ba)
8.13	know the reactions of the elements of Group 1 (Li to K) and Group 2 (Mg to Ba) with oxygen, chlorine and water
8.14	know the reactions of: i oxides of Group 1 and 2 elements with water and dilute acid ii hydroxides of Group 1 and 2 elements with dilute acid
8.15	know the trends in solubility of the hydroxides and sulfates of Group 2 elements
8.16	understand the reasons for the trends in thermal stability of the nitrates and the carbonates of the elements in Groups 1 and 2 in terms of the size and charge of the cations involved

8.17	understand the formation of characteristic flame colours by Group 1 and 2 compounds in terms of electron transitions *Students will be expected to know the flame colours for Group 1 and 2 compounds.*
8.18	know experimental procedures to show: i patterns in the thermal decomposition of Group 1 and 2 nitrates and carbonates *Students will be expected to know tests for carbon dioxide and oxygen; and to recognise nitrogen dioxide by its colour and acidic pH.* ii flame colours in compounds of Group 1 and 2 elements
8.19	know reactions, including ionic equations where appropriate, for identifying: i carbonate ions, CO_3^{2-}, and hydrogencarbonate ions, HCO_3^- , using an aqueous acid to form carbon dioxide (and testing the gas with limewater) ii sulfate ions, SO_4^{2-}, using acidified barium chloride solution iii ammonium ions, NH_4^+, using sodium hydroxide solution and warming to form ammonia (and testing with litmus and HCl fumes)
8.20	be able to calculate solution concentrations, in mol dm^{-3} and g dm^{-3}, including simple acid-base titrations using the indicators methyl orange and phenolphthalein
8.21	**CORE PRACTICAL 3** **Finding the concentration of a solution of hydrochloric acid.**
8.22	understand how to minimise the sources of measurement uncertainty in volumetric analysis and estimate the overall uncertainty in the calculated result
8.23	**CORE PRACTICAL 4** **Preparation of a standard solution from a solid acid and use it to find the concentration of a solution of sodium hydroxide.**
	Further suggested practicals: i experiments to study the thermal decomposition of Group 1 and 2 nitrates and carbonates ii flame tests on compounds of Group 1 and 2 iii simple acid-base titrations using the indicators methyl orange and phenolphthalein to calculate solution concentrations in g dm^{-3} and mol dm^{-3} iv the solubility of calcium hydroxide by titration v determination of moles of water of crystallisation by titration

8C: Inorganic chemistry of Group 7 (limited to chlorine, bromine and iodine)

Students will be assessed on their ability to:

8.24	understand reasons for the trends for Group 7 elements in: i melting and boiling temperatures and physical state at room temperature ii electronegativity iii reactivity down the group
8.25	understand the trend in reactivity of Group 7 elements in terms of the redox reactions of Cl_2, Br_2 and I_2 with halide ions in aqueous solution *Students are expected to know the colours of the elements in standard conditions, in aqueous solution and in a non-polar organic solvent.*
8.26	understand, in terms of changes in oxidation number, the following reactions of the halogens: i oxidation reactions with Group 1 and 2 metals ii the disproportionation reaction of chlorine with water and the use of chlorine in water treatment iii the disproportionation reaction of chlorine with cold, dilute aqueous sodium hydroxide to form bleach iv the disproportionation reaction of chlorine with hot alkali v reactions analogous to those specified above
8.27	understand the following reactions: i solid Group 1 halides with concentrated sulfuric acid, to illustrate the trend in reducing ability of the hydrogen halides ii precipitation reactions of the aqueous anions Cl^-, Br^- and I^- with aqueous silver nitrate solution and nitric acid, and the solubility of the precipitates in aqueous ammonia solution iii hydrogen halides with ammonia gas (to produce ammonium halides) and with water (to produce acids)
8.28	be able to make predictions about fluorine and astatine and their compounds, in terms of knowledge of trends in halogen chemistry
	Further suggested practicals: i reaction of solid potassium halides with concentrated sulfuric acid ii precipitation reaction for halides and other anions

Topic 9: Introduction to Kinetics and Equilibria

9A: Kinetics

Students will be assessed on their ability to:

9.1	understand, in terms of the collision theory, the effect of changes in concentration, temperature, pressure and surface area on the rate of a chemical reaction
9.2	understand that reactions take place only when collisions have sufficient energy, known as the activation energy
9.3	be able to calculate the rate of a reaction from: i the time taken for a reaction, using rate = 1/time ii the gradient of suitable graph, by drawing a tangent, either for initial rate, or at a time, t
9.4	understand qualitatively, in terms of the Maxwell-Boltzmann distribution of molecular energies, how changes in temperature affect the rate of a reaction
9.5	understand the role of catalysts in providing alternative reaction routes of lower activation energy
9.6	be able to draw the reaction profiles for uncatalysed and catalysed reactions, including the energy level of the intermediate formed with the catalyst
9.7	understand the use of catalysts in industry to make processes more sustainable by using less energy and/or higher atom economy
9.8	be able to interpret the action of a catalyst in terms of a qualitative understanding of the Maxwell-Boltzmann distribution of molecular energies
	Further suggested practical Experiments to demonstrate the factors that influence the rate of chemical reactions, including the decomposition of hydrogen peroxide, reaction of marble chips with acid, reaction of thiosulfate ions with acid

9B: Equilibria

Students will be assessed on their ability to:

9.9	know that many reactions are readily reversible and that they can reach a state of dynamic equilibrium in which: i the rate of the forward reaction is equal to the rate of the backward reaction ii the concentrations of the reactants and the products remain constant
9.10	be able to predict and justify the qualitative effects of changes of temperature, pressure and concentration on the position of equilibrium in a homogeneous system
9.11	evaluate data to explain the necessity, for many industrial processes, to reach a compromise between the yield and the rate of reaction

	Further suggested practicals: Demonstrate the effect of a change of temperature, pressure and concentration on a system at equilibrium: i chlorine reacting with iodine to form iodine(**I**) chloride, which then reacts with chlorine to form iodine(**III**) chloride ii the equilibrium system between nitrogen dioxide (NO_2) and dinitrogen tetroxide (N_2O_4)

Topic 10: Organic Chemistry: Halogenoalkanes, Alcohols and Spectra

Related topics in Units 4 and 5 will assume knowledge of this material.

10A: General principles

Students will be assessed on their ability to:

10.1	be able to classify reactions (including those in Unit 1) as addition, elimination, substitution, oxidation, reduction, hydrolysis or polymerisation
10.2	understand the concept of a reaction mechanism
10.3	understand that heterolytic bond breaking results in species that are electrophiles or nucleophiles
10.4	know the definition of the term ‘nucleophile’
10.5	understand the link between bond polarity and the type of reaction mechanism a compound will undergo

10B: Halogenoalkanes

Students will be assessed on their ability to:

10.6	understand the nomenclature of halogenoalkanes and be able to draw their structural, displayed and skeletal formulae
10.7	understand the distinction between primary, secondary and tertiary halogenoalkanes
10.8	understand the reactions of halogenoalkanes with: i aqueous alkali, including KOH(aq) to produce alcohols (where the hydroxide ion acts as a nucleophile) ii ethanolic potassium hydroxide to produce alkenes by an elimination reaction (where the hydroxide ion acts as a base) iii aqueous silver nitrate in ethanol (where water acts as a nucleophile) iv alcoholic ammonia under pressure to produce amines (where the ammonia acts as a nucleophile) v alcoholic potassium cyanide to produce nitriles (where the cyanide ion acts as a nucleophile) *Students should know this is an example of increasing the length of the carbon chain.*
10.9	understand the mechanisms of the nucleophilic substitution reactions between primary halogenoalkanes and: i aqueous potassium hydroxide ii ammonia *S_N1 and S_N2 substitution mechanisms will be tested in Unit 4.*

10.10	understand that experimental observations and data can be used to compare the relative rates of hydrolysis of: i primary, secondary and tertiary structural isomers of a halogenoalkane ii primary chloro-, bromo- and iodoalkanes using aqueous silver nitrate in ethanol
10.11	**CORE PRACTICAL 5** **Investigation of the rates of hydrolysis of some halogenoalkanes.**
10.12	know the trend in reactivity of primary, secondary and tertiary halogenoalkanes
10.13	understand, in terms of bond enthalpy, the trend in reactivity of chloro-, bromo- and iodoalkanes
10.14	**CORE PRACTICAL 6** **Chlorination of 2-methylpropan-2-ol with concentrated hydrochloric acid.**
	Further suggested practicals: i the use of silver nitrate solution to identify the halogen present in halogenoalkanes ii preparation of 1-bromobutane from butan-1-ol, potassium bromide and sulfuric acid

10C: Alcohols

Students will be assessed on their ability to:

10.15	understand the nomenclature of alcohols and be able to draw their structural, displayed and skeletal formulae
10.16	understand the distinction between primary, secondary and tertiary alcohols
10.17	understand the reactions of alcohols with: i oxygen in air (combustion) ii halogenating agents • PCl_5 to produce chloroalkanes (including its use as a qualitative test for the presence of the –OH group) • 50% concentrated sulfuric acid and potassium bromide to produce bromoalkanes • red phosphorus and iodine to produce iodoalkanes iii concentrated phosphoric acid to form alkenes by elimination *Descriptions of the mechanisms of these reactions are not required.*

10.18	understand that potassium dichromate(VI) in dilute sulfuric acid can oxidise: i primary alcohols to produce aldehydes (which give a positive result with Benedict's or Fehling's solution) if the product is distilled as it forms ii primary alcohols to produce carboxylic acids (which give a positive result with sodium carbonate or sodium hydrogencarbonate) if the reagents are heated under reflux iii secondary alcohols to produce ketones *In equations, the oxidising agent can be represented by [O].*
10.19	understand, the following techniques in the preparation and purification of a liquid organic compound: i heating under reflux ii extraction with a solvent using a separating funnel iii distillation iv drying with an anhydrous salt v boiling temperature determination
10.20	**CORE PRACTICAL 7** **The oxidation of propan-1-ol to produce propanal and propanoic acid.**
	Further suggested practical: Investigation of reactions of primary and secondary alcohols, including propan-1-ol and propan-2-ol

10D: Mass spectra and IR

Students will be assessed on their ability to:

10.21	be able to interpret data from mass spectra to suggest possible structures of simple organic compounds using the m/z of the molecular ion and fragmentation patterns
10.22	be able to use infrared spectra, or data from infrared spectra, to deduce functional groups present in organic compounds, and predict infrared absorptions, given wavenumber data, due to familiar functional groups including: i C–H stretching absorptions in alkanes, alkenes and aldehydes ii C=C stretching absorption in alkenes iii O–H stretching absorptions in alcohols and carboxylic acids iv C=O stretching absorptions in aldehydes, ketones and carboxylic acids v C–X stretching absorption in halogenoalkanes vi N-H stretching absorption in amines
10.23	**CORE PRACTICAL 8** **Analysis of some inorganic and organic unknowns.**

Unit 3: Practical Skills in Chemistry I

IAS compulsory unit

Externally assessed

Unit description

Introduction

This unit consists of a written practical examination, covering the skills and techniques developed during practical work in Units 1 and 2.

Although the unit content contains eight core practical activities, the examination will not be limited to recall of these core practicals but may include questions where students are expected to apply their knowledge to new practical situations.

Students should, therefore, develop their practical skills by completing a range of different practicals that require a variety of different techniques.

As students carry out practical activities, they should be encouraged to write laboratory reports using appropriate scientific, technical and mathematical language, conventions and symbols.

Development of practical skills, knowledge and understanding

Students are expected to develop experimental skills and a knowledge and understanding of the necessary techniques by carrying out a range of practicals while they study Units 1 and 2.

This unit will assess students' knowledge and understanding of the practical procedures and techniques they develop.

To prepare for assessment of this unit, centres should give students opportunities to carry out practical activities, collect and analyse data, and draw conclusions. Students should – at the least – carry out the eight core practicals in class. By completing these practicals students will be able to:

- follow and interpret experimental instructions, covering the full range of laboratory exercises set throughout the course, with minimal help from the teacher
- always work with interest and enthusiasm in the laboratory, completing most laboratory exercises in the time allocated
- manipulate apparatus, use chemicals, carry out all common laboratory procedures and use data logging (where appropriate) with the highest level of skill that may be reasonably expected at this level
- work sensibly and safely in the laboratory, paying due regard to health and safety requirements without the need for reminders from the teacher
- gain accurate and consistent results in quantitative exercises, make most of the expected observations in qualitative exercises and obtain products in preparations of high yield and purity.

Assessment information

- First assessment: June 2019.
- The assessment is 1 hour and 20 minutes.
- The assessment is out of 50 marks.
- Students must answer all questions.
- This paper may include short-open, open-response and calculation questions.
- This paper will include a minimum of 6 marks that target mathematics at Level 2 or above.
- Students will be expected to apply their knowledge and understanding of practical skills to familiar and unfamiliar situations.
- Calculators may be used in the examination (see *Appendix 8: Use of calculators*).

The question paper will assess the following abilities.

Independent thinking in a practical context	• Solve problems set in a practical context. • Apply scientific knowledge to practical contexts.
Use and application of scientific methods and practices	• Identify and state how to control variables to improve experimental validity. • Present data in appropriate ways. • Evaluate results and draw conclusions. • Appreciate measurement uncertainties and errors. • Comment on the method for an experiment.
Numeracy and the application of mathematical concepts in a practical context	• Plot and interpret graphs. • Process and analyse data using appropriate mathematical skills. • Use appropriate numbers of significant figures based on the experimental data. • Consider the accuracy and precision of data.
Use of apparatus and equipment	• Recognise a range of laboratory apparatus and select appropriate apparatus for a particular scenario. • Understand how to use a range of apparatus and techniques appropriate to the knowledge and understanding included in this specification. • Consider the range and resolution of apparatus. • Identify health and safety issues and discuss how these may be dealt with.

Questions may require students to:

- recall and/or interpret observations relating to tests for ions and gases in Units 1 and 2
- recall and/or interpret observations relating to tests for organic functional groups in Units 1 and 2
- manipulate data and comment on experimental methods and techniques for a range of experiments involving measurements in Units 1 and 2, including molar mass calculations, titrations, thermochemical investigations and simple kinetics experiments
- comment on experimental methods and techniques in the preparation of inorganic or organic compounds in Units 1 and 2.

Unit 4: Rates, Equilibria and Further Organic Chemistry

IA2 compulsory unit

Externally assessed

Unit description

Introduction

In this unit, students make a quantitative study of chemical kinetics and extend their study of organic reaction mechanisms.

The topics of entropy and equilibria show how chemists are able to predict quantitatively the direction and extent of chemical change.

The unit tests the equilibrium law by showing the degree to which it can accurately predict changes during acid-base reactions, notably the changes to pH during titrations.

The organic chemistry in this unit covers carbonyl compounds, and carboxylic acids and their derivatives.

Students are required to apply their knowledge gained in Units 1 and 2, to all aspects of this unit. This includes nomenclature, ideas of isomerism, bond polarity and bond enthalpy, reagents and reaction conditions, reaction types and mechanisms. Students are also expected to use formulae and balanced equations and calculate chemical quantities.

Chemistry in action

This unit shows how the principles of kinetics and thermodynamics can help to identify optimal conditions for the manufacture of chemicals.

The study of entropy links thermodynamics and equilibrium, and shows how chemists approach fundamental questions about the stability of chemicals and the direction of chemical change.

The historical development of theories explaining acids and bases shows how scientific ideas change as a result of new evidence and fresh thinking.

The study of buffer solutions shows the importance of equilibrium systems in living cells, in medicines, in foods and in the natural environment.

The two broad areas of application of chemistry are synthesis and analysis. In this unit, synthesis is illustrated by reactions of carbonyl compounds (notably with cyanide ions) and the production of esters for use as solvents, flavourings and perfumes. The main analytical technique featured is nuclear magnetic resonance (NMR), including coverage of magnetic resonance imaging.

Practical skills	Through practical work, students will learn about the methods used to measure reaction rates. They will collect data, analyse it and interpret the results. They then see how knowledge of rate equations and other evidence can enable chemists to propose models to describe the mechanisms of reactions. Simple practical work can be used to investigate equilibrium systems. Students can develop their skill at volumetric analysis, with a number of titration activities as part of their exploration of acid-base equilibria. Although the organic section of the unit contains no core practical activities, students would be expected to encounter simple test-tube reactions for organic functional groups – such as the use of Benedict’s or Tollens’ reagents. There are also opportunities to undertake synthetic reactions, for example to make and purify an ester.
Mathematical skills	There are opportunities for the development of mathematical skills in this unit. This includes plotting and justifying the shapes of rate-concentration and concentration-time graphs, calculating the half-life of a reaction, calculating the activation energy from a suitable graph and rearranging the Arrhenius equation. Also, calculating entropy changes, constructing Born-Haber cycles and calculating missing values, constructing expressions for K_c and K_p and calculating values with relevant units, estimating the change in value of an equilibrium constant when a variable changes, using logarithms and exponentials for converting from concentration to pH of a buffer solution, plotting and interpreting titration curves and representing chiral molecules with appropriate diagrams. There is also an opportunity for calculating R_f values and interpreting infrared spectra and using the (n + 1) rule for proton NMR. (Please see *Appendix 6: Mathematical skills and exemplifications* for further information.)

Assessment information

- First assessment: January 2020.
- The assessment is 1 hour and 45 minutes.
- The assessment is out of 90 marks.
- Students must answer all questions.
- This paper has three sections:
  - Section A: multiple choice questions
  - Section B: mixture of short-open, open-response, calculations and extended-writing questions
  - Section C: data or calculation question.
- This paper will contain questions that require information from the Data Booklet (see *Appendix 9*).
- This paper will include a minimum of 22 marks that target mathematics at Level 2 or above.
- Students will be expected to apply their knowledge and understanding of experimental methods in familiar and unfamiliar contexts.
- This paper may contain some synoptic questions which require knowledge and understanding from Units 1 and 2.
- Calculators may be used in the examination (see *Appendix 8: Use of calculators*).

Topic 11: Kinetics

Knowledge of the concepts introduced in Unit 2, Topic 9A: Kinetics will be assumed and extended in this topic.

Students will be assessed on their ability to:

11.1	understand the terms: i rate of reaction ii rate equation, rate=$k[A]^m[B]^n$ where m and n are 0, 1 or 2 iii order with respect to a substance in a rate equation iv overall order of a reaction v rate constant vi half-life vii rate-determining step viii activation energy ix heterogeneous and homogeneous catalyst
11.2	be able to calculate the half-life of a reaction, using data from a suitable graph, and identify a reaction with a constant half-life as being first order
11.3	be able to select and justify a suitable experimental technique to obtain rate data for a given reaction, including: i titration ii colorimetry iii mass change iv volume of gas evolved v other suitable technique(s) for a given reaction
11.4	understand experiments that can be used to investigate reaction rates by: i an initial-rate method, carrying out separate experiments where different initial concentrations of one reagent are used *A 'clock reaction' is an acceptable approximation of this method.* ii a continuous monitoring method to generate data to enable concentration-time or volume-time graphs to be plotted
11.5	be able to deduce the order (0, 1 or 2) with respect to a substance in a rate equation, using data from: i a concentration-time graph ii a rate-concentration graph iii an initial-rate method

11.6	understand how to: i obtain data to calculate the order with respect to the reactants (and the hydrogen ion) in the acid-catalysed iodination of propanone ii use these data to make predictions about species involved in the rate-determining step iii deduce a possible mechanism for the reaction
11.7	be able to deduce the rate-determining step from a rate equation and vice versa
11.8	be able to deduce a reaction mechanism, using knowledge of the rate equation and the stoichiometric equation for a reaction
11.9	understand that knowledge of the rate equations for the hydrolysis of halogenoalkanes can be used to provide evidence for S_N1 and S_N2 mechanisms for tertiary and primary halogenoalkane hydrolysis
11.10	be able to use calculations and graphical methods to find the activation energy for a reaction from experimental data *The Arrhenius equation will be given if needed.*
11.11	understand the use of a solid (heterogeneous) catalyst for industrial reactions, in the gas phase, in terms of providing a surface for the reaction
11.12	**CORE PRACTICALS 9a and 9b** **Following the rate of the iodine-propanone reaction by a titrimetric method and investigating a 'clock reaction' (Harcourt-Esson, iodine clock).**
11.13	**CORE PRACTICAL 10** **Finding the activation energy of a reaction.**
	Further suggested practicals: i the reaction between marble chips and hydrochloric acid (change of mass or change in volume of gas) ii the reaction between magnesium and hydrochloric acid to determine the activation energy iii following the rate of the iodine-propanone reaction by a colorimetric method iv the catalysis by a cobalt(II) salt of potassium sodium tartrate and hydrogen peroxide v the action of the enzyme urease on urea and thiourea

Topic 12: Entropy and Energetics

12A: Entropy

Students will be assessed on their ability to:

12.1	understand that, since endothermic reactions can occur spontaneously at room temperature, enthalpy changes alone do not control whether reactions occur
12.2	understand entropy as a measure of disorder of a system in terms of the random dispersal of molecules and of energy quanta between molecules
12.3	understand that the entropy of a substance increases with temperature, that entropy increases as solid → liquid → gas and that perfect crystals at zero kelvin have zero entropy
12.4	be able to interpret the natural direction of change as being in the direction of increasing total entropy (positive entropy change), including gases spread spontaneously through a room
12.5	understand why entropy changes occur during: i changes of state ii dissolving of a solid ionic lattice iii reactions in which there is a change in the number of moles from reactants to products
12.6	understand that the total entropy change of any reaction is the sum of the entropy change of the system and the entropy change of the surroundings, summarised by the expression: $\Delta S_{\text{total}} = \Delta S_{\text{system}} + \Delta S_{\text{surroundings}}$
12.7	be able to calculate the entropy change of the system for a reaction, ΔS_{system}, given the entropies of the reactants and products
12.8	be able to calculate the entropy change in the surroundings, and hence ΔS_{total}, using the expression $\Delta S_{\text{surroundings}} = \frac{-\Delta H}{T}$
12.9	understand that the feasibility of a reaction depends on: i the balance between ΔS_{system} and $\Delta S_{\text{surroundings}}$, so that even endothermic reactions can occur spontaneously at room temperature ii temperature, as higher temperatures decrease the magnitude of $\Delta S_{\text{surroundings}}$ so its contribution to ΔS_{total} is less *Students should be able to calculate the temperature at which a reaction is feasible.* *Students may also use $\Delta G = \Delta H - T\Delta S_{system}$ in answers, although this approach is not a requirement of the specification.*
12.10	understand that reactions can occur as long as ΔS_{total} is positive even if one of the other entropy changes is negative
12.11	understand and distinguish between the concepts of thermodynamic stability and kinetic stability

	Further suggested practicals: Investigate chemical reactions in terms of disorder and enthalpy change, including: i dissolving a solid, including adding ammonium nitrate crystals to water ii gas evolution, including reacting ethanoic acid with ammonium carbonate iii exothermic reaction producing a solid, including burning magnesium ribbon in air iv endothermic reaction of two solids, including mixing solid barium hydroxide, $Ba(OH)_2.8H_2O$ with solid ammonium chloride

12B: Lattice energy

Students will be assessed on their ability to:

12.12	be able to define the terms: i standard enthalpy change of atomisation, $\Delta_{at}H$ ii electron affinity iii lattice energy (as the exothermic process for the formation of one mole of an ionic solid from its gaseous ions)
12.13	be able to construct Born-Haber cycles and carry out related calculations
12.14	understand that a comparison of the experimental lattice energy value (from a Born-Haber cycle) with the theoretical value (obtained from electrostatic theory) in a particular compound indicates the degree of covalent bonding
12.15	understand that polarisation of anions by cations leads to some covalency in an ionic bond, based on evidence from the Born-Haber cycle
12.16	be able to define the terms 'enthalpy change of solution, $\Delta_{sol}H$' and 'enthalpy change of hydration, $\Delta_{hyd}H$ of an ion'
12.17	be able to use energy cycles and energy level diagrams to calculate the enthalpy change of solution of an ionic compound, using enthalpy change of hydration and lattice energy
12.18	understand the effect of ionic charge and ionic radius on the values of enthalpy change of hydration and the lattice energy of an ionic compound
12.19	be able to use entropy and enthalpy changes of solution values to predict the solubility of ionic compounds and discuss trends in the solubility of ionic compounds covered in Unit 2
	Further suggested practical Calculate the enthalpy change when a variety of ionic solids are dissolved in water

Topic 13: Chemical Equilibria

Knowledge of the concepts introduced in Unit 2, Topic 9B Chemical Equilibria will be assumed and extended in this topic.

Students will be assessed on their ability to:

13.1	be able to deduce an expression for K_c , for homogeneous and heterogeneous systems, in terms of equilibrium concentrations
13.2	be able to deduce an expression for K_p for homogeneous and heterogeneous systems, in terms of equilibrium partial pressures in atm
13.3	be able to calculate a value, with units where appropriate, for the equilibrium constants (K_c and K_p) for homogeneous and heterogeneous reactions, from experimental data
13.4	understand how, if at all, a change in temperature, pressure or the presence of a catalyst affects the equilibrium composition in a homogeneous or heterogeneous system
13.5	understand that the value of the equilibrium constant is not affected by changes in concentration or pressure or by the addition of a catalyst
13.6	know the effect of changing the temperature on the equilibrium constant (K_c and K_p) for both exothermic and endothermic reactions
13.7	understand that the effect of temperature on the position of equilibrium is explained using a change in the value of the equilibrium constant
13.8	understand the effect of a change in temperature on: i the value of ΔS_{total} ii the magnitude of the equilibrium constant, since $\Delta S_{\text{total}} = R \ln K$
13.9	be able to apply knowledge of the value of equilibrium constants to predict the extent to which a reaction takes place
	Further suggested practicals: i the reaction of ethanol and ethanoic acid (this can be used as an example of the use of ICT to present and analyse data) ii the equilibrium $Fe^{2+}(aq) + Ag^{+}(aq) \rightleftharpoons Fe^{3+}(aq) + Ag(s)$ iii the distribution of ammonia or iodine between two immiscible solvents iv the thermal decomposition of ammonium chloride v the effect of temperature and pressure changes in the system $2NO_2 \rightleftharpoons N_2O_4$

Topic 14: Acid-base Equilibria

Knowledge of the concepts introduced in Unit 2, Topic 9B Chemical Equilibria will be assumed and extended in this topic.

Students will be assessed on their ability to:

14.1	understand that a Brønsted–Lowry acid is a proton donor and a Brønsted–Lowry base is a proton acceptor and that acid-base reactions involve proton transfer
14.2	be able to identify Brønsted–Lowry conjugate acid-base pairs
14.3	be able to define the term 'pH'
14.4	be able to calculate pH from hydrogen ion concentration
14.5	be able to calculate the concentration of hydrogen ions in a solution, in mol dm^{-3}, from its pH, using the expression $[H^+] = 10^{-pH}$
14.6	understand the difference between a strong acid and a weak acid in terms of the degree of dissociation
14.7	be able to calculate the pH of a strong acid
14.8	be able to deduce the expression for the acid dissociation constant, K_a, for a weak acid
14.9	be able to calculate the pH of a weak acid from K_a or pK_a values, making relevant assumptions *Students will not be expected to solve quadratic equations.*
14.10	be able to define the ionic product of water, K_w
14.11	be able to calculate the pH of a strong base from its concentration, using K_w or pK_w
14.12	be able to define the terms 'pK_a' and 'pK_w'
14.13	be able to analyse data from the following experiments: i measuring the pH of a variety of substances, including equimolar solutions of strong and weak acids, strong and weak bases, and salts ii comparing the pH of a strong and weak acid after dilution 10, 100 and 1000 times
14.14	be able to calculate K_a for a weak acid from experimental data given the pH of a solution containing a known mass of acid
14.15	be able to draw and interpret titration curves, using all combinations of strong and weak monoprotic and diprotic acids with bases, and apply these principles to diprotic acids and bases
14.16	be able to select a suitable indicator for a titration, using a titration curve and appropriate data
14.17	know what is meant by the term 'buffer solution'
14.18	understand the action of a buffer solution
14.19	be able to calculate the pH of a buffer solution given appropriate data
14.20	be able to calculate the concentrations of solutions required to prepare a buffer solution of a given pH

14.21	understand how to use a weak acid-strong base or strong acid-weak base titration curve to: i demonstrate buffer action ii determine K_a from the pH at the point where half the acid is neutralised/ equivalence point
14.22	understand the importance of buffer solutions in biological environments: i buffers in cells and in blood (H_2CO_3/HCO_3^-) ii in foods to prevent deterioration due to pH change (caused by bacterial or fungal activity)
14.23	**CORE PRACTICAL 11** **Finding the K_a value for a weak acid.**
	Further suggested practicals: i carry out the measuring of the pH of solutions mentioned in 14.13 ii obtain data to draw titration curves mentioned in 14.15 (which gives an opportunity to use data loggers) iii analysis of vinegar

Topic 15: Organic Chemistry: Carbonyls, Carboxylic Acids and Chirality

15A: Chirality

Students will be assessed on their ability to:

15.1	know that optical isomerism is a result of chirality in molecules with a single chiral centre
15.2	understand that optical isomerism results from chiral centre(s) in a molecule with asymmetric carbon atom(s) and that optical isomers (enantiomers) are object and non-superimposable mirror images and be able to draw 3D diagrams of these optical isomers
15.3	know that optical activity is the ability of a single optical isomer to rotate the plane of polarisation of plane-polarised monochromatic light in molecules containing a single chiral centre
15.4	know what is meant by the term ‘racemic mixture’
15.5	be able to use data on optical activity of reactants and products as evidence for S_N1 and S_N2 mechanisms and addition to carbonyl compounds

15B: Carbonyl compounds

Students will be assessed on their ability to:

15.6	understand the nomenclature of aldehydes and ketones and be able to draw their structural, displayed and skeletal formulae
15.7	understand that aldehydes and ketones: i do not form intermolecular hydrogen bonds and this affects their physical properties ii can form hydrogen bonds with water and this affects their solubility
15.8	understand the reactions of carbonyl compounds with: i Fehling's or Benedict's solution, Tollens' reagent and acidified dichromate(VI) ions *In equations, the oxidising agent can be represented as [O].* ii lithium tetrahydridoaluminate(III) (lithium aluminium hydride) in dry ether (ethoxyethane) *In equations, the reducing agent can be represented by [H].* iii HCN, in the presence of KCN, as a nucleophilic addition reaction, using curly arrows, relevant lone pairs, dipoles and evidence of optical activity to show the mechanism iv 2,4-dinitrophenylhydrazine (2,4-DNPH), as a qualitative test for the presence of a carbonyl group and to identify a carbonyl compound given data of the melting temperatures of derivatives *The equation for this reaction is not required.* v iodine in the presence of alkali (the iodoform test)
	Further suggested practical: Reactions of aldehydes and ketones given in 15.8 i, iv and v

15C: Carboxylic acids

Students will be assessed on their ability to:

15.9	understand the nomenclature of carboxylic acids and be able to draw their structural, displayed and skeletal formulae
15.10	understand that hydrogen bonding affects the physical properties of carboxylic acids, in relation to their boiling temperatures and solubility
15.11	understand that carboxylic acids can be prepared by the oxidation of alcohols or aldehydes and the hydrolysis of nitriles
15.12	understand the reactions of carboxylic acids with: i lithium tetrahydridoaluminate(III) (lithium aluminium hydride) in dry ether (ethoxyethane) ii bases to produce salts iii phosphorus(V) chloride (phosphorus pentachloride) iv alcohols in the presence of an acid catalyst
	Further suggested practicals: i solubility of a range of carboxylic acids, aldehydes and ketones ii preparation of carboxylic acids by the oxidation of alcohols and aldehydes iii reactions of carboxylic acids given in 15.12 ii, iii and iv

15D: Carboxylic acid derivatives

Students will be assessed on their ability to:

15.13	understand the nomenclature of acyl chlorides and esters and be able to draw their structural, displayed and skeletal formulae
15.14	understand the reactions of acyl chlorides with: i water ii alcohols iii concentrated ammonia iv amines
15.15	understand the hydrolysis reactions of esters, in acidic and alkaline solution
15.16	understand how polyesters, such as terylene, are formed by condensation polymerisation reactions.
	Further suggested practicals: i demonstration of the reactions of ethanoyl chloride given in 15.14 i, ii and iii ii the preparation of esters such as ethyl ethanoate as a solvent or a pineapple flavouring iii hydrolysis of an ester

15E: Spectroscopy and chromatography

Knowledge of the concepts introduced in Unit 2, Topic 10D: Mass spectra and IR will be assumed and extended in this topic

Students will be assessed on their ability to:

15.17	be able to use data from mass spectra to: i suggest possible structures of a simple organic compound given accurate relative molecular masses ii calculate the accurate relative molecular mass of a compound, given accurate relative atomic masses to four decimal places
15.18	understand that carbon-13, (^{13}C) NMR spectroscopy provides information about the positions of ^{13}C atoms in a molecule
15.19	be able to use data from ^{13}C NMR spectroscopy to: i predict the different environments for carbon atoms present in a molecule, given values of chemical shift, δ ii justify the number of peaks present in a ^{13}C NMR spectrum in terms of the number of carbon atoms in different environments
15.20	be able to use both low and high resolution proton NMR spectroscopy to: i predict the different types of proton present in a molecule, given values of chemical shift, δ ii relate relative peak areas, or ratio number of protons, to the relative numbers of ^1H atoms in different environments iii deduce the splitting patterns of adjacent, non-equivalent protons using the (n+1) rule and hence suggest the possible structures for a molecule iv predict the chemical shifts and splitting patterns of the ^1H atoms in a given molecule
15.21	know that chromatography separates components of a mixture using a mobile phase and a stationary phase
15.22	be able to calculate R_f values from one-way chromatograms in paper and thin-layer chromatography (TLC) and understand reasons for differences in R_f values
15.23	know that high-performance liquid chromatography, HPLC, and gas chromatography, GC, are types of column chromatography that separate substances because of different retention times in the column and may be used in conjunction with mass spectrometry, in applications such as forensics or drug testing in sport

Unit 5: Transition Metals and Organic Nitrogen Chemistry

IA2 compulsory unit

Externally assessed

Unit description

Introduction

In this unit, the study of electrode potentials builds on the study of redox in Unit 2, including the concept of oxidation number and the use of redox half equations. Students will study further chemistry related to redox, including transition metals.

The organic chemistry section of this unit focuses on arenes and organic nitrogen compounds such as amines, amides, amino acids and proteins. The organic synthesis section requires students to use the knowledge and understanding of organic chemistry that they have gained over the entire specification.

This unit draws on all the other units in the International Advanced Level in Chemistry and students are expected to use their prior knowledge when learning about the areas in this unit. Students will, again encounter ideas of isomerism, bond polarity and bond enthalpy, reagents and reaction conditions, reaction types and mechanisms. Students are also expected to use formulae and balanced equations, and calculate chemical quantities.

Chemistry in action

The study of chemical cells illustrates the impact on scientific thinking when it emerges that ideas developed in different contexts can be shown to be related to a major explanatory principle. In this unit, cell emfs and equilibrium constants are shown to be related to the fundamental criterion for the feasibility of a chemical reaction: the total entropy change.

The explanatory power of the energy-level model for electronic structures is further illustrated by showing how it can help to account for the existence and properties of transition metals. In this context there are opportunities to show the limitations of the models used at this level and to indicate the need for more sophisticated explanations.

Study of the structure of benzene is another example that shows how scientific models develop in response to new evidence. This links to further investigations of the models that chemists use to describe the mechanisms of organic reactions.

The study of catalysts touches on a ‘frontier’ area for current chemical research and development, which is of theoretical and practical importance. This provides an opportunity to show how the scientific community reports and validates new knowledge.

Practical skills	As in previous units, students can begin their practical work in this unit with some simple test-tube reactions, investigating the reactions of transition metal ions in solution. This may lead to an exploration of redox reactions and, therefore, to the core practical on electrochemical cells. Skills in volumetric analysis can be consolidated through titrations for redox systems such as iodine-thiosulfate or manganate(VII) titrations. An opportunity to explore preparative inorganic chemistry is provided in the core practical devoted to making a transition metal complex. In organic chemistry, there are further functional groups to explore and the possibility of preparing an azo dye. The final core practical is an organic synthesis and can be used to showcase a selection of the techniques that students have developed to carry out reactions and purify products efficiently and safely.
Mathematical skills	There are opportunities for the development of mathematical skills in this unit. This includes calculating redox potentials, balancing redox equations from half cells, calculating masses and concentrations from redox titrations, investigating the geometry of transition metal complexes, calculating the resonance stability of benzene from thermodynamic data and calculating percentage yields. (Please see *Appendix 6: Mathematical skills and exemplifications* for more detail.)

Assessment information

- First assessment: June 2020.
- The assessment is 1 hour and 45 minutes.
- The assessment is out of 90 marks.
- Students must answer all questions.
- This paper has three sections:
  - Section A: multiple choice questions
  - Section B: mixture of short-open, open-response, calculations and extended-writing questions
  - Section C: contemporary context question.
- This paper will contain questions that require information from the Data Booklet (see *Appendix 9*).
- This paper will include a minimum of 18 marks that target mathematics at Level 2 or above.
- Students will be expected to apply their knowledge and understanding of experimental methods in familiar and unfamiliar contexts.
- This paper may contain some synoptic questions which require knowledge and understanding from Units 1, 2 and 4.
- Calculators may be used in the examination (see *Appendix 8: Use of calculators*).

Topic 16: Redox Equilibria

Students will be assessed on their ability to:

16.1	understand the terms ‘oxidation’ and ‘reduction’ in terms of electron transfer and changes in oxidation number, applied to *s*-, *p*- and *d*-block elements
16.2	know what is meant by the term ‘standard electrode potential’, $E^\ominus$
16.3	know that the standard electrode potential, $E^\ominus$, is measured in conditions of: i 298 K temperature ii 100 kPa pressure of gases iii 1.00 mol dm^{-3} concentration of ions
16.4	know the features of the standard hydrogen electrode and understand why a reference electrode is necessary
16.5	understand that different methods are used to measure standard electrode potentials of: i metals or non-metals in contact with their ions in aqueous solution ii ions of the same element with different oxidation numbers
16.6	**CORE PRACTICAL 12** **Investigating some electrochemical cells.**
16.7	be able to calculate a standard emf, $E^\ominus_{cell}$, by combining two standard electrode potentials
16.8	be able to write cell diagrams using the conventional representation of half-cells
16.9	understand the importance of the conditions when measuring an electrode potential, *E*
16.10	be able to use standard electrode potentials to predict the thermodynamic feasibility of a reaction
16.11	understand that $E^\ominus_{cell}$ is directly proportional to the total entropy change and to ln*K* for a reaction
16.12	understand the limitations of predictions made using standard electrode potentials, in terms of kinetic stability of systems and departure from standard conditions
16.13	know that standard electrode potentials are sometimes referred to as standard reduction potentials and can be listed as an electrochemical series
16.14	understand how standard electrode potentials can be used to predict the thermodynamic feasibility of disproportionation reactions
16.15	be able to carry out both structured and unstructured titration calculations involving redox reactions, including iron(II) ions and potassium manganate(VII) and sodium thiosulfate and iodine
16.16	be able to discuss the uncertainty of measurements and their implications for the validity of the final results

16.17	**CORE PRACTICALS 13a and 13b** **Carry out redox titrations with both:** **i iron(II) ions and potassium manganate(VII)** **ii sodium thiosulfate and iodine**
16.18	understand that fuel cells use the energy released on the reaction of a fuel with oxygen to generate a voltage *Knowledge that methanol and other hydrogen-rich fuels are used in fuel cells is expected.*
16.19	know the electrode reactions that occur in a hydrogen-oxygen fuel cell *Knowledge of hydrogen-oxygen fuel cells with both acidic and alkaline electrolyte is expected.*
	Further suggested practicals: i investigate the percentage of copper in brass, using iodine-thiosulfate titration ii investigate the percentage of iron in iron tablets, using potassium manganate(VII) titration iii prepare crystals of potassium iodate(VII) and measure their purity

Topic 17: Transition Metals and their Chemistry

Students will be assessed on their ability to:

17.1	know that transition metals are *d*-block elements that form one or more stable ions with incompletely-filled *d*-orbitals
17.2	be able to deduce the electronic configurations of atoms and ions of the *d*-block elements of Period 4 (Sc-Zn) given their atomic number and charge (if any)
17.3	understand why transition metals show variable oxidation number
17.4	know what is meant by the term 'ligand'
17.5	understand that dative (coordinate) covalent bonding is involved in the formation of complex ions
17.6	know that a complex ion is a central metal ion surrounded by ligands
17.7	know that aqueous solutions of transition metal ions are usually coloured
17.8	understand that the colour of aqueous ions, and other complex ions, is a consequence of the splitting of the energy levels of the *d*-orbitals by ligands
17.9	understand why there is a lack of colour in some aqueous ions and other complex ions
17.10	understand the meaning of the term 'coordination number'
17.11	understand that colour changes in transition metal ions may arise as a result of changes in: i oxidation number of the ion ii ligand iii coordination number of the complex
17.12	understand that H_2O, OH^- and NH_3 act as monodentate ligands
17.13	understand why complexes with six-fold coordination have an octahedral shape, such as those formed by metal ions with H_2O, OH^- and NH_3 as ligands
17.14	know that transition metal ions may form tetrahedral complexes with relatively large ions such as Cl^-
17.15	know that square planar complexes are also formed by transition metal ions and that *cis*-platin is an example of such a complex which is used in cancer treatment where it is supplied as a single isomer and not in a mixture with the *trans* form
17.16	understand the terms 'bidentate' and 'hexadentate' in relation to ligands, and be able to identify examples such as $NH_2CH_2CH_2NH_2$ and $EDTA^{4-}$
17.17	know that haemoglobin is an iron(II) complex containing a polydentate ligand and that ligand exchange occurs when an oxygen molecule bound to haemoglobin is replaced by a carbon monoxide molecule *The structure of the haem group will not be assessed.*
17.18	know the colours of the oxidation states of vanadium (+5, +4, +3 and +2) in its compounds
17.19	understand redox reactions for the interconversion of the oxidation states of vanadium (+5, +4, +3 and +2), in terms of the relevant $E^\ominus$ values

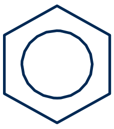
17.20	understand, in terms of the relevant *E* values, that the dichromate(VI) ion, $Cr_2O_7^{2-}$ i can be reduced to Cr^{3+} and Cr^{2+} ions using zinc in acidic conditions ii can be produced by the oxidation of Cr^{3+} ions using hydrogen peroxide in alkaline conditions (followed by acidification)
17.21	know that the dichromate(VI) ion, $Cr_2O_7^{2-}$ can be converted into chromate(VI) ions as a result of the equilibrium $Cr_2O_7^{2-} + H_2O \rightleftharpoons 2CrO_4^{2-} + 2H^+$
17.22	be able to record observations and write suitable equations for the reactions of $Cr^{3+}(aq)$, $Mn^{2+}(aq)$, $Fe^{2+}(aq)$, $Fe^{3+}(aq)$, $Co^{2+}(aq)$, $Ni^{2+}(aq)$, $Cu^{2+}(aq)$ and $Zn^{2+}(aq)$ with aqueous sodium hydroxide and aqueous ammonia, including in excess
17.23	be able to write ionic equations to show the meaning of amphoteric behaviour, deprotonation and ligand exchange in the reactions in 17.22
17.24	understand that ligand exchange, and an accompanying colour change, occurs in the formation of: i $[Cu(NH_3)_4(H_2O)_2]^{2+}$ from $[Cu(H_2O)_6]^{2+}$ via $Cu(OH)_2(H_2O)_4$ ii $[CuCl_4]^{2-}$ from $[Cu(H_2O)_6]^{2+}$ iii $[CoCl_4]^{2-}$ from $[Co(H_2O)_6]^{2+}$
17.25	understand, in terms of the positive increase in ΔS_{system}, that the substitution of a monodentate ligand by a bidentate or hexadentate ligand leads to a more stable complex ion
17.26	know that transition metals and their compounds can act as heterogeneous and homogeneous catalysts
17.27	know that a heterogeneous catalyst is in a different phase from the reactants and that the reaction occurs at the surface of the catalyst
17.28	understand, in terms of oxidation number, how V_2O_5 acts as a catalyst in the contact process
17.29	understand how a catalytic converter decreases carbon monoxide and nitrogen monoxide emissions from internal combustion engines by: i adsorption of CO and NO molecules onto the surface of the catalyst, resulting in the weakening of bonds and chemical reaction ii desorption of CO_2 and N_2 product molecules from the surface of the catalyst
17.30	know that a homogeneous catalyst is in the same phase as the reactants and appreciate that the catalysed reaction will proceed via an intermediate species
17.31	understand the role of Fe^{2+} ions in catalysing the reaction between I^- and $S_2O_8^{2-}$ ions
17.32	know the role of Mn^{2+} ions in autocatalysing the reaction between MnO_4^- and $C_2O_4^{2-}$ ions
17.33	**CORE PRACTICAL 14** **The preparation of a transition metal complex.**

	Further suggested practicals: i prepare the different oxidation states of vanadium (17.18/19) ii investigate the equilibrium reaction in 17.21 iii carry out the reactions of transition metal ions with sodium hydroxide and ammonia solutions (17.22) iv carry out the ligand exchange reactions in 17.24 v investigate the kinetics of the reaction between MnO_4^- and $C_2O_4^{2-}$ in 17.32

Topic 18: Organic Chemistry – Arenes

Knowledge of the common uses of organic compounds mentioned in this topic is expected.

Students will be assessed on their ability to:

18.1	be able to use thermochemical, X-ray diffraction and infrared data as evidence for the structure and stability of the benzene ring *Students may represent the structure of benzene as*  or  *as appropriate in equations and mechanisms.*
18.2	understand that the delocalised model for the structure of benzene involves overlap of *p*-orbitals to form π-bonds
18.3	understand why benzene is resistant to bromination, compared to alkenes, in terms of delocalisation of π-bonds in benzene compared to the localised electron density of the π-bond in alkenes
18.4	know the following reactions of benzene, limited to: i oxygen in air (combustion to form a smoky flame) ii bromine, in the presence of a catalyst iii a mixture of concentrated nitric and sulfuric acids iv fuming sulfuric acid v halogenoalkanes and acyl chlorides with aluminium chloride as catalyst (Friedel-Crafts reaction)
18.5	understand the mechanism of the electrophilic substitution reactions of benzene in halogenation, nitration and Friedel-Crafts reactions, including the generation of the electrophile
18.6	understand the reaction of phenol with bromine water and the reasons for the relative ease of this reaction compared to benzene
	Further suggested practical: Carry out the reactions in 18.4, and 18.6 where appropriate (using methylbenzene or methoxybenzene)

Topic 19: Organic Nitrogen Compounds: Amines, Amides, Amino Acids and Proteins

Students will be assessed on their ability to:

19.1	understand the nomenclature of amides, amines and amino acids and be able to draw their structural, displayed and skeletal formulae
19.2	understand the reactions of primary aliphatic amines (using butylamine as an example) and aromatic amines (using phenylamine as an example) with: i water to form an alkaline solution ii acids to form salts iii halogenoalkanes iv ethanoyl chloride v copper(II) ions to form a complex ion
19.3	understand that amines are miscible with water as a result of hydrogen bonding, and the reasons for the difference in basicity between ammonia, primary aliphatic amines and primary aromatic amines
19.4	understand, in terms of reagents and general reaction conditions, the preparation of primary aliphatic amines: i from halogenoalkanes ii by the reduction of nitriles
19.5	know the preparation of aromatic amines by the reduction of aromatic nitro-compounds using tin and concentrated hydrochloric acid
19.6	be able to describe the reaction of aromatic amines with nitrous acid to form benzenediazonium ions, followed by a coupling reaction with phenol to form a dye
19.7	understand that amides can be prepared from acyl chlorides
19.8	be able to describe: i condensation polymerisation for the formation of polyamides such as nylon and proteins ii addition polymerisation, including poly(propenamide) and poly(ethenol)
19.9	be able to draw the structural formulae of the repeat units of the polymers in 19.8
19.10	be able to comment on the physical properties of polyamides and the solubility in water of the addition polymer poly(ethenol) in terms of hydrogen bonding, including soluble laundry bags or liquid-detergent capsules (liquitabs)
19.11	be able to describe experiments to investigate the characteristic behaviour of amino acids limited to: i acidity and basicity and the formation of zwitterions ii effect of aqueous solutions on plane-polarised monochromatic light iii formation of peptide bonds by condensation polymerisation
19.12	**CORE PRACTICAL 15** **Analysis of some inorganic and organic unknowns.**

	Further suggested practicals: i carry out some of the reactions of amines from 19.2 i, ii and v ii prepare an azo dye from 19.6 iii carry out reactions of amino acids from 19.11 i iv prepare nylon-6.6 or 6.10 from 19.8

Topic 20: Organic Synthesis

Students will be assessed on their ability to:

20.1	be able to deduce the empirical formulae, molecular formulae and structural formulae from data drawn from combustion analysis, element percentage composition, characteristic reactions of functional groups, infrared spectra, mass spectra and NMR spectra (both ^{13}C and proton)
20.2	understand methods of increasing the length of the carbon chain in a molecule by the use of magnesium to form Grignard reagents and the reactions of the latter with carbon dioxide and with carbonyl compounds in dry ether
20.3	be able to use knowledge of organic chemistry contained given in this specification to solve problems such as: i predicting the properties of unfamiliar compounds containing one or more of the functional groups included in the specification and explain these predictions ii planning reaction schemes of up to four steps, recalling familiar reactions and using unfamiliar reactions given sufficient information iii selecting suitable practical procedures for carrying out reactions involving compounds with functional groups included in this specification iv identifying appropriate control measures to reduce risk based on data of hazards
20.4	**CORE PRACTICAL 16** **The preparation of aspirin.**
20.5	understand the following techniques used in the preparation and purification of organic compounds: i refluxing ii purification by washing, including with water and sodium carbonate solution iii solvent extraction iv recrystallisation v drying vi distillation vii steam distillation viii melting temperature determination ix boiling temperature determination
	Further suggested practicals: i carry out the preparation of an organic compound, including cholesteryl benzoate (a liquid crystal) or methyl 3-nitrobenzoate ii preparation of oil of wintergreen

Unit 6: Practical Skills in Chemistry II

IA2 compulsory unit

Externally assessed

Unit description

Introduction

This unit consists of a written practical examination, covering the skills and techniques developed during practical work in Units 4 and 5, as well as the tests for anions and cations, gases and organic functional groups from Units 1 and 2.

Although the unit content contains eight core practical activities, the examination will not be limited to recall of these core practicals, there may be questions where students need to apply their knowledge to new practical situations.

Students should, therefore, develop their practical skills by completing a range of different practicals that require a variety of different techniques.

As students carry out practical activities, they should be encouraged to write laboratory reports using appropriate scientific, technical and mathematical language, conventions and symbols.

Development of practical skills, knowledge and understanding

Students are expected to develop experimental skills and knowledge and understanding of the necessary techniques by carrying out a range of practicals while they study Units 4 and 5.

This unit will assess students’ knowledge and understanding of the practical procedures and techniques that they develop.

To prepare for assessment of this unit, centres should give students opportunities to carry out practical activities, to collect and analyse data, and to draw conclusions. Students should – at the least – carry out the eight core practicals in class. By completing these practicals, students will be able to:

- follow and interpret experimental instructions, covering the full range of laboratory exercises set throughout the course, with minimal help from the teacher
- always work with interest and enthusiasm in the laboratory, completing most laboratory exercises in the time allocated
- manipulate apparatus, use chemicals, carry out all common laboratory procedures and use data logging (where appropriate) with the highest level of skill that may be reasonably expected at this level
- work sensibly and safely in the laboratory, paying due regard to health and safety requirements without the need for reminders from the teacher
- gain accurate and consistent results in quantitative exercises, make the most of the expected observations in qualitative exercises and obtain products in preparations of high yield and purity.

Assessment information

- First assessment: June 2020.
- The assessment is 1 hour and 20 minutes.
- The assessment is out of 50 marks.
- Students must answer all questions.
- This paper may include short-open, open-response and calculation questions.
- This paper will include a minimum of 6 marks that target mathematics at Level 2 or above.
- Students will be expected to apply their knowledge and understanding of practical skills to familiar and unfamiliar situations.
- Calculators may be used in the examination (see *Appendix 8: Use of calculators*).

The question paper will assess the following abilities.

Independent thinking in a practical context	• Solve problems set in a practical context. • Apply scientific knowledge to practical contexts.
Use and application of scientific methods and practices	• Identify and state how to control variables to improve experimental validity. • Present data in appropriate ways. • Evaluate results and draw conclusions. • Appreciate measurement uncertainties and errors. • Comment on the method for an experiment.
Numeracy and the application of mathematical concepts in a practical context	• Plot and interpret graphs. • Process and analyse data using appropriate mathematical skills. • Use appropriate numbers of significant figures based on the experimental data. • Consider the accuracy and precision of data.
Use of apparatus and equipment	• Recognise a range of laboratory apparatus and select appropriate apparatus for a particular scenario. • Understand how to use a range of apparatus and techniques appropriate to the knowledge and understanding included in this specification. • Consider the range and resolution of apparatus. • Identify health and safety issues and discuss how these may be dealt with.

Although Unit 6 will predominantly assess knowledge and understanding related to Units 4 and 5, questions may also require students to draw on knowledge and understanding from Units 1 and 2.

Questions may require students to:

- recall and/or interpret observations relating to tests for ions and gases across the whole specification
- recall and/or interpret observations relating to tests for organic functional groups across the whole specification
- manipulate data and comment on experimental methods and techniques for a range of experiments involving measurements across the whole specification, including titrations, thermochemical investigations, equilibrium systems and kinetics experiments
- comment on experimental methods and techniques in the preparation of inorganic or organic compounds across the whole specification.

Assessment information

Assessment requirements

The Pearson Edexcel International Advanced Subsidiary in Chemistry consists of three externally-examined units.

The Pearson Edexcel International Advanced Level in Chemistry consists of six externally-examined units.

Students must complete all assessments.

Please see the *Assessment availability and first award* section for information on when the assessment for each unit will be available from.

Unit	IAS or IA2	Assessment information	Number of raw marks allocated in the unit
Unit 1: Structure, Bonding and Introduction to Organic Chemistry	IAS	Externally assessed Written examination: 1 hour and 30 minutes Availability: January, June and October First assessment: January 2019	80 marks
Unit 2: Energetics, Group Chemistry, Halogenoalkanes and Alcohols	IAS	Externally assessed Written examination: 1 hour and 30 minutes Availability: January, June and October First assessment: June 2019	80 marks
Unit 3: Practical Skills in Chemistry I	IAS	Externally assessed Written examination: 1 hour and 20 minutes Availability: January, June and October First assessment: June 2019	50 marks

Unit	IAS or IA2	Assessment information	Number of raw marks allocated in the unit
Unit 4: Rates, Equilibria and Further Organic Chemistry	IA2	Externally assessed Written examination: 1 hour and 45 minutes Availability: January, June and October First assessment: January 2020	90 marks
Unit 5: Transition Metals and Organic Nitrogen Chemistry	IA2	Externally assessed Written examination: 1 hour and 45 minutes Availability: January, June and October First assessment: June 2020	90 marks
Unit 6: Practical Skills in Chemistry II	IA2	Externally assessed Written examination: 1 hour and 20 minutes Availability: January, June and October First assessment: June 2020	50 marks

Sample assessment materials

Sample papers and mark schemes can be found in the *Pearson Edexcel International Advanced Subsidiary/Advanced Level in Chemistry Sample Assessment Materials (SAMs)* document.

A full list of command words that will be used in the assessment across the IAS/IAL Science qualifications can be found in *Appendix 7: Taxonomy*.

Assessment objectives and weightings

		% in IAS	% in IA2	% in IAL
AO1	Demonstrate knowledge and understanding of science.	34–36	29–31	32–34
AO2	(a) Application of knowledge and understanding of science in familiar and unfamiliar contexts.	34–36	33–36	33–36
	(b) Analysis and evaluation of scientific information to make judgements and reach conclusions.	9–11	14–16	11–14
AO3	Experimental skills in science, including analysis and evaluation of data and methods.	20	20	20

Relationship of assessment objectives to units for the International Advanced Subsidiary qualification

Unit number	**Assessment objective (%)**			
	AO1	**AO2(a)**	**AO2(b)**	**AO3**
Unit 1	17–18	17–18	4.5–5.5	0.0
Unit 2	17–18	17–18	4.5–5.5	0.0
Unit 3	0.0	0.0	0.0	20
Total for International Advanced Subsidiary	34–36	34–36	9–11	20

Relationship of assessment objectives to units for the International Advanced Level qualification

Unit number	**Assessment objective (%)**			
	AO1	**AO2(a)**	**AO2(b)**	**AO3**
Unit 1	8.5–9.0	8.5–9.0	2.2–2.8	0
Unit 2	8.5–9.0	8.5–9.0	2.2–2.8	0
Unit 3	0	0	0	10
Unit 4	7.3–7.8	8.4–8.9	3.6–4.0	0
Unit 5	7.3–7.8	8.4–8.9	3.6–4.0	0
Unit 6	0	0	0	10
Total for International Advanced Level	32–34	33–36	11–14	20

NB Totals have been rounded either up or down.

Assessment availability and first award

Unit	**January 2019**	**June 2019**	**October 2019**	**January 2020**	**June 2020**
1	✓	✓	✓	✓	✓
2	✗	✓	✓	✓	✓
3	✗	✓	✓	✓	✓
4	✗	✗	✗	✓	✓
5	✗	✗	✗	✗	✓
6	✗	✗	✗	✗	✓
IAS award	✗	✓	✓	✓	✓
IAL award	✗	✗	✗	✗	✓

From June 2020, **all six units will be assessed** in January, June and October for the lifetime of the qualification.

From June 2020, **IAL and IAS will both be awarded** in January, June and October for the lifetime of the qualification.

Administration and general information

Entries and resitting of units

Entries

Details of how to enter students for the examinations for these qualifications can be found in our *International Information Manual*. A copy is made available to all examinations officers and is available on our website, qualifications.pearson.com.

Resitting of units

Students can resit any unit irrespective of whether the qualification is to be cashed in. If a student 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. Please refer to the *Entry, Aggregation and Certification* document on our website: qualifications.pearson.com/IAL-entry-certification-procedures.

Access arrangements, reasonable adjustments, special consideration and malpractice

Equality and fairness are central to our work. Our equality policy requires all students to have equal opportunity to access our qualifications and assessments, and our qualifications to be awarded in a way that is fair to every student.

We are committed to making sure that:

- students with a protected characteristic (as defined by the UK Equality Act 2010) are not, when they are undertaking one of our qualifications, disadvantaged in comparison to students who do not share that characteristic
- all students achieve the recognition they deserve for undertaking a qualification and that this achievement can be compared fairly to the achievement of their peers.

Language of assessment

Assessment of these qualifications will be available in English only. All student work must be in English.

We recommend that students are able to read and write in English at Level B2 of the Common European Framework of Reference for Languages.

Access arrangements

Access arrangements are agreed before an assessment. They allow students with special educational needs, disabilities or temporary injuries to:

- access the assessment
- show what they know and can do without changing the demands of the assessment.

The intention behind an access arrangement is to meet the particular needs of an individual student with a disability without affecting the integrity of the assessment. Access arrangements are the principal way in which awarding bodies comply with the duty under the Equality Act 2010 to make ‘reasonable adjustments’.

Access arrangements should always be processed at the start of the course. Students will then know what is available and have the access arrangement(s) in place for assessment.

Reasonable adjustments

The Equality Act 2010 requires an awarding organisation to make reasonable adjustments where a student with a disability would be at a substantial disadvantage in undertaking an assessment. The awarding organisation is required to take reasonable steps to overcome that disadvantage.

A reasonable adjustment for a particular student may be unique to that individual and therefore might not be in the list of available access arrangements.

Whether an adjustment will be considered reasonable will depend on a number of factors, including:

- the needs of the student with the disability
- the effectiveness of the adjustment
- the cost of the adjustment; and
- the likely impact of the adjustment on the student with the disability and other students.

An adjustment will not be approved if it involves unreasonable costs to the awarding organisation, timeframes or affects the security or integrity of the assessment. This is because the adjustment is not ‘reasonable’.

Special consideration

Special consideration is a post-examination adjustment to a student's mark or grade to reflect temporary injury, illness or other indisposition at the time of the examination/ assessment, which has had, or is reasonably likely to have had, a material effect on a candidate’s ability to take an assessment or demonstrate their level of attainment in an assessment.

Further information

Please see our website for further information about how to apply for access arrangements and special consideration.

For further information about access arrangements, reasonable adjustments and special consideration please refer to the JCQ website: www.jcq.org.uk.

Candidate malpractice

Candidate malpractice refers to any act by a candidate that compromises or seeks to compromise the process of assessment or which undermines the integrity of the qualifications or the validity of results/certificates.

Candidate malpractice in examinations **must** be reported to Pearson using a *JCQ Form M1* (available at www.jcq.org.uk/exams-office/malpractice). The form can be emailed to pqsmalpractice@pearson.com or posted to: Investigations Team, Pearson, 190 High Holborn, London, WC1V 7BH. Please provide as much information and supporting documentation as possible. Note that the final decision regarding appropriate sanctions lies with Pearson.

Failure to report malpractice constitutes staff or centre malpractice.

Staff/centre malpractice

Staff and centre malpractice includes both deliberate malpractice and maladministration of our qualifications. As with candidate malpractice, staff and centre malpractice is any act that compromises or seeks to compromise the process of assessment or which undermines the integrity of the qualifications or the validity of results/certificates.

All cases of suspected staff malpractice and maladministration **must** be reported immediately, before any investigation is undertaken by the centre, to Pearson on a *JCQ Form M2(a)* (available at www.jcq.org.uk/exams-office/malpractice).

The form, supporting documentation and as much information as possible can be emailed to pqsmalpractice@pearson.com or posted to: Investigations Team, Pearson, 190 High Holborn, London, WC1V 7BH. Note that the final decision regarding appropriate sanctions lies with Pearson.

Failure to report malpractice itself constitutes malpractice.

More-detailed guidance on malpractice can be found in the latest version of the document *JCQ General and vocational qualifications Suspected Malpractice in Examinations and Assessments,* available at www.jcq.org.uk/exams-office/malpractice.

Awarding and reporting

The Pearson Edexcel International Advanced Subsidiary in Chemistry will be graded on a five-grade scale from A to E. The Pearson Edexcel International Advanced Level in Chemistry will be graded on a six-point scale from A* to E. Individual unit results will be reported. Only Units 1, 2 and 3 will contribute to the International Advanced Subsidiary grade. All six units will contribute to the International Advanced Level grade.

The first certification opportunity for the Pearson Edexcel International Advanced Subsidiary in Chemistry will be in August 2019. The first certification opportunity for the Pearson Edexcel International Advanced Level in Chemistry will be in August 2020.

A pass in an International Advanced Subsidiary subject is indicated by one of the five grades A, B, C, D, E, of which grade A is the highest and grade E the lowest.

A pass in an International Advanced Level subject is indicated by one of the six grades A*, A, B, C, D, E, of which grade A* is the highest and grade E the lowest.

Students whose level of achievement is below the minimum judged by Pearson to be of sufficient standard to be recorded on a certificate will receive an unclassified U result.

Unit results

Students will receive a uniform mark between 0 and the maximum uniform mark for each unit.

The uniform marks at each grade threshold for each unit are:

Units 1, 2, 4 and 5

Unit grade	**Maximum uniform mark**	**A**	**B**	**C**	**D**	**E**
	120	**96**	**84**	**72**	**60**	**48**

Units 3 and 6

Unit grade	**Maximum uniform mark**	**A**	**B**	**C**	**D**	**E**
	60	**48**	**42**	**36**	**30**	**24**

Qualification results

The minimum uniform marks required for each grade:

International Advanced Subsidiary (cash-in code: XCH11)

Qualification grade	**Maximum uniform mark**	**A**	**B**	**C**	**D**	**E**
	300	**240**	**210**	**180**	**150**	**120**

Students with a uniform mark in the range 0–119 will be Unclassified (U).

International Advanced Level (cash-in code: YCH11)

Qualification grade	**Maximum uniform mark**	**A**	**B**	**C**	**D**	**E**
	600	**480**	**420**	**360**	**300**	**240**

Students with a uniform mark in the range 0–239 will be Unclassified (U).

To be awarded an A*, students will need to achieve an A for the International Advanced Level qualification (at least 480 uniform marks) and at least 90% of the total uniform marks available across the IA2 units combined (at least 270 uniform marks).

Student recruitment and progression

Pearson follows the Joint Council for Qualifications (JCQ) policy concerning recruitment to our qualifications in that:

- they must be available to anyone who is capable of reaching the required standard
- they must be free from barriers that restrict access and progression
- equal opportunities exist for all students.

Prior learning and other requirements

Students who would benefit most from studying these qualifications are likely to have a Level 2 qualification in this subject such as a GCSE or International GCSE in Chemistry.

Progression

Students can progress from these qualifications to:

- a range of different, relevant academic or vocational higher education qualifications, for example a degree in chemistry or in a related subject, including chemical engineering and forensic science, or equivalent qualifications such as BTEC Higher Nationals
- employment
- further training.

Appendices

Appendix 1: Codes

Type of code	Use of code	Code
Unit codes	Each unit is assigned a unit code. This unit code is used as an entry code to indicate that a student wishes to take the assessment for that unit. Centres will need to use the entry codes only when entering students for their examination.	Unit 1: WCH11/01 Unit 2: WCH12/01 Unit 3: WCH13/01 Unit 4: WCH14/01 Unit 5: WCH15/01 Unit 6: WCH16/01
Cash-in codes	The cash-in code is used as an entry code to aggregate the student's unit scores to obtain the overall grade for the qualification. Centres will need to use the entry codes only when entering students for their qualification.	International Advanced Subsidiary – XCH11 International Advanced Level – YCH11
Entry codes	The entry codes are used to: • enter a student for the assessment of a unit • aggregate the student's unit scores to obtain the overall grade for the qualification.	Please refer to the *Pearson Information Manual*, available on our website.

Appendix 2: Pearson World Class Qualification design principles

Pearson's World Class Qualification design principles mean that all Edexcel qualifications are developed to be **rigorous, demanding, inclusive and empowering**.

Demanding - The content and assessment are demanding, meaningful and meet the needs of end-users

Rigorous - The design of assessments ensures confidence in the grades awarded

Inclusive - The qualification is accessible to all its target group of students

Empowering – The qualification provides students with the knowledge and skills to progress successfully

We work collaboratively to gain approval from an external panel of educational thought-leaders and assessment experts from across the globe. This is to ensure that Edexcel qualifications are globally relevant, represent world-class best practice in qualification and assessment design, maintain a consistent standard and support learner progression in today's fast-changing world.

Pearson's Expert Panel for World-Class Qualifications is chaired by Sir Michael Barber, a leading authority on education systems and reform. He is joined by a wide range of key influencers with expertise in education and employability.

"I'm excited to be in a position to work with the global leaders in curriculum and assessment to take a fresh look at what young people need to know and be able to do in the 21st century, and to consider how we can give them the opportunity to access that sort of education." Sir Michael Barber.

Endorsement from Pearson's Expert Panel for World Class Qualifications for the International Advanced Subsidiary (IAS) / International Advanced Level (IAL) development process

December 2015

"We were chosen, either because of our expertise in the UK education system, or because of our experience in reforming qualifications in other systems around the world as diverse as Singapore, Hong Kong, Australia and a number of countries across Europe.

We have guided Pearson through what we judge to be a rigorous world class qualification development process that has included, where appropriate:

- extensive international comparability of subject content against the highest-performing jurisdictions in the world
- benchmarking assessments against UK and overseas providers to ensure that they are at the right level of demand
- establishing External Subject Advisory Groups, drawing on independent subject-specific expertise to challenge and validate our qualifications.

Importantly, we have worked to ensure that the content and learning is future oriented, and that the design has been guided by Pearson's Efficacy Framework. This is a structured, evidenced process which means that learner outcomes have been at the heart of this development throughout.

We understand that ultimately it is excellent teaching that is the key factor to a learner's success in education but as a result of our work as a panel we are confident that we have supported the development of Edexcel IAS and IAL qualifications that are outstanding for their coherence, thoroughness and attention to detail and can be regarded as representing world-class best practice."

Sir Michael Barber (Chair)
Chief Education Advisor, Pearson plc

Professor Lee Sing Kong
Dean and Managing Director, National Institute of Education International, Singapore

Dr Peter Hill
Former Chief Executive ACARA

Bahram Bekhradnia
President, Higher Education Policy Institute

Professor Jonathan Osborne
Stanford University

Dame Sally Coates
Director of Academies (South), United Learning Trust

Professor Dr Ursula Renold
Federal Institute of Technology, Switzerland

Professor Bob Schwartz
Harvard Graduate School of Education

Professor Janice Kay
Provost, University of Exeter

Jane Beine
Head of Partner Development, John Lewis Partnership

Jason Holt
CEO, Holts Group

All titles correct as at December 2015.

Appendix 3: Transferable skills

The need for transferable skills

In recent years, higher-education institutions and employers have consistently flagged the need for students to develop a range of transferable skills to enable them to respond with confidence to the demands of undergraduate study and the world of work.

The Organisation for Economic Co-operation and Development (OECD) defines skills, or competencies, as 'the bundle of knowledge, attributes and capacities that can be learned and that enable individuals to successfully and consistently perform an activity or task and can be built upon and extended through learning.'[1]

To support the design of our qualifications, the Pearson Research Team selected and evaluated seven global 21st-century skills frameworks. Following on from this process, we identified the National Research Council's (NRC) framework [2] as the most evidence-based and robust skills framework, and have used this as a basis for our adapted skills framework.

The framework includes cognitive, intrapersonal skills and interpersonal skills.

The skills have been interpreted for this specification to ensure they are appropriate for the subject. All of the skills listed are evident or accessible in the teaching, learning and/or assessment of the qualifications. Some skills are directly assessed. Pearson materials will support you in identifying these skills and developing these skills in students.

The table overleaf sets out the framework and gives an indication of the skills that can be found in chemistry and indicates the interpretation of the skill in this area. A full subject interpretation of each skill, with mapping to show opportunities for student development is given on the subject pages of our website: qualifications.pearson.com

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[1] OECD – *Better Skills, Better Jobs, Better Lives* (OECD Publishing, 2012)

[2] Koenig, J. A. (2011) *Assessing 21st Century Skills: Summary of a Workshop*, (National Academies Press, 2011)

Cognitive skills	Cognitive processes and strategies	• Critical thinking • Problem solving • Analysis • Reasoning/argumentation • Interpretation • Decision making • Adaptive learning • Executive function
	Creativity	• Creativity • Innovation
Intrapersonal skills	Intellectual openness	• Adaptability • Personal and social responsibility • Continuous learning • Intellectual interest and curiosity
	Work ethic/ conscientiousness	• Initiative • Self-direction • Responsibility • Perseverance • Productivity • Self-regulation (metacognition, forethought, reflection) • Ethics • Integrity
	Positive core self-evaluation	• Self-monitoring/self-evaluation/self-reinforcement
Interpersonal skills	Teamwork and collaboration	• Communication • Collaboration • Teamwork • Cooperation • Empathy/perspective taking • Negotiation
	Leadership	• Responsibility • Assertive communication • Self-presentation

Developing the ability to interpret graphs.

Taking responsibility for carrying out practical work in a safe manner, following all safety requirements.

Working with others when carrying out practical experiments.

Appendix 4: Level 3 Extended Project qualification

What is the Extended Project?

The Extended Project is a stand-alone qualification that can be taken alongside International Advanced Level (IAL) qualifications. It supports the development of independent learning skills and helps to prepare students for their next step – whether that be higher education or employment. The qualification:

- is recognised by higher education for the skills it develops
- is worth half of an International Advanced Level (IAL) qualification at grades A*–E
- carries UCAS points for university entry.

The Extended Project encourages students to develop skills in the following areas: research, critical thinking, extended writing and project management. Students identify and agree a topic area of their choice for in-depth study (which may or may not be related to an IAL subject they are already studying), guided by their teacher.

Students can choose from one of four approaches to produce:

- a dissertation (for example an investigation based on predominately secondary research)
- an investigation/field study (for example a practical experiment)
- a performance (for example in music, drama or sport)
- an artefact (for example creating a sculpture in response to a client brief or solving an engineering problem).

The qualification is non-examination assessment based and students are assessed on the skills of managing, planning and evaluating their project. Students will research their topic, develop skills to review and evaluate the information, and then present the final outcome of their project.

The Extended Project has 120 guided learning hours (GLH) consisting of a 40-GLH taught element that includes teaching the technical skills (for example research skills) and an 80-GLH guided element that includes mentoring students through the project work. The qualification is 100% internally assessed and externally moderated.

How to link the Extended Project with chemistry

The Extended Project creates the opportunity to develop transferable skills for progression to higher education and to the workplace through the exploration of either an area of personal interest or a topic of interest from the chemistry qualification content.

Through the Extended Project, students will develop skills that support their study of chemistry, including:

- conducting, organising and using research
- independent reading in the subject area
- planning, project management and time management
- stating a proposal to be tested in investigations
- collecting, handling and interpreting data and evidence
- evaluating arguments and processes, including arguments in favour of alternative interpretations of data and evaluation of experimental methodology
- critical thinking.

In the context of the Extended Project, critical thinking refers to the ability to identify and develop arguments for a point of view or hypothesis and to consider and respond to alternative arguments.

Types of Extended Project related to chemistry

Students may produce a dissertation on any topic that can be researched and argued. A dissertation might involve an investigation such as:

- Should legislation be used to enforce the principles of green chemistry?
- Could nanochemistry revolutionise medicine?
- Is the use of oil-dispersants an effective way of tackling oil spills?

The dissertation uses secondary research sources to provide a reasoned defence or a point of view, with consideration of counter-arguments.

An alternative might be an investigative project or field study involving the collection of data from primary research, for example:

- Are calorific values in diet foods accurate?
- Can changing the method of synthesis significantly alter the material properties of a polymer?

There is also scope for chemistry-based artefact Extended Projects. For example, a student might set out to design, make and test an item of apparatus such as a spectrometer. Extended Projects involving a performance can also be chemistry based. For example, a social issue relating to chemistry could be explored through drama.

Using the Extended Project to support breadth and depth

In the Extended Project, students are assessed on the quality of the work they produce and the skills they develop and demonstrate through completing this work. Students should demonstrate that they have extended themselves in some significant way beyond what they have been studying in chemistry. Students can demonstrate extension in one or more dimensions:

- ***deepening understanding*** – where a student explores a topic in greater depth than in the specification content
- ***broadening skills*** – where a student learns a new skill. In a chemistry-based project, this might involve learning to assemble and manipulate an unfamiliar piece of apparatus or learning advanced data-handling techniques
- ***widening perspectives*** – where the student's project spans different subjects. This might involve discussing historical, philosophical or ethical aspects of a chemistry-based topic or making links with other subject areas such as biology or economics.

A wide range of information to support the delivery and assessment of the Extended Project, including the specification, teacher guidance for all aspects, an editable scheme of work and exemplars for all four approaches, can be found on our website.

Appendix 5: Glossary

Term	Definition
Assessment objectives	The requirements that students need to meet to succeed in the qualification. Each assessment objective has a unique focus, which is then targeted in examinations or coursework. Assessment objectives may be assessed individually or in combination.
External assessment	An examination that is held at the same time and place in a global region.
International Advanced Subsidiary	Abbreviated to IAS.
International Advanced Level	Abbreviated to IAL.
International A2 (IA2)	The additional content required for an IAL.
Modular	Modular qualifications contain units of assessment. These units can be taken during the course of study. The final qualification grade is worked out from the combined unit results.
Raw marks	Raw marks are the actual marks that students achieve when taking an assessment. When calculating an overall grade, raw marks often need to be converted so that it is possible to see the proportionate achievement of a student across all units of study.
Uniform Mark Scale (UMS)	Student actual marks (or raw marks) will be converted into a UMS mark so that it is possible to see the proportionate result of a student. Two units may each be worth 25% of a total qualification. The raw marks for each unit may differ, but the uniform mark will be the same.
Unit	A modular qualification will be divided into a number of units. Each unit will have its own assessment.

Appendix 6: Mathematical skills and exemplifications

In order to be able to develop their skills, knowledge and understanding in chemistry, students need to have been taught, and to have acquired competence in, the appropriate areas of mathematics relevant to the subject as indicated in the table on the following pages[1].

The assessment of quantitative skills will include at least 20% Level 2 or above mathematical skills. These skills will be applied in the context of chemistry.

All mathematical content will be assessed within the lifetime of the qualifications.

The following tables illustrate where these mathematical skills may be developed and could be assessed. Those shown in bold type would only be tested in the full International Advanced Level course.

This list of examples is not exhaustive. These skills could be developed in other areas of specification content.

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[1] The information in this appendix has been taken directly from the document *GCE AS and A level regulatory requirements for biology, chemistry, physics and psychology* published by the Department for Education (April 2014).

	Mathematical skills	**Exemplification of mathematical skill in the context of A Level Chemistry (assessment is not limited to the examples given below)**
(i) B.0 – arithmetic and numerical computation		
B.0.0	Recognise and make use of appropriate units in calculation	Candidates may be tested on their ability to: • convert between units, e.g. cm^3 to dm^3 as part of volumetric calculations • **give units for an equilibrium constant or a rate constant** • understand that different units are used in similar topic areas, so that conversions may be necessary, e.g. entropy in J mol^{-1} K^{-1} and enthalpy changes in kJ mol^{-1}
B.0.1	Recognise and use expressions in decimal and ordinary form	Candidates may be tested on their ability to: • use an appropriate number of decimal places in calculations, e.g. for pH • carry out calculations using numbers in standard and ordinary form, e.g. use of Avogadro constant • understand standard form when applied to areas such as (but not limited to) K_w • convert between numbers in standard and ordinary form • understand that significant figures need retaining when making conversions between standard and ordinary form, e.g. 0.0050 mol dm^{-3} is equivalent to 5.0 x 10^{-3} mol dm^{-3}
B.0.2	Use ratios, fractions and percentages	Candidates may be tested on their ability to: • calculate percentage yields • calculate the atom economy of a reaction • construct and/or balance equations using ratios
B.0.3	Make estimates of the results of calculations (without using a calculator).	Candidates may be tested on their ability to: • **evaluate the effect of changing experimental parameters on measurable values, e.g. how the value of K_c would change with temperature given different specified conditions**
B.0.4	Use calculators to find and use power, **exponential and logarithmic functions**	Candidates may be tested on their ability to: • carry out calculations using the Avogadro constant • **carry out pH and pK_a calculations** • **make appropriate mathematical approximations in buffer calculations**

	Mathematical skills	**Exemplification of mathematical skill in the context of A Level Chemistry (assessment is not limited to the examples given below)**
(ii)	**B.1 – handling data**	
B.1.1	Use an appropriate number of significant figures	Candidates may be tested on their ability to: • report calculations to an appropriate number of significant figures given raw data quoted to varying numbers of significant figures • understand that calculated results can only be reported to the limits of the least accurate measurement
B.1.2	Find arithmetic means	Candidates may be tested on their ability to: • calculate weighted means, e.g. calculation of an atomic mass based on supplied isotopic abundances • select appropriate titration data (i.e. identification of outliers) in order to calculate mean titres
B.1.3	Identify uncertainties in measurements and use simple techniques to determine uncertainty when data are combined	Candidates may be tested on their ability to: • determine uncertainty when two burette readings are used to calculate a titre value
(iii)	**B.2 – algebra**	
B.2.1	Understand and use the symbols: =, <, <<, >>, >, ∝, ~, equilibrium sign	No exemplification required.
B.2.2	Change the subject of an equation	Candidates may be tested on their ability to: • carry out structured and unstructured mole calculations, **e.g. calculate a rate constant *k* from a rate equation**
B.2.3	Substitute numerical values into algebraic equations using appropriate units for physical quantities	Candidates may be tested on their ability to: • carry out structured and unstructured mole calculations • **carry out rate calculations** • **calculate the value of an equilibrium constant K_c**
B.2.4	Solve algebraic equations	Candidates may be tested on their ability to: • carry out Hess's law calculations • **calculate a rate constant *k* from a rate equation**
B.2.5	**Use logarithms in relation to quantities that range over several orders of magnitude**	**Candidates may be tested on their ability to:** • **carry out pH and pK_a calculations**

	Mathematical skills	**Exemplification of mathematical skill in the context of A Level Chemistry (assessment is not limited to the examples given below)**
(iv)	**B.3 – graphs**	
B.3.1	Translate information between graphical, numerical and algebraic forms	Candidates may be tested on their ability to: • interpret and analyse spectra • **determine the order of a reaction from a graph** • **derive rate expression from a graph**
B.3.2	Plot two variables from experimental or other data	Candidates may be tested on their ability to: • plot concentration–time graphs from collected or supplied data and draw an appropriate best-fit curve
B.3.3	**Determine the slope and intercept of a linear graph**	Candidates may be tested on their ability to: • **calculate the rate constant of a zero-order reaction by determination of the gradient of a concentration–time graph**
B.3.4	**Calculate rate of change from a graph showing a linear relationship**	Candidates may be tested on their ability to: • **calculate the rate constant of a zero-order reaction by determination of the gradient of a concentration–time graph**
B.3.5	**Draw and use the slope of a tangent to a curve as a measure of rate of change**	Candidates may be tested on their ability to: • **determine the order of a reaction using the initial rates method**
(v)	**B.4 – geometry and trigonometry**	
B.4.1	Appreciate angles and shapes in regular 2D and 3D structures.	Candidates may be tested on their ability to: • predict/identify shapes of and bond angles in molecules with and without a lone pair(s), for example NH_3, CH_4, H_2O etc
B.4.2	Visualise and represent 2D and 3D forms including two-dimensional representations of 3D objects	Candidates may be tested on their ability to: • draw different forms of isomers • **identify chiral centres from a 2D or 3D representation**
B.4.3	Understand the symmetry of 2D and 3D shapes	Candidates may be tested on their ability to: • describe the types of stereoisomerism shown by molecules/complexes • **identify chiral centres from a 2D or 3D representation**

Appendix 7: Taxonomy

The following table lists the command words used across the IAS/IAL Science qualifications in the external assessments.

Command word	Definition
Add/Label	Requires the addition or labelling to stimulus material given in the question, for example labelling a diagram or adding units to a table.
Assess	Give careful consideration to all the factors or events that apply and identify which are the most important or relevant. Make a judgement on the importance of something, and come to a conclusion where needed.
Calculate	Obtain a numerical answer, showing relevant working. If the answer has a unit, this must be included.
Comment on	Requires the synthesis of a number of factors from data/information to form a judgement. More than two factors need to be synthesised.
Compare and contrast	Looking for the similarities **and** differences of two (or more) things. Should not require the drawing of a conclusion. Answer must relate to both (or all) things mentioned in the question. The answer must include at least one similarity and one difference.
Complete/Record	Requires the completion of a table/diagram/equation.
Criticise	Inspect a set of data, an experimental plan or a scientific statement and consider the elements. Look at the merits and/or faults of the information presented and back judgements made.
Deduce	Draw/reach conclusion(s) from the information provided.
Derive	Combine two or more equations or principles to develop a new equation.
Describe	To 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.
Determine	The answer must have an element which is quantitative from the stimulus provided, or must show how the answer can be reached quantitatively.
Devise	Plan or invent a procedure from existing principles/ideas.
Discuss	Identify the issue/situation/problem/argument that is being assessed within the question. Explore all aspects of an issue/situation/problem. Investigate the issue/situation/problem etc. by reasoning or argument.
Draw	Produce a diagram either using a ruler or using freehand.
Estimate	Give an approximate value for a physical quantity or measurement or uncertainty.

Command word	Definition
Evaluate	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 its context.
Explain	An explanation requires a justification/exemplification of a point. The answer must contain some element of reasoning/justification, this can include mathematical explanations.
Give/State/Name	All of these command words are really synonyms. They generally all require recall of one or more pieces of information.
Give a reason/reasons	When a statement has been made and the requirement is only to give the reasons why.
Identify	Usually requires some key information to be selected from a given stimulus/resource.
Justify	Give evidence to support (either the statement given in the question or an earlier answer).
Plot	Produce a graph by marking points accurately on a grid from data that is provided and then drawing a line of best fit through these points. A suitable scale and appropriately labelled axes must be included if these are not provided in the question.
Predict	Give an expected result or outcome.
Show that	Prove that a numerical figure is as stated in the question. The answer must be to at least 1 more significant figure than the numerical figure in the question.
Sketch	Produce a freehand drawing. For a graph this would need a line and labelled axes with important features indicated, the axes are not scaled.
State what is meant by	When the meaning of a term is expected but there are different ways of how these can be described.
Suggest	Use your knowledge and understanding in an unfamiliar context. May include material or ideas that have not been learnt directly from the specification.
Write	When the questions ask for an equation.

Appendix 8: Use of calculators

Students may use a calculator in assessments for these qualifications. Centres are responsible for making sure that calculators used by their students meet the requirements given in the table below.

Students must be familiar with the requirements before their assessments for these qualifications.

Calculators must be:	**Calculators must not:**
• of a size suitable for use on a desk • either battery or solar powered • free of lids, cases and covers that contain printed instructions or formulae.	• be designed or adapted to offer any of these facilities: o language translators o symbolic algebraic manipulation o symbolic differentiation or integration o communication with other machines or the internet • be borrowed from another candidate during an examination for any reason* • have retrievable information stored in them. This includes: o databanks o dictionaries o mathematical formulae o text.
The candidate is responsible for the following: • the calculator's power supply • the calculator's working condition • clearing anything stored in the calculator.	

*An invigilator may give a student a calculator.

Further information can be found in the JCQ documents *Instructions for conducting examinations* and *Information for candidates for written examinations*, available at www.jcq.org.uk/exams-office.

Appendix 9: Data booklet

This appendix shows the data included in a Data Booklet that will be available on our website. Centres will be sent copies of the Data Booklet for the first examination series. Centres can make additional fresh copies by printing the Data Booklet from our website. Candidates must use an unmarked copy of the Data Booklet in examinations.

Acknowledgement of source

The data used in the Data Booklet is derived from the *Nuffield Advanced Science, Revised Book of Data* (ISBN 058235448X), Nuffield Foundation.

Physical constants

Avogadro constant (L)	6.02×10^{23} mol^{-1}
Elementary charge (e)	1.60×10^{-19} C
Gas constant (R)	8.31 J mol^{-1} K^{-1}
Molar volume of a gas at room temperature and pressure (r.t.p.):	24 dm^3 mol^{-1}
Ionic product of water (K_w)	1.00×10^{-14} mol^2 dm^{-6}

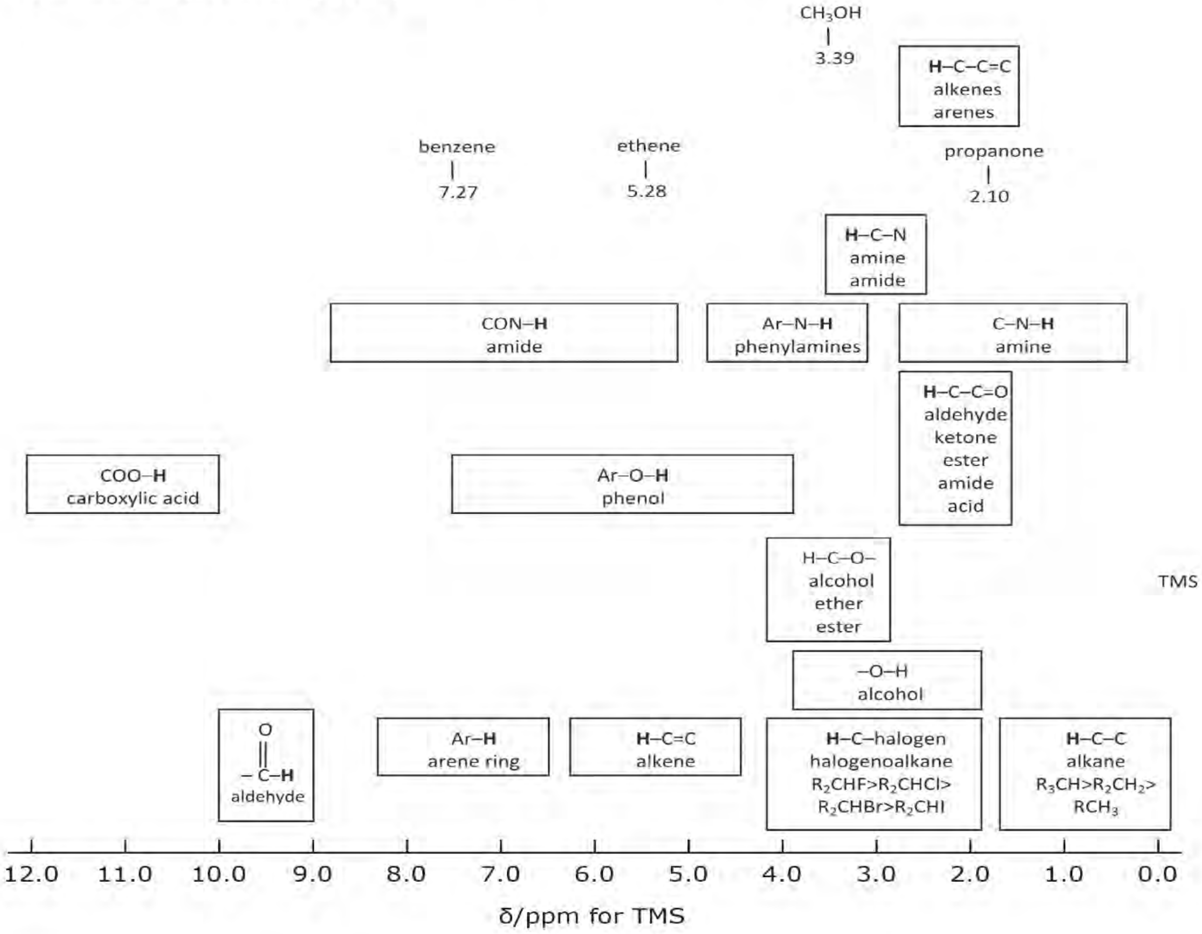
1 dm^3 = 1 000 cm^3 = 0.001 m^3

Infrared spectroscopy

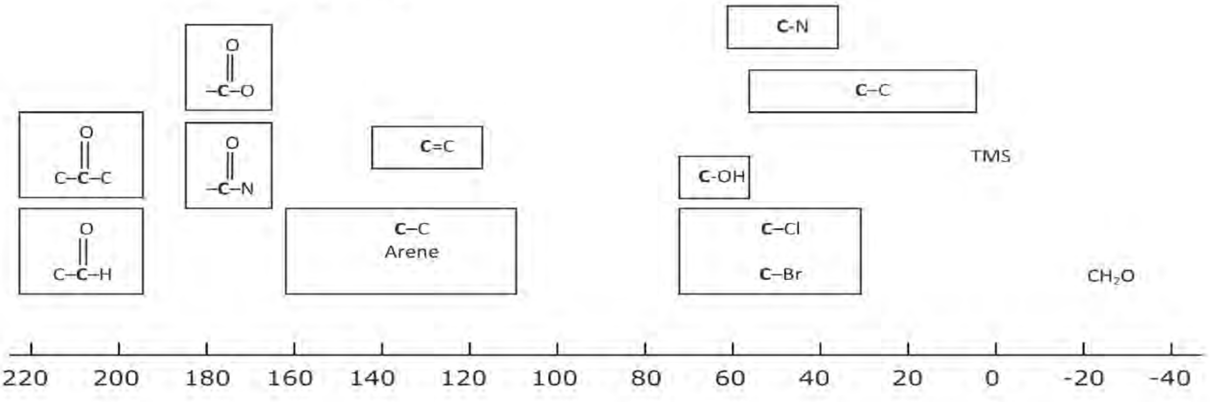
Correlation of infrared absorption wavenumbers with molecular structure

Group		Wavenumber range/cm^{-1}
C-H stretching vibrations		
Alkane		2962-2853
Alkene		3095-3010
Alkyne		3300
Arene		3030
Aldehyde		2900-2820 and 2775-2700
C-H bending vibrations		
Alkane		1485-1365
Arene	5 adjacent hydrogen atoms	750 and 700
	4 adjacent hydrogen atoms	750
	3 adjacent hydrogen atoms	780
	2 adjacent hydrogen atoms	830
	1 isolated hydrogen atom	880
N-H stretching vibrations		
Amine		3500-3300
Amide		3500-3140
O-H stretching vibrations		
Alcohols and phenols		3750-3200
Carboxylic acids		3300-2500
C=C stretching vibrations		
Isolated alkene		1669-1645
Arene		1600, 1580, 1500, 1450
C=O stretching vibrations		
Aldehydes, saturated alkyl		1740-1720
Ketones, alkyl		1720-1700
Ketones, aryl		1700-1680
Carboxylic acids, alkyl		1725-1700
Carboxylic acids, aryl		1700-1680
Carboxylic acid, anhydrides		1850-1800 and 1790-1740
Acyl halides, chlorides		1795
Acyl halides, bromides		1810
Esters, saturated		1750-1735
Amides		1700-1630
Triple bond stretching vibrations		
$C{\equiv}N$		2260-2215
$C{\equiv}C$		2260-2100

^{1}H nuclear magnetic resonance chemical shifts relative to tetramethylsilane (TMS)



^{13}C nuclear magnetic resonance chemical shifts relative to tetramethylsilane (TMS)



Pauling electronegativities

Pauling electronegativity index

							H										He
							2·1										
Li	Be											B	C	N	O	F	Ne
1·0	1·5											2·0	2·5	3·0	3·5	4·0	
Na	Mg											Al	Si	P	S	Cl	Ar
0·9	1·2											1·5	1·9	2·1	2·5	3·0	
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
0·8	1·0	1·3	1·5	1·6	1·6	1·5	1·8	1·8	1·8	1·9	1·6	1·6	2·0	2·0	2·4	2·8	
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
0·8	1·0	1·2	1·3	1·6	2·1	1·9	2·2	2·2	2·2	1·9	1·6	1·7	1·9	1·9	2·1	2·5	
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
0·7	0·9	1·1	1·3	1·5	2·3	1·9	2·2	2·2	2·2	2·5	2·0	1·6	1·8	1·9	2·0	2·2	

Indicators

		pK_{in} (at 298 K)	***acid***	**pH range**	***alkaline***
1	Thymol blue (acid)	1.7	red	1.2–2.8	yellow
2	Screened methyl orange	3.7	purple	3.2–4.2	green
3	Methyl orange	3.7	red	3.2–4.4	yellow
4	Bromophenol blue	4.0	yellow	2.8–4.6	blue
5	Bromocresol green	4.7	yellow	3.8–5.4	blue
6	Methyl red	5.1	red	4.2–6.3	yellow
7	Litmus		red	5.0–8.0	blue
8	Bromothymol blue	7.0	yellow	6.0–7.6	blue
9	Phenol red	7.9	yellow	6.8–8.4	red
10	Phenolphthalein (in ethanol)	9.3	colourless	8.2–10.0	red

Standard electrode potentials

$E^\ominus$ Standard electrode potential of aqueous system at 298 K, that is, standard emf of electrochemical cell in the hydrogen half-cell forms the left-hand side electrode system.

	Right-hand electrode system	**$E^\ominus$/V**
1	$Na^+ + e^- \rightleftharpoons Na$	−2.71
2	$Mg^{2+} + 2e^- \rightleftharpoons Mg$	−2.37
3	$Al^{3+} + 3e^- \rightleftharpoons Al$	−1.66
4	$V^{2+} + 2e^- \rightleftharpoons V$	−1.18
5	$Zn^{2+} + 2e^- \rightleftharpoons Zn$	−0.76
6	$Cr^{3+} + 3e^- \rightleftharpoons Cr$	−0.74
7	$Fe^{2+} + 2e^- \rightleftharpoons Fe$	−0.44
8	$Cr^{3+} + e^- \rightleftharpoons Cr^{2+}$	−0.41
9	$V^{3+} + e^- \rightleftharpoons V^{2+}$	−0.26
10	$Ni^{2+} + 2e^- \rightleftharpoons Ni$	−0.25
11	$H^+ + e^- \rightleftharpoons \frac{1}{2}H_2$	0.00
12	$S_4O_6^{2-} + 2e^- \rightleftharpoons 2S_2O_3^{2-}$	+0.09
13	$Cu^{2+} + e^- \rightleftharpoons Cu^+$	+0.15
14	$Cu^{2+} + 2e^- \rightleftharpoons Cu$	+0.34
15	$VO^{2+} + 2H^+ + e^- \rightleftharpoons V^{3+} + H_2O$	+0.34
16	$O_2 + 2H_2O + 4e^- \rightleftharpoons 4OH^-$	+0.40
17	$S_2O_3^{2-} + 6H^+ + 4e^- \rightleftharpoons 2S + 3H_2O$	+0.47
18	$Cu^+ + e^- \rightleftharpoons Cu$	+0.52
19	$I_2 + 2e^- \rightleftharpoons 2I^-$	+0.54
20	$O_2 + 2H^+ + 2e^- \rightleftharpoons H_2O_2$	+0.68
21	$Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$	+0.77
22	$Ag^+ + e^- \rightleftharpoons Ag$	+0.80
23	$NO_3^- + 2H^+ + e^- \rightleftharpoons NO_2 + H_2O$	+0.80
24	$ClO^- + H_2O + 2e^- \rightleftharpoons Cl^- + 2OH^-$	+0.89
25	$VO_2^+ + 2H^+ + e^- \rightleftharpoons VO^{2+} + H_2O$	+1.00
26	$Br_2 + 2e^- \rightleftharpoons 2Br^-$	+1.09
27	$O_2 + 4H^+ + 4e^- \rightleftharpoons 2H_2O$	+1.23
28	$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightleftharpoons 2Cr^{3+} + 7H_2O$	+1.33
29	$Cl_2 + 2e^- \rightleftharpoons 2Cl^-$	+1.36
30	$MnO_4^- + 8H^+ + 5e^- \rightleftharpoons Mn^{2+} + 4H_2O$	+1.51
31	$H_2O_2 + 2H^+ + 2e^- \rightleftharpoons 2H_2O$	+1.77

The Periodic Table of Elements

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

1	2											3	4	5	6	7	0 (8)
							1.0 **H** hydrogen 1										*(18)* 4.0 **He** helium 2
(1)	*(2)*											*(13)*	*(14)*	*(15)*	*(16)*	*(17)*	
6.9 **Li** lithium 3	9.0 **Be** beryllium 4											10.8 **B** boron 5	12.0 **C** carbon 6	14.0 **N** nitrogen 7	16.0 **O** oxygen 8	19.0 **F** fluorine 9	20.2 **Ne** neon 10
23.0 **Na** sodium 11	24.3 **Mg** magnesium 12	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*	27.0 **Al** aluminium 13	28.1 **Si** silicon 14	31.0 **P** phosphorus 15	32.1 **S** sulfur 16	35.5 **Cl** chlorine 17	39.9 **Ar** argon 18
39.1 **K** potassium 19	40.1 **Ca** calcium 20	45.0 **Sc** scandium 21	47.9 **Ti** titanium 22	50.9 **V** vanadium 23	52.0 **Cr** chromium 24	54.9 **Mn** manganese 25	55.8 **Fe** iron 26	58.9 **Co** cobalt 27	58.7 **Ni** nickel 28	63.5 **Cu** copper 29	65.4 **Zn** zinc 30	69.7 **Ga** gallium 31	72.6 **Ge** germanium 32	74.9 **As** arsenic 33	79.0 **Se** selenium 34	79.9 **Br** bromine 35	83.8 **Kr** krypton 36
85.5 **Rb** rubidium 37	87.6 **Sr** strontium 38	88.9 **Y** yttrium 39	91.2 **Zr** zirconium 40	92.9 **Nb** niobium 41	95.9 **Mo** molybdenum 42	[98] **Tc** technetium 43	101.1 **Ru** ruthenium 44	102.9 **Rh** rhodium 45	106.4 **Pd** palladium 46	107.9 **Ag** silver 47	112.4 **Cd** cadmium 48	114.8 **In** indium 49	118.7 **Sn** tin 50	121.8 **Sb** antimony 51	127.6 **Te** tellurium 52	126.9 **I** iodine 53	131.3 **Xe** xenon 54
132.9 **Cs** caesium 55	137.3 **Ba** barium 56	138.9 **La*** lanthanum 57	178.5 **Hf** hafnium 72	180.9 **Ta** tantalum 73	183.8 **W** tungsten 74	186.2 **Re** rhenium 75	190.2 **Os** osmium 76	192.2 **Ir** iridium 77	195.1 **Pt** platinum 78	197.0 **Au** gold 79	200.6 **Hg** mercury 80	204.4 **Tl** thallium 81	207.2 **Pb** lead 82	209.0 **Bi** bismuth 83	[209] **Po** polonium 84	[210] **At** astatine 85	[222] **Rn** radon 86
[223] **Fr** francium 87	[226] **Ra** radium 88	[227] **Ac*** actinium 89	[261] **Rf** rutherfordium 104	[262] **Db** dubnium 105	[266] **Sg** seaborgium 106	[264] **Bh** bohrium 107	[277] **Hs** hassium 108	[268] **Mt** meitnerium 109	[271] **Ds** darmstadtium 110	[272] **Rg** roentgenium 111							

Elements with atomic numbers 112-116 have been reported but not fully authenticated

* Lanthanide series	140 **Ce** cerium 58	141 **Pr** praseodymium 59	144 **Nd** neodymium 60	[147] **Pm** promethium 61	150 **Sm** samarium 62	152 **Eu** europium 63	157 **Gd** gadolinium 64	159 **Tb** terbium 65	163 **Dy** dysprosium 66	165 **Ho** holmium 67	167 **Er** erbium 68	169 **Tm** thulium 69	173 **Yb** ytterbium 70	175 **Lu** lutetium 71
* Actinide series	232 **Th** thorium 90	[231] **Pa** protactinium 91	238 **U** uranium 92	[237] **Np** neptunium 93	[242] **Pu** plutonium 94	[243] **Am** americium 95	[247] **Cm** curium 96	[245] **Bk** berkelium 97	[251] **Cf** californium 98	[254] **Es** einsteinium 99	[253] **Fm** fermium 100	[256] **Md** mendelevium 101	[254] **No** nobelium 102	[257] **Lr** lawrencium 103

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ISBN 978-1-4469-4996-2