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ASSESSMENT and QUALIFICATIONS ALLIANCE

General Certificate of Education

Chemistry 5421/6421

2008

Material accompanying this Specification

- Specimen and Past Papers and Mark Schemes
- Reports of the Examination
- Teachers' Guides

SPECIFICATION

This specification will be published annually on the AQA Website (www.aqa.org.uk). If there are any changes to the specification centres will be notified in print as well as on the Website. The version on the Website is the definitive version of the specification.

Further copies of this specification booklet are available from:

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Contents

Background Information

Scheme of Assessment

Subject Content

Key Skills and Other Issues

Centre-Assessed Coursework

Awarding and Reporting

Appendices

Background Information

1 Advanced Subsidiary and Advanced Level Specifications

1.1 Advanced Subsidiary (AS)

Advanced Subsidiary courses were introduced in September 2000 for the award of the first qualification in August 2001. They may be used in one of two ways:

- as a final qualification, allowing candidates to broaden their studies and to defer decisions about specialism;
- as the first half (50%) of an Advanced Level qualification, which must be completed before an Advanced Level award can be made.

Advanced Subsidiary is designed to provide an appropriate assessment of knowledge, understanding and skills expected of candidates who have completed the first half of a full Advanced Level qualification. The level of demand of the AS examination is that expected of candidates half-way through a full A Level course of study.

1.2 Advanced Level (AS+A2)

The Advanced Level examination is in two parts:

- Advanced Subsidiary (AS) – 50% of the total award;
- a second examination, called A2 – 50% of the total award.

Most Advanced Subsidiary and Advanced Level courses are modular. The AS comprises three teaching and learning modules and the A2 comprises a further three teaching and learning modules. Each teaching and learning module is normally assessed through an associated assessment unit. The specification gives details of the relationship between the modules and assessment units.

With the two-part design of Advanced Level courses, centres may devise an assessment schedule to meet their own and candidates' needs. For example:

- assessment units may be taken at stages throughout the course, at the end of each year or at the end of the total course;
- AS may be completed at the end of one year and A2 by the end of the second year;
- AS and A2 may be completed at the end of the same year.

Details of the availability of the assessment units for each specification are provided in Section 3.

2

Specification at a Glance
Chemistry

AS Examination 5421

Unit 1

1 hour — 30% of the total AS marks
15% of the total A Level marks

Structured Questions

AS Subject Content Module 1 Atomic Structure, Bonding and Periodicity

Unit 2

1 hour — 30% of the total AS marks
15% of the total A Level marks

Structured Questions

AS Subject Content Module 2 Foundation Physical and Inorganic Chemistry

Unit 3

3(a) and 3(b)

3(a)	3(b)
1 hour 25% of the total AS marks *12½% of the total A Level marks* Structured Questions AS Subject Content Module 3 Introduction to Organic Chemistry	15% of the total AS marks *7½% of the total A Level marks* Centre-Assessed Coursework or Practical Examination 2 hours

Advanced Subsidiary Award

5421

+

A2 Examination 6421

Unit 4

1½ hours — *15% of the total A Level marks*

Structured Questions
A2 Subject Content Module 4 Further Physical and Organic Chemistry

Unit 5

2 hours — *20% of the total A Level marks (incl. 10% synoptic)*

Structured Questions
A2 Subject Content Module 5 Thermodynamics and Further Inorganic Chemistry

Unit 6

6(a) and 6(b)

6(a)	6(b)
1 hour *10% of the total A Level marks* Synoptic Objective Questions	*5% of the total A Level marks* Centre-Assessed Coursework or Practical Examination 2 hours

Advanced Award

6421

3 Availability of Assessment Units and Entry Details

3.1 Availability of Assessment Units

Examinations based on this specification are available as follows:

	Availability of Units		Availability of Qualification	
	AS	**A2**	**AS**	**A Level**
January	All*	CHM4	✓	✓
June	All	All	✓	✓

* In the January session entries will **not** be allowed for CH3P (Unit 3a + Practical Examination).

3.2 Sequencing of Units

In Chemistry it is recommended that AS Units (1, 2 and 3) are studied before A2 Units (4, 5 and 6). Units 5 and 6(a) include the synoptic assessment of the whole A Level course, testing candidates' understanding of the different elements of Chemistry. It is recommended, but not required, that Units 5 and 6(a) are taken at the end of the course.

3.3 Entry Codes

Normal entry requirements apply, but the following information should be noted.

The following unit entry codes should be used:

AS	A2
Unit 1 - CHM1 Unit 2 - CHM2 Unit 3 - CH3C or CH3P	Unit 4 - CHM4 Unit 5 - CHM5 Unit 6 - CH6C or CH6P

The **Subject Code** for entry to the AS only award is 5421
The **Subject Code** for entry to the Advanced Level award is 6421.

3.4 Classification Codes

Candidates entered for Advanced Subsidiary or Advanced Level Chemistry (5421 and/or 6421) may not enter for any GCE Chemistry specification in the same examination series with any other unitary awarding body. This does not preclude candidates from taking AS and A2 units in Chemistry with AQA in the same examination series. Candidates may not take AS in one specification and A2 from a different specification.

Every specification is assigned to a national classification code indicating the subject area to which it belongs.

Centres should be aware that candidates who enter for more than one GCE qualification with the same classification code, will have only one grade (the highest) counted for the purpose of the School and College Performance Tables.

The classification for this specification is 1110.

3.5 Private Candidates

This specification is available to private candidates who wish to take the written unit options (CH3P and CH6P).

Entries for the coursework options (CH3C and CH6C) are not accepted from private candidates unless they have already received results for the coursework units.

Private candidates should write to the Entries Section at AQA for a copy of *Supplementary Guidance for Private Candidates.*

3.6 Access Arrangements and Special Consideration

AQA pays due regard to the provisions of the Disability Discrimination Act 1995 in its administration of this specification.

Arrangements may be made to enable candidates with disabilities or other difficulties to access the assessment. An example of an access arrangement is the production of a Braille paper for a candidate with a visual impairment. Special consideration may be requested for candidates whose work has been affected by illness or other exceptional circumstances.

Further details can be found in the Joint Council for Qualifications (JCQ) document:
Access Arrangements and Special Consideration
Regulations and Guidance relating to Candidates who are Eligible for Adjustments in Examination
GCE, AEA, VCE, GCSE, GNVQ, Entry Level & Key Skills
This document can be viewed via the AQA web site (www.aqa.org.uk)

Applications for access arrangements and special consideration should be submitted to AQA by the Examinations Officer at the centre.

3.7 Language of Examinations

All Assessment Units in this subject are provided in English only.

Scheme of Assessment

4 Introduction

4.1 Rationale

This GCE Chemistry specification complies with:

- the Subject Criteria for Chemistry;
- the *GCSE, GCE, VCE, GNVQ and AEA Code of Practice 2006/7*;
- the GCE Advanced Subsidiary and Advanced Level Qualification: Specific Criteria;
- the Arrangements for the Statutory Regulation of External Qualifications in England, Wales and Northern Ireland: Common Criteria.

This qualification is a recognised part of the National Qualifications framework. As such, AS and A Level provide progression from Key Stage 4, through post-16 studies, and form the basis for entry into higher education or employment.

The specification is derived from the existing AQA/NEAB modular and end-of-course GCE Chemistry syllabuses and provides a logical sequence of topics progressing from GCSE through AS to A level and beyond. Technological applications and social, economic and environmental implications pervade the specification and have been taken into account in preparing the subject content. Practical work is seen as integral to the teaching of the theory and candidates should carry out practical work within the context of each of the theory modules. Candidates' practical skills are assessed either through coursework, set and marked by teachers and moderated by AQA, or by a practical examination, set and marked by AQA. The specification adopts a traditional, academic and practical teaching approach with no optional topics.

5

Aims

This AS and A Level specification should encourage candidates to:

a. develop essential knowledge and understanding of the concepts of chemistry, and the skills needed for the use of these in new and changing situations;

b. develop an understanding of the link between theory and experiment;

c. be aware of how advances in information technology and instrumentation are used in chemistry;

d. appreciate the contributions of chemistry to society and the responsible use of scientific knowledge and evidence;

e. sustain and develop their enjoyment of, and interest in, chemistry.

In addition, the A Level specification should encourage candidates to:

f. bring together knowledge of ways in which different areas of chemistry relate to each other.

6 Assessment Objectives

The Assessment Objectives 6.1, 6.2 and 6.3 are common to both AS and A Level. Assessment Objective 6.4 applies only to the A2 part of the A Level course.

The schemes of assessment will assess candidates' ability to:

At AS and A Level

6.1	Knowledge with Understanding (AO1)	a. recognise, recall and show understanding of specific chemical facts, terminology, principles, concepts and practical techniques; b. draw on existing knowledge to show understanding of the responsible use of chemistry in society; c. select, organise and present relevant information clearly and logically, using specialist vocabulary where appropriate.
6.2	Application of Knowledge and Understanding, Analysis and Evaluation (AO2)	a. describe, explain and interpret phenomena and effects in terms of chemical principles and concepts, presenting arguments and ideas clearly and logically, using specialist vocabulary where appropriate; b. interpret and translate, from one form into another, data presented as continuous prose or in tables, diagrams and graphs; c. carry out relevant calculations; d. apply chemical principles and concepts to unfamiliar situations, including those related to the responsible use of chemistry in society; e. assess the validity of chemical information, experiments, inferences and statements.
6.3	Experiment and Investigation (AO3)	a. devise and plan experimental and investigative activities, selecting appropriate techniques; b. demonstrate safe and skilful practical techniques; c. make observations and measurements with appropriate precision and record these methodically; d. interpret, explain, evaluate and communicate the results of their experimental and investigative activities clearly and logically using chemical knowledge and understanding, and using appropriate specialist vocabulary.

At A Level

6.4	Synthesis of Knowledge, Understanding and Skills (AO4)	a. bring together knowledge, principles and concepts from different areas of chemistry, including experiment and investigation, and apply them in a particular context, expressing ideas clearly and logically and using appropriate specialist vocabulary; b. use chemical skills in context which bring together different areas of the subject.

6.5 Quality of Written Communication

The quality of written communication is assessed in all assessment units where candidates are required to produce extended written material. Candidates will be assessed according to their ability to:

- select and use a form and style of writing appropriate to purpose and complex subject matter;
- organise relevant information clearly and coherently, using specialist vocabulary when appropriate;
- ensure text is legible, and spelling, grammar and punctuation are accurate, so that meaning is clear.

The assessment of the quality of written communication is included in all four Assessment Objectives.

7 Scheme of Assessment - *Advanced Subsidiary (AS)*

The Scheme of Assessment has a modular structure. The Advanced Subsidiary (AS) award comprises three compulsory assessment units.

7.1 Assessment Units

Unit 1 *30% of the total AS marks*	Written Paper 60 marks	1 hour

This unit assesses ***Module 1*** of the AS Subject Content. It comprises Section A, a number of structured questions and Section B, extended answer questions. Questions in Section B provide an opportunity for answers written in continuous prose to be marked for the quality of the language used. All questions are compulsory.

Unit 2 *30% of the total AS marks*	Written Paper 60 marks	1 hour

This unit assesses ***Module 2*** of the AS Subject Content. It comprises Section A, a number of structured questions and Section B, extended answer questions. Questions in Section B provide an opportunity for answers written in continuous prose to be marked for the quality of the language used. All questions are compulsory.

Unit 3 comprises two part-units : 3(a) and 3(b)

Unit 3(a) *25% of the total AS marks*	Written Paper 60 marks	1 hour

This unit assesses ***Module 3*** of the AS Subject Content. It comprises Section A, a number of structured questions and Section B, extended answer questions. Questions in Section B provide an opportunity for answers written in continuous prose to be marked for the quality of the language used. All questions are compulsory.

Unit 3(b)

15% of the total AS marks

Either	Centre-Assessed Coursework 30 marks

This centre-assessed component requires teachers to assess candidates' performance in the four skill areas listed in Section 18, based on assessments carried out during normal coursework as an integral part of the scheme of work. External moderation by inspection.

Or	Practical Examination 2 hours 30 marks

This part-unit assesses the four skill areas listed in Section 18 and consists of both planning and practical exercises. All exercises are compulsory.

7.2 Weighting of Assessment Objectives for AS

The approximate relationship between the relative percentage weighting of the Assessment Objectives (AOs) and the overall Scheme of Assessment is shown in the following table:

Assessment Objectives	Unit Weightings (%)				Overall Weighting of AOs (%)
	1	2	3(a)	3(b)	
Knowledge with understanding (AO1)	$17^{1}/_{3}$	$17^{1}/_{3}$	$14^{1}/_{3}$	-	49
Applications of Knowledge and Understanding, Analysis and Evaluation (AO2)	$12\,^{2}/_{3}$	$12\,^{2}/_{3}$	$10\,^{2}/_{3}$	-	36
Experiment and Investigation (AO3)	-	-	-	15	15
Overall Weighting of Units (%)	30	30	25	15	100

Candidates' marks for each assessment unit are scaled to achieve the correct weightings.

8 Scheme of Assessment - *Advanced Level (AS+A2)*

The Scheme of Assessment has a modular structure. The A Level award comprises three compulsory assessment units from the AS Scheme of Assessment and three compulsory assessment units from the A2 scheme of assessment.

The details of the AS assessment units are given in Section 7 above and comprise the following three units:

8.1 AS Assessment Units

Unit 1 *15% of the total A Level marks*	Written Paper 60 marks	1 hour
Unit 2 *15% of the total A Level marks*	Written Paper 60 marks	1 hour
Unit 3(a) *12½% of the total A Level marks*	Written Paper 60 marks	1 hour
Unit 3(b) *7½% of the total A Level marks* Either	Centre-Assessed Coursework 30 marks	
Or	Practical Examination 30 marks	2 hours

8.2 A2 Assessment Units

Unit 4 *15% of the total A Level marks*	Written Paper 90 marks	1½ hours

This unit assesses ***Module 4*** of the A2 Subject Content and consists of a number of structured questions of varying length. They allow for both short answers and those of a more extended nature, including the opportunity for answers written in continuous prose. All questions are compulsory. Candidates' answers in continuous prose will be marked for the quality of the language used.

Unit 5 *20% of the total A Level marks*	Written Paper 120 marks	2 hours

This unit assesses ***Module 5*** of the A2 Subject Content and consists of a number of structured questions of varying length. They allow for both short answers and those of a more extended nature, including the opportunity for answers written in continuous prose. All questions are compulsory. Some questions or parts of questions will be allocated to synoptic assessment. Candidates' answers in continuous prose will be marked for the quality of the language used.

Unit 6 comprises two part-units : 6(a) and 6(b)		
Unit 6(a) *10 % of the total A Level marks*	Written Paper 60 marks	1 hour

This part-unit is allocated to synoptic assessment and consists of forty objective questions in the form of multiple choice and ***either*** matching pairs ***or*** multiple completion items. All questions are compulsory.

Unit 6(b) *5% of the total A Level marks*	
Either	Centre-Assessed Coursework 30 marks

This centre-assessed component requires teachers to assess candidates' performance in the four skill areas listed in Section 18, based on assessments carried out during normal coursework as an integral part of the scheme of work. External moderation by inspection.

Or	Practical Examination 2 hours 30 marks

This part-unit assesses the four skill areas listed in Section 18 and consists of both planning and practical exercises. All exercises are compulsory.

8.3 Synoptic Assessment

The Advanced Subsidiary and Advanced Level Criteria state that A Level specifications must include synoptic assessment (representing at least 20% of the total A Level marks).

Assessment Objective 4 relates specifically to synoptic assessment. Synoptic assessment in chemistry involves the explicit drawing together of knowledge, understanding and skills learned in different parts of the A Level course. The emphasis of synoptic assessment is on understanding and application of the principles included in this chemistry specification.

Synoptic assessment requires candidates to make connections between different areas of chemistry, for example, by applying knowledge and understanding of principles and concepts of chemistry in planning experimental work and in the analysis and evaluation of data.

Synoptic assessment should include opportunities for candidates to use, in contexts which may be new to them, skills and ideas that permeate chemistry, for example, writing chemical equations, quantitative work, relating empirical data to knowledge and understanding.

All the marks for Unit 6(a) are allocated to synoptic assessment together with at least 50 % of the marks for Unit 5.

Unit 5 will include synoptic assessment of the AS Subject Content and of Module 4 of the A2 Subject Content.

Unit 6(a) will be allocated to synoptic assessment of the whole A Level course.

8.4 Weighting of Assessment Objectives for A Level

The approximate relationship between the relative percentage weighting of the Assessment Objectives (AOs) and the overall Scheme of Assessment is shown in the following table.

A Level Assessment Units (AS + A2)

Assessment Objectives	**Unit Weightings (%)**								**Overall Weighting of**
	1	2	3(a)	3(b)	4	5	6(a)	6(b)	AOs (%)
Knowledge with Understanding (AO1)	8 2/3	8 2/3	7 1/6	-	7½	5	-	-	37
Application of Knowledge and Understanding, Analysis and Evaluation (AO2)	6 1/3	6 1/3	5 1/3	-	7½	5	-	-	30½
Experiment and Investigation (AO3)	-	-	-	7½	-	-	-	5	12½
Synthesis of Knowledge, Understanding and Skills (AO4)	-	-	-	-		10	10	-	20
Overall Weighting of Units (%)	15	15	12½	7½	15	20	10	5	100

Candidates' marks for each assessment unit are scaled to achieve the correct weightings.

Subject Content

9 Summary of Subject Content

9.1 AS Modules

MODULE 1 – Atomic Structure, Bonding and Periodicity

1. Atomic Structure
2. Amount of Substance
3. Bonding
4. Periodicity

MODULE 2 – Foundation Physical and Inorganic Chemistry

1. Energetics
2. Kinetics
3. Equilibria
4. Redox Reactions
5. Group VII, The Halogens
6. Extraction of Metals

MODULE 3 – Introduction to Organic Chemistry/Practical

(a) Introduction to Organic Chemistry
   1. Nomenclature and Isomerism
   2. Petroleum and Alkanes
   3. Alkenes and Epoxyethane
   4. Haloalkanes
   5. Alcohols

(b) Centre-Assessed Coursework or Practical Examination

9.2 A2 Modules

MODULE 4 – Further Physical and Organic Chemistry

1. Kinetics
2. Equilibria
3. Acids and Bases
4. Nomenclature and Isomerism in Organic Chemistry
5. Compounds containing the Carbonyl Group
6. Aromatic Chemistry
7. Amines
8. Amino Acids
9. Polymers
10. Organic Synthesis and Analysis
11. Structure Determination

MODULE 5 – Thermodynamics and Further Inorganic Chemistry

1. Thermodynamics
2. Periodicity
3. Redox Equilibria
4. Transition Metals
5. Reactions of Inorganic Compounds in Aqueous Solution

MODULE 6 – Synoptic Assessment/Practical

(a) Synoptic Assessment

(b) Centre-Assessed Coursework or Practical Examination

10

AS Module 1
Atomic Structure, Bonding and Periodicity

Introduction

In order to understand the chemical reactivity of atoms and molecules it is essential to understand their structures at both sub-atomic and molecular levels. In this module sub-atomic structure is considered together with ideas of chemical bonding which will be developed in later modules. The relationship between atomic structure, chemical reactivity and the position an element occupies in the Periodic Table is developed using the elements of Period 3 and Group II.

Wherever possible, candidates should carry out experimental work to illustrate the theoretical principles included in this module.

Candidates should:

10.1 Atomic Structure

10.1.1	Fundamental particles	be able to describe the properties of protons, neutrons and electrons in terms of relative charge and relative mass.
10.1.2	Protons, neutrons and electrons	understand the importance of these particles in the structure of the atom.
10.1.3	Mass number and isotopes	be able to recall the meaning of mass number (A) and atomic (proton) number (Z). be able to explain the existence of isotopes. understand the principles of a simple mass spectrometer, limited to ionisation, acceleration, deflection and detection. be able to interpret simple mass spectra of elements and calculate relative atomic mass from isotopic abundance, limited to mononuclear ions. know that mass spectrometry can be used to determine relative molecular mass.
10.1.4	Electron arrangement	be able to describe the electronic structures of atoms and ions up to $Z = 36$ in terms of levels and sub-levels s, p and d, considered as energy levels not quantum numbers. understand how ionisation energies in Group II (Be – Ba) and in Period 3 (Na – Ar) give evidence for electron arrangement in levels and sub-levels.

10.2 Amount of Substance

10.2.1	Relative atomic mass and relative molecular mass	be able to define relative atomic mass (A_r) and relative molecular mass (M_r) in terms of ^{12}C. (The term relative formula mass will be used for ionic compounds.)
10.2.2	The mole and the Avogadro constant (L)	understand the concept of a mole as applied to electrons, atoms, molecules, ions, formulae and equations. understand the concept of the Avogadro constant. (Calculation not required)
10.2.3	The ideal gas equation	be able to recall the ideal gas equation $pV = nRT$ and be able to apply it to simple calculations in S.I. units, for ideal gases.
10.2.4	Empirical and molecular formulae	be able to calculate empirical formulae from data giving percentage composition by mass. understand the relationship between empirical and molecular formulae.
10.2.5	Balanced equations and associated calculations	be able to write balanced equations (full and ionic) for reactions studied. be able to balance equations for unfamiliar reactions when reactants and products are specified. be able to calculate reacting masses from balanced equations (full and ionic). be able to calculate reacting volumes of gases. be able to calculate concentrations and volumes for reactions in solutions, limited to titrations of monoprotic acids and bases and examples for which the equations are given.

10.3 Bonding

10.3.1	Nature of ionic, covalent and metallic bonds	understand that ionic bonding involves attraction between oppositely charged ions formed by electron transfer. know that a covalent bond involves a shared pair of electrons. know that co-ordinate bonding is dative covalency. understand that metallic bonding involves a lattice of positive ions surrounded by delocalised electrons.
10.3.2	Bond polarity and the polarisation of ions	understand that electronegativity is the power of an atom to withdraw electron density from a covalent bond. understand that the electron distribution in a covalent bond may not be symmetrical. know that covalent bonds between different elements will be polar to different extents. know that anions can be polarised by cations of high charge density, limited to chlorides of elements in Period 3.
10.3.3	Forces acting between molecules	understand qualitatively how molecules may interact by permanent dipole–dipole, induced dipole–dipole (van der Waals') forces and hydrogen bonding.

10.3.4	States of matter	understand the behaviour of gases, liquids and solids in terms of the particles, their motion and the forces acting between them. be able to explain the energy changes associated with changes of state. recognise the four types of crystal: ionic, metallic, molecular and giant covalent (macromolecular). know the structures of NaCl, I_2, diamond and graphite. be able to relate the physical properties of materials to the type of structure and bonding present.
10.3.5	Shapes of simple molecules and ions in terms of electron pair repulsion	understand the concept of bonding and lone (non-bonding) pairs of electrons as charge clouds. be able to use this concept to predict the shapes of, and bond angles in, simple molecules and ions, limited to 2, 3, 4, 5 and 6 co-ordination. Know that lone pair/lone pair repulsion is greater than lone pair/bonding pair repulsion, which is greater than bonding pair/bonding pair repulsion, and understand the resulting effect on bond angles.

10.4 Periodicity

10.4.1	Classification of elements in s, p and d blocks	be able to classify an element as s, p or d block according to its position in the Periodic Table.
10.4.2	Properties of the elements of Period 3 (Na – Ar) to illustrate periodic trends	be able to describe the trends in atomic radius, first ionisation energy, electronegativity, electrical conductivity, melting and boiling points of the elements Na – Ar. understand the reasons for the trends in these properties.
10.4.3	Group II	understand the trends in atomic radius, first ionisation energy, electronegativity and melting point of the elements Mg – Ba. know the reactions of the elements Mg – Ba with water and recognise the trend. know the relative solubilities of the hydroxides of the elements Mg – Ba and that $Mg(OH)_2$ is sparingly soluble. know the relative solubilities of the sulphates of the elements Mg – Ba. Know the test used to identify sulphate ions.

11

AS Module 2

Foundation Physical and Inorganic Chemistry

Introduction

This module introduces chemical energetics and kinetics. An understanding of the factors affecting the rate of reaction is essential in order to control rates to advantage. The position of equilibrium can have major economic disadvantages by limiting the yield of a given reaction. This module considers the way in which adjustment of conditions may be used to favour a particular, desired, chemical outcome. The methods used for the extraction of metals from natural sources involve an understanding of the social and economic aspects of the processes as well as an appreciation of the underlying chemistry.

Wherever possible, candidates should carry out experimental work to illustrate the theoretical principles included in this module.

A knowledge of the chemistry in Module 1 is assumed in this module.

Candidates should:

11.1 Energetics

11.1.1	Enthalpy change (ΔH)	know that reactions can be endothermic or exothermic. understand that enthalpy change (ΔH) is the heat energy change measured under conditions of constant pressure. know that standard enthalpy changes refer to standard conditions, i.e. 100 kPa and a stated temperature (e.g. ΔH_{298}). be able to recall the definition of standard enthalpies of combustion ($\Delta H^{\ominus}_{c}$) and formation ($\Delta H^{\ominus}_{f}$).
11.1.2	Calorimetry	be able to calculate the enthalpy change from the heat change in a reaction using the equation $q = mc\Delta T$.
11.1.3	Simple applications of Hess's Law	know Hess's Law and be able to use it to perform simple calculations.
11.1.4	Bond enthalpies	be able to determine mean bond enthalpies from given data. be able to use mean bond enthalpies to calculate a value of ΔH for simple reactions.

11.2 Kinetics

11.2.1	Collision theory	understand that reactions can only occur when collisions take place between particles having sufficient energy.
11.2.2	Maxwell–Boltzmann distribution	have a qualitative understanding of the Maxwell–Boltzmann distribution of molecular energies in gases. be able to draw and interpret distribution curves for different temperatures.

11.2.3	Factors affecting reaction rate	
	Concentration and physical state	understand the qualitative effect of changes in concentration (or pressure for gases) or surface area on the rate of reaction.
	Temperature	understand the qualitative effect of temperature changes on the rate of reaction.
		be able to define the term activation energy and understand its significance.
		understand that most collisions do not lead to reaction.
		understand how small temperature increases can lead to a large increase in rate.
	Catalysts	know the meaning of the term catalyst.
		understand that catalysts work by providing an alternative reaction route of lower activation energy.

11.3 Equilibria

11.3.1	The dynamic nature of equilibria	know that many chemical reactions are reversible.
		understand that for a reaction in equilibrium, although the concentrations of reactants and products remain constant, both forward and reverse reactions are still proceeding.
11.3.2	Qualitative effects of changes of pressure, temperature and concentration on a system in equilibrium	be able to use Le Chatelier's principle to predict the effects of changes in temperature, pressure and concentration on the position of equilibrium in homogeneous reactions.
		know that a catalyst does not affect the position of equilibrium.
11.3.3	Importance of equilibria in industrial processes	be able to apply these concepts to given chemical processes.
		be able to predict qualitatively the effect of temperature on the position of equilibrium from the sign of ΔH for the forward reaction.
		understand why a compromise temperature and pressure may be used.

11.4 Redox Reactions

11.4.1	Oxidation and reduction	know that oxidation is the process of electron loss.
		know that reduction is the process of electron gain.
11.4.2	Oxidation states	know and be able to apply the rules for assigning oxidation states in order to work out the oxidation state of an element in a compound from its formula.
		understand oxidation and reduction reactions of s and p block elements.
11.4.3	Redox equations	be able to write half-equations identifying the oxidation and reduction processes in redox reactions when the reactants and products are specified.
		be able to combine half-equations to give an overall redox equation.

11.5 Group VII, the Halogens

11.5.1	Trends in physical properties	understand the trends in electronegativity and boiling point of the halogens.
11.5.2	Trends in chemical properties	understand that the ability of the halogens to oxidise decreases down the group (e.g. the displacement reactions with halide ions in aqueous solution).
11.5.3	Trends in properties of the halides	understand the trend in reducing ability of the halide ions. know the different products formed by reaction of NaX and H_2SO_4. be able to use silver nitrate solution as a test to identify and distinguish between F^-, Cl^-, Br^- and I^-. know the trend in solubility of the silver halides in ammonia.
11.5.4	Uses of chlorine and chlorate(I)	know the reactions of chlorine with water and the use of chlorine in water treatment. know the reaction of chlorine with cold, dilute, aqueous NaOH and the uses of the solutions formed.

11.6 Extraction of Metals

11.6.1	Reduction of metal oxides with carbon	understand how Fe is extracted by carbon reduction at high temperature in a continuous process from Fe_2O_3; know that both C and CO are reductants in this process. understand the use of limestone in this extraction process and the use of slag in the construction industry. understand that Fe from the Blast Furnace is purified by the removal of C and P in a basic oxygen converter, and that S is removed by using Mg. know that pollution problems can arise from the use of carbon as reductant and the use of sulphide ores. understand the general limitation of carbon reduction because of carbide formation (e.g. Ti or W).
11.6.2	Reduction of metal oxides by electrolysis of melts	understand how Al is manufactured from purified bauxite (energy considerations, electrode equations and conditions only).
11.6.3	Reduction of metal halides with metal	understand how Ti is extracted from TiO_2 via $TiCl_4$ in a batch process (equations and conditions only: either Na or Mg as a reducing agent). understand the cost implications and hence the limited use despite the unique properties and high natural abundance of Ti.

11.6.4	Economic factors and recycling	understand that the choice of the reduction method depends upon the cost of the reductant, the energy requirements and the required purity of the metal. understand how and why Fe and Al are recycled. know the problems associated with recycling and know the social and economic benefits.

12

AS Module 3

Introduction to Organic Chemistry/Practical

(a) Introduction to Organic Chemistry

Introduction

Compounds of carbon constitute an enormous range of materials with diverse properties which include living systems, petroleum and synthetic materials such as drugs, medicines and plastics. This module provides an introduction to the study of organic compounds by consideration of the chemistry of a number of functional groups. Wherever possible, candidates should carry out experimental work to illustrate the theoretical principles included in this module.

A knowledge of the chemistry in module 1 is assumed in this module.

Candidates should:

12.1 Nomenclature and Isomerism

12.1.1	Nomenclature	know and understand the terms empirical formula, molecular formula, structural formula, homologous series and functional group. be able to apply IUPAC rules for nomenclature to simple organic compounds, limited to chains with up to 6 carbon atoms and the functional groups listed in this module.
12.1.2	Isomerism	know and understand the meaning of the term structural isomerism. be able to draw the structures of chain, position and functional group isomers. know that the alkenes can exhibit stereoisomerism limited to geometrical, *cis-trans,* isomerism. be able to draw the structures of *cis* and *trans* isomers.

12.2 Petroleum and Alkanes

12.2.1	Petroleum: fractional distillation	know that petroleum is a mixture consisting mainly of alkane hydrocarbons. understand that different components (fractions) of this mixture can be drawn off at different levels in a fractionating column because of the temperature gradient.
12.2.2	Petroleum: cracking	understand that cracking involves the breaking of C–C bonds in alkanes. know that thermal cracking occurs by a free-radical mechanism and takes place at high pressure and high temperature and produces a high percentage of alkenes (mechanism not required).

		know that catalytic cracking occurs by a carbocation mechanism and takes place at a slight pressure, high temperature and in the presence of a zeolite catalyst and is used mainly to produce motor fuels and aromatic hydrocarbons (mechanism not required).
		understand the economic reasons for the cracking of alkanes (e.g. ethene used for poly(ethene); conversion of heavy fractions into higher value products).
12.2.3	Petroleum: combustion	know that sulphur-containing impurities are found in petroleum fractions and that combustion of these impurities produces oxides of sulphur which are toxic and can cause acid rain.
		know that alkanes are used as fuels and understand that their combustion can be complete or incomplete and that the internal combustion engine produces a number of pollutants (e.g. NO_x, CO and unburned hydrocarbons).
		know that these pollutants can be removed by catalytic converters (mechanism not required).
12.2.4	Alkanes: chlorination	understand the reaction mechanism of methane with chlorine as a free-radical substitution reaction in terms of initiation, propagation and termination steps.

12.3 Alkenes and Epoxyethane

12.3.1	Alkenes: structure and bonding	know that bonding in alkenes involves a double covalent bond.
		know that the arrangement >C=C< is planar.
		understand that the double bond in an alkene is a centre of high electron density.
12.3.2	Alkene reactions	know that alkenes can be hydrogenated catalytically and understand the use of this process in the manufacture of margarine.
		know that alkenes decolourise bromine water.
		understand the mechanism of electrophilic addition of alkenes with HBr, H_2SO_4 and Br_2.
		be able to predict the products of addition to unsymmetrical alkenes by reference to the relative stabilities of primary, secondary and tertiary carbocation intermediates.
		understand that alcohols are produced industrially by hydration of alkenes in the presence of an acid catalyst.
		know the typical conditions for the industrial production of ethanol from ethene.
		know that addition polymers may be formed from alkenes.
12.3.3	Epoxyethane	know that epoxyethane is produced by direct synthesis from ethene and air or oxygen in the presence of a silver catalyst; understand the hazards of this process (details of plant not required).
		know that the 3-membered ring is strained, resulting in high reactivity.
		know that hydrolysis produces ethane-1,2 diol which is of industrial importance in the production of antifreeze and polyesters.

12.4 Haloalkanes

12.4.1	Nucleophilic substitution	understand that haloalkanes contain polar bonds.
		understand that haloalkanes are susceptible to nucleophilic attack, limited to OH^-, CN^- and NH_3.
		understand the mechanism of nucleophilic substitution in primary haloalkanes.
		understand that the carbon–halogen bond enthalpy influences the rate of hydrolysis.
12.4.2	Elimination	understand concurrent displacement and elimination (including mechanisms) in the reaction of a haloalkane (e.g. 2-bromopropane with potassium hydroxide) and the role of the reagent as both base and nucleophile.

12.5 Alcohols

12.5.1	Ethanol production	know that ethanol is produced industrially by fermentation.
		know the conditions for this reaction and understand the economic and environmental advantages and disadvantages of this process compared with the industrial production from ethene.
12.5.2	Classification and reactions	understand that alcohols can be classified as primary, secondary or tertiary.
		understand that tertiary alcohols are not easily oxidised.
		understand that primary alcohols can be oxidised to aldehydes and carboxylic acids and that secondary alcohols can be oxidised to ketones by a suitable oxidising agent such as acidified potassium dichromate(VI) (equations showing [O] as oxidant are acceptable).
		be able to use a simple chemical test to distinguish between aldehydes and ketones (e.g. Fehling's solution or Tollens' reagent).
12.5.3	Elimination	know that alkenes can be formed from alcohols by elimination (mechanism not required).

(b) Practical Either Centre-Assessed Coursework

(see Sections 18 to 24)

Or Practical Examination

The external practical examination assesses the same four skill areas as those covered by the centre-assessed coursework alternative. These are

- Planning
- Implementing
- Analysing evidence and drawing conclusions
- Evaluating evidence and procedures

Candidates will not be permitted to use books and laboratory notebooks during the examination.

Candidates will be required to carry out a Planning exercise which will be set in the context of the content of the three AS modules, AS Module 1 Atomic Structure, Bonding and Periodicity, AS Module 2 Foundation Physical and Inorganic Chemistry and AS Module 3 Introduction to Organic Chemistry.

The remaining three skills, Skill 2 Implementing, Skill 3 Analysing evidence and drawing conclusions and Skill 4 Evaluating evidence and procedures will be assessed by a practical exercise(s) which will be set in the same general context as that for the planning exercise although it is unlikely that the practical exercise will be the same task.

The mark scheme for the practical examination will be based on the coursework mark descriptors for the four skills which are the same for both the AS and A2. The difference in standard of the AS and A2 depends upon the related scientific knowledge and understanding and the complexity and demand of the practical activity set.

The guidance material for practical work which is published separately, will provide examples of practical activities appropriate for AS, and for A2, and guidance on the application of the mark descriptors for the four skills. These exemplars will provide a guide to the type and complexity of the exercises that may be set in the practical examination.

Details of the apparatus and materials required for the practical examination will be sent to centres in advance of the date of the examination.

Candidates choosing the coursework alternative or the practical examination at AS do not have to follow the same form of assessment at A2.

13

A2 Module 4

Further Physical and Organic Chemistry

Introduction

This module develops the concepts of physical chemistry introduced in the foundation modules. Kinetics and equilibria are both treated quantitatively. Acids, bases and buffer solutions and the changes in pH during titrations are considered.

The study of organic chemistry is extended to include compounds containing the carbonyl group, aromatic compounds, amines, amino acids and polymers. The final section examines the way in which spectroscopic techniques are used to determine the molecular formulae and structures of organic compounds. The emphasis is on problem solving rather than on spectroscopic theory.

Wherever possible, candidates should carry out experimental work to illustrate the theoretical principles included in this module.

Candidates should:

13.1 Kinetics

13.1.1	Simple rate equations	understand and be able to use rate equations of the form Rate = $k[A]^m [B]^n$ where m and n are the orders of reaction with respect to reactants A and B (m, n restricted to values 1, 2 or 0).
13.1.2	Determination of rate equation	be able to derive the rate equation for a reaction from data relating initial rate to the concentrations of the different reactants. be able to explain the qualitative effect of changes in temperature on the rate constant k.

13.2 Equilibria

13.2.1	Equilibrium constants K_c and K_p for homogeneous systems	know that K_c is the equilibrium constant calculated from equilibrium concentrations for a system at constant temperature. know that K_p is the equilibrium constant calculated from partial pressures for a system at constant temperature (the relationship between K_c and K_p is not required). be able to derive partial pressures from mole fractions and total pressure. be able to construct an expression for K_c or K_p for an homogeneous system in equilibrium; be able to perform calculations involving such expressions.
13.2.2	Qualitative effects of changes of pressure, temperature and concentration	be able to predict the effects of changes of temperature, pressure and concentration on the position of equilibrium and on the value of the equilibrium constant. know that a catalyst does not affect the value of the equilibrium constant.

13.3 Acids and Bases

13.3.1	Brønsted-Lowry acid–base equilibria in aqueous solution	know that an acid is a proton donor. know that a base is a proton acceptor. know that acid–base equilibria involve the transfer of protons.
13.3.2	Definition and determination of pH	know that $pH = -\log_{10}[H^+]$, where [ ] represents the concentration in mol dm^{-3}. be able to convert concentration into pH and vice-versa. be able to calculate the pH of a solution of a strong acid from its molar concentration.
13.3.3	The ionic product of water, K_w	know that water is weakly dissociated. know that $K_w = [H^+][OH^-] = 10^{-14}$ mol^2 dm^{-6} at 25 °C be able to calculate the pH of a strong base from its molar concentration.
13.3.4	Weak acids and bases	know that weak acids and weak bases dissociate only partially in aqueous solution.
13.3.5	K_a for weak acids	be able to construct an expression, with units, for the dissociation constant K_a for a weak acid. know that $pK_a = -\log_{10} K_a$ be able to calculate the pH of a weak acid from the dissociation constant, K_a, and the molar concentration. be able to perform calculations relating pH to pK_a for weak acids and to relate pK_a for weak acids to pH.
13.3.6	pH curves, titrations and indicators	understand the typical shape of pH curves for acid–base titrations in all combinations of weak and strong monoprotic acids and bases. understand the shape of the pH curves for the titration of sodium carbonate with monoprotic acids, e.g. HCl, and for the titration of diprotic acids, e.g. ethanedioic acid, with NaOH; be able to perform mole calculations for these titrations. know that indicators change colour over a narrow pH range; be able to select an appropriate indicator by consideration of the pH curve.
13.3.7	Buffer action	be able to explain qualitatively the action of acidic and basic buffers. be able to calculate the pH of acidic buffer solutions.

13.4 Nomenclature and Isomerism in Organic Chemistry

13.4.1	Naming organic compounds	be able to apply IUPAC rules for nomenclature to simple organic compounds, limited to chains with up to 6 carbon atoms, benzene and the functional groups listed in this module and in AS3.

13.4.2	Isomerism	know and understand the meaning of the term structural isomerism. know that geometrical isomerism and optical isomerism are forms of stereoisomerism. understand that geometrical isomers exist in *cis* and *trans* forms due to restricted rotation about the C=C bond. know that an asymmetric carbon atom is chiral and gives rise to optical isomers which exist as mirror images and differ only in their effect on plane-polarised light. understand the meaning of the terms enantiomer and racemate. understand why racemates are formed. be able to draw the structures of isomers.

13.5 Compounds Containing the Carbonyl Group

13.5.1	Aldehydes and ketones	recall that aldehydes are readily oxidised to carboxylic acids and that this forms the basis of a simple chemical test to distinguish between aldehydes and ketones (e.g. Fehling's solution or Tollens' reagent). know that aldehydes can be reduced to primary alcohols and ketones to secondary alcohols using reducing agents such as $NaBH_4$. Mechanisms showing H^- are required (equations showing [H] as reductant are acceptable). understand the mechanism of the reaction of carbonyl compounds with HCN as a further example of nucleophilic addition producing hydroxynitriles.
13.5.2	Carboxylic acids and esters	know that carboxylic acids are weak acids but will liberate CO_2 from carbonates. know that carboxylic acids and alcohols react, in the presence of a strong acid catalyst, to give esters. know that esters can have pleasant smells. know the common uses of esters (e.g. as solvents, plasticisers and food flavourings). know that esters can be hydrolysed, including the production of soap, glycerol and higher fatty acids from naturally-occurring esters.
13.5.3	Acylation	know the reactions of water, alcohols, ammonia and primary amines with acyl chlorides and acid anhydrides. understand the mechanism of nucleophilic addition–elimination reactions between water, alcohols, ammonia and primary amines with acyl chlorides. understand the industrial advantages of ethanoic anhydride over ethanoyl chloride in the manufacture of the drug aspirin.

13.6 Aromatic Chemistry

13.6.1	Bonding	understand the nature of the bonding in a benzene ring, limited to planar structure and bond length intermediate between single and double.
13.6.2	Delocalisation stability	understand that delocalisation confers stability to the molecule. be able to use thermochemical evidence from enthalpies of hydrogenation to illustrate this principle.
13.6.3	Electrophilic substitution	understand that electrophilic attack in arenes results in substitution; mechanisms limited to the monosubstitutions given below.
13.6.4	Nitration	understand that nitration is an important step in synthesis (e.g. explosive manufacture and formation of amines from which dyestuffs are manufactured). understand the mechanism of nitration, including the generation of the nitronium ion.
13.6.5	Friedel–Crafts reactions	understand that Friedel–Crafts alkylation and acylation reactions are important steps in synthesis. understand the mechanism of alkylation and acylation using $AlCl_3$ as catalyst. know that industrially ethylbenzene is manufactured from benzene and ethene using $HCl/AlCl_3$; know that this is an important intermediate in the manufacture of polystyrene (details of processes not required).

13.7 Amines

13.7.1	Base properties (Brønsted–Lowry)	be able to explain the difference in base strength between ammonia, primary aliphatic and primary aromatic amines in terms of the availability of a lone pair on the N atom.
13.7.2	Nucleophilic properties	understand that the nucleophilic substitution reactions (including mechanism) of ammonia and amines with haloalkanes form primary, secondary, tertiary amines and quaternary ammonium salts; know the use of the latter as cationic surfactants.
13.7.3	Preparation	know that primary aliphatic amines can be prepared from haloalkanes and by the reduction of nitriles. know that aromatic amines are prepared by the reduction of nitro compounds.

13.8 Amino Acids

13.8.1	Acid and base properties	understand that amino acids have both acidic and basic properties, including the formation of zwitterions.
13.8.2	Proteins	understand that proteins are sequences of amino acids joined by peptide links. understand that hydrolysis of the peptide link produces the constituent amino acids. understand the importance of hydrogen bonding in proteins (detailed structures not required).

13.9 Polymers

13.9.1 Addition polymers

know that addition polymers may be formed directly from compounds containing C=C bonds.

be able to draw polymer structures from monomer structures and vice versa.

understand that polyalkenes are chemically inert and therefore non-biodegradable.

13.9.2 Condensation polymers

understand that condensation polymers may be formed by reactions between dibasic acids and diols, between dicarboxylic acids and diamines and between amino acids.

know the linkage of the repeating units of polyesters (e.g. Terylene) and polyamides (e.g. nylon 6,6).

understand that polyesters and polyamides can be broken down by hydrolysis and are, therefore, biodegradable (mechanisms not required).

13.10 Organic Synthesis and Analysis

13.10.1 Applications

be able to use the organic reactions described above in synthesis and analysis, using the characteristic reactions of functional groups in this module and in AS3 (alkenes, haloalkanes and alcohols).

13.11 Structure Determination

13.11.1 Data sources

be able to use data from all the analytical techniques listed below to determine the structure of specified compounds.

13.11.2 Mass spectrometry

understand that mass spectrometry can be used to determine the molecular formula of a compound from the mass of the molecular ion.

understand that the fragmentation of a molecular ion

$M^{+\cdot} \rightarrow X^{+} + Y^{\cdot}$

gives rise to a characteristic relative abundance spectrum (rearrangement processes not required).

know that the more stable X^{+} species give higher peaks, limited to carbocation and acylium (RCO^{+}) ions.

13.11.3 Infra-red spectroscopy

understand that certain groups in a molecule absorb infra-red radiation at characteristic frequencies.

understand that "fingerprinting" allows identification of a molecule by comparison of spectra.

be able to use spectra to identify particular functional groups and to identify impurities, limited to data presented in wave-number form.

13.11.4 Nuclear magnetic resonance spectroscopy

understand that nuclear magnetic resonance gives information about the relative number and position of hydrogen atoms in a molecule.

understand that proton n.m.r. spectra are obtained using samples dissolved in proton-free solvents (e.g. deuterated solvents and CCl_4).

understand why tetramethylsilane (TMS) is used as a standard.

know the use of the δ scale for recording chemical shift.

understand that chemical shift depends on the molecular environment.

understand how integrated spectra indicate the relative numbers of protons in different environments.

be able to use the $n+1$ rule to deduce the spin–spin splitting patterns of adjacent, non-equivalent protons, limited to doublet, triplet and quartet formation in simple aliphatic compounds.

14

A2 Module 5

Thermodynamics and Further Inorganic Chemistry

Introduction

Energetics, introduced in the first of the foundation modules, is extended into thermodynamics by the introduction of entropy and free energy. Chemical properties of elements and compounds of Period 3 are studied to illustrate periodic trends. The study of redox chemistry reactions in AS2 is extended to include electrode potentials and their use to predict the direction of simple redox reactions. The characteristic properties of transition metal complexes are studied including their use in industry, as catalysts and in medicine.

The reactions of metal ions in aqueous solution are systematised through an understanding of hydrolysis and substitution reactions of selected metal aqua ions.

Wherever possible, candidates should carry out experimental work to illustrate the theoretical principles included in this module.

Candidates should:

14.1 Thermodynamics

14.1.1 Enthalpy change (ΔH)

be able to define and apply the terms enthalpy of formation, ionisation enthalpy, enthalpy of atomisation of an element and of a compound, bond dissociation enthalpy, electron affinity, lattice enthalpy (defined as either lattice dissociation or lattice formation), enthalpy of hydration and enthalpy of solution.

be able to construct a Born–Haber cycle for the formation of simple ionic compounds.

be able to calculate enthalpies of solution for ionic compounds from lattice enthalpies and enthalpies of hydration.

be able to use mean bond enthalpies to calculate an approximate value of ΔH for other reactions.

be able to explain why values from mean bond enthalpy calculations differ from those determined from enthalpy cycles.

14.1.2 Free-energy change (ΔG) and entropy change (ΔS)

understand that ΔH, whilst important, is not sufficient to explain spontaneous change (e.g. spontaneous endothermic reactions).

understand that the concept of increasing disorder (entropy change ΔS) accounts for the above deficiency, illustrated by physical change (e.g. melting, evaporation) and chemical change (e.g. dissolution, evolution of CO_2 from hydrogencarbonates with acid).

understand that the balance between entropy and enthalpy determines the feasibility of a reaction; know that this is given by the relationship $\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus}$ (derivation not required).

be able to calculate entropy changes from absolute entropy values.

14.2 Periodicity

14.2.1	Study of the reactions of Period 3 elements Na – Ar to illustrate periodic trends	be able to describe trends in the reactions of the elements with water, limited to Na and Mg. be able to describe the trends in the reactions of the elements Na, Mg, Al, Si, P and S with oxygen, limited to the formation of Na_2O, MgO, Al_2O_3, SiO_2, P_4O_{10} and SO_2. be able to describe the trends in the reactions of the elements Na, Mg, Al, Si and P with chlorine, limited to the formation of NaCl, $MgCl_2$, $AlCl_3$, $SiCl_4$ and PCl_5.
14.2.2	A survey of the acid-base properties of the oxides of Period 3 elements	understand the link between the physical properties of the highest oxides of the elements Na – S and their structure and bonding. be able to describe the reactions of the oxides of the elements Na – S with water, limited to Na_2O, MgO, Al_2O_3, SiO_2, P_4O_{10}, SO_2 and SO_3. know the change in pH of the resulting solutions across the Period. be able to explain the trends in these properties in terms of the type of bonding present. be able to write equations for the reactions which occur between these oxides and given simple acids and bases.
14.2.3	A survey of the reactions of the chlorides of Period 3 elements with water	understand the link between the physical properties of the chlorides of the elements Na – P and their structure and bonding. be able to describe the reactions of the chlorides of the elements Na – P with water, limited to NaCl, $MgCl_2$, $AlCl_3$, $SiCl_4$ and PCl_5. know the change in pH of the resulting solutions across the Period. be able to explain the trends in these properties in terms of the type of bonding present.

14.3 Redox Equilibria

14.3.1	Variable oxidation state	understand oxidation and reduction as electron transfer reactions applied to reactions of d block elements. know and be able to apply the rules for assigning oxidation states in order to work out the oxidation state of an element in a compound from its formula. understand that changes in oxidation state involve redox processes. be able to write half-equations identifying the oxidation and reduction processes in redox reactions when the reactants and products are specified. be able to combine half-equations to give an overall redox equation.
14.3.2	Electrode potentials	know the IUPAC convention for writing half-equations for electrode reactions. know and be able to use the conventional representation of cells. understand how cells are used to measure electrode potentials by reference to the standard hydrogen electrode and know that secondary standards are normally used.

know the importance of the conditions when measuring the electrode potential, E (Nernst equation not required).

know that standard electrode potential, $E^{\ominus}$, refers to conditions of 298 K, 100 kPa and 1.00 mol dm^{-3} solution of ions.

14.3.3 Electrochemical series

know that standard electrode potentials can be listed as an electrochemical series.

be able to use $E^{\ominus}$ values to predict the direction of simple redox reactions and to calculate the e.m.f of a cell.

14.4 Transition Metals

14.4.1 General properties of transition metals

know that transition metal characteristics of elements Ti – Cu arise from an incomplete d sub-level in atoms or ions.

know that these characteristics include complex formation, formation of coloured ions, variable oxidation state and catalytic activity.

14.4.2 Complex formation

be able to define the term ligand.

know that co-ordinate bonding is involved in complex formation.

understand that a complex is a central metal ion surrounded by ligands.

know the meaning of co-ordination number.

understand that ligands can be unidentate (e.g. H_2O, NH_3 and Cl^-)

or bidentate (e.g. $NH_2CH_2CH_2NH_2$ and $C_2O_4^{2-}$) or multidentate (e.g. $EDTA^{4-}$).

know that haem is an iron(II) complex with a multidentate ligand.

14.4.3 Shapes of complex ions

know that transition metal ions commonly form octahedral complexes with small ligands (e.g. H_2O and NH_3).

know that transition metal ions commonly form tetrahedral complexes with larger ligands (e.g. Cl^-).

know that Ag^+ commonly forms linear complexes, (e.g. $[Ag(NH_3)_2]^+$, $[Ag(S_2O_3)_2]^{3-}$ and $[Ag(CN)_2]^-$).

14.4.4 Formation of coloured ions

know that transition metal ions can be identified by their colour, limited to the complexes in this module.

know that colour changes arise from changes in oxidation state, co-ordination number and ligand.

know that colour arises from electronic transitions from the ground state to excited states: $\Delta E = h\nu$.

know the use of ultraviolet and visible spectrophotometry in determining the concentration of metal ions in solution after the addition of a suitable ligand to intensify the colour.

14.4.5	Variable oxidation states	know that transition elements show variable oxidation states.
		know that VO^{2+}, V^{3+} and V^{2+} are formed by reduction of VO_2^+ by zinc in acid solution.
		know that Cr^{3+} and Cr^{2+} are formed by reduction of $Cr_2O_7^{2-}$ by zinc in acid solution.
		know the redox titrations of Fe^{2+} with MnO_4^- and $Cr_2O_7^{2-}$ in acid solution.
		be able to perform calculations for these titrations and for others when the reductant and its oxidation product are given.
		know the oxidation of Co^{2+} by air in ammoniacal solution.
		know the oxidations in alkaline solution of Co^{2+} and Cr^{3+} by H_2O_2.
14.4.6	Catalysis	know that transition metals and their compounds can act as heterogeneous and homogeneous catalysts.
	Heterogeneous	know that a heterogeneous catalyst is in a different phase from the reactants and that the reaction occurs at the surface.
		understand that adsorption of reactants at active sites on the surface may lead to catalytic action.
		know that the strength of adsorption helps to determine the activity (e.g. W too strong adsorption, Ag too weak adsorption, and hence the utility of Ni and Pt).
		understand the use of a support medium to maximise the surface area and minimise the cost (e.g. Rh on a ceramic support in catalytic converters).
		know that V_2O_5 is used as a catalyst in the Contact Process.
		know that Fe is used as a catalyst in the Haber Process.
		know that catalysts can become poisoned by impurities and consequently have reduced efficiency; know that this has a cost implication (e.g. poisoning by sulphur in the Haber Process and by lead in catalytic converters in cars).
	Homogeneous	know that when catalysts and reactants are in the same phase, the reaction proceeds through an intermediate species (e.g. the reaction between I^- and $S_2O_8^{2-}$ catalysed by Fe^{2+} and autocatalysis by Mn^{2+} in titrations of $C_2O_4^{2-}$ with MnO_4^-).
14.4.7	Other applications of transition metal complexes	understand the importance of variable oxidation states in catalysis; both heterogeneous and homogeneous catalysts (e.g. V_2O_5 in the Contact Process and autocatalysis by Mn^{2+} in MnO_4^- titrations).
		understand that Fe(II) in haemoglobin enables oxygen to be transported in the blood, and why CO is toxic.
		know that the Pt(II) complex cisplatin is used as an anticancer drug.

understand that $[Ag(NH_3)_2]^+$ is used in Tollens' reagent to distinguish between aldehydes and ketones and that $[Ag(S_2O_3)_2]^{3-}$ is formed in photography.

know that $[Ag(CN)_2]^-$ is used in electroplating.

14.5 Reactions of Inorganic Compounds in Aqueous Solution

14.5.1 Lewis acids and bases

know the definitions of a Lewis acid and Lewis base; understand the importance of lone pair electrons in co-ordinate bond formation.

14.5.2 Metal-aqua ions

know that metal–aqua ions are formed in aqueous solution:
$[M(H_2O)_6]^{2+}$, limited to M = Fe, Co and Cu;
$[M(H_2O)_6]^{3+}$, limited to M = Al, V, Cr and Fe.

know that these aqua ions can be present in the solid state (e.g. $FeSO_4.7H_2O$ and $Co(NO_3)_2.6H_2O$).

14.5.3 Acidity or hydrolysis reactions

understand the equilibria

$[M(H_2O)_6]^{2+} + H_2O \rightleftharpoons [M(H_2O)_5(OH)]^+ + H_3O^+$ and

$[M(H_2O)_6]^{3+} + H_2O \rightleftharpoons [M(H_2O)_5(OH)]^{2+} + H_3O^+$ to show

generation of acidic solutions with M^{3+}, and very weakly acidic solutions with M^{2+}.

understand that the acidity of $[M(H_2O)_6]^{3+}$ is greater than that of $[M(H_2O)_6]^{2+}$ in terms of the polarising power (charge/size ratio) of the metal ion.

be able to describe and explain the simple test-tube reactions of

M^{2+} (aq) ions, limited to M = Fe, Co and Cu, and of M^{3+} (aq) ions,

limited to M = Al, Cr and Fe, with the bases OH^-, NH_3 and CO_3^{2-}.

know that MCO_3 is formed but that $M_2(CO_3)_3$ is not formed.

know that some metal hydroxides show amphoteric character by dissolving in both acids and bases (e.g. hydroxides of Al^{3+} and Cr^{3+}).

know the equilibrium reaction

$2CrO_4^{2-} + 2H^+ \rightleftharpoons Cr_2O_7^{2-} + H_2O$

14.5.4 Substitution reactions

understand that the ligands NH_3 and H_2O are similar in size and are uncharged, and that ligand exchange occurs without change of co-ordination number (e.g. Co^{2+} and Cr^{3+}).

know that substitution may be incomplete (e.g. the formation of $[Cu(NH_3)_4(H_2O)_2]^{2+}$).

understand that the Cl^- ligand is larger than these uncharged ligands and that ligand exchange can involve a change of co-ordination number (e.g. Co^{2+} and Cu^{2+}).

know that substitution of unidentate ligand with a bidentate or a multidentate ligand leads to a more stable complex.

understand this chelate effect in terms of a positive entropy change in these reactions.

15

A2 Module 6

Synoptic Assessment/Practical

(a) Synoptic Assessment (see Section 8.3)

(b) Either Centre-Assessed Coursework (see Sections 18 to 24).

Or Practical Examination.

The external practical examination assesses the same four skill areas as those covered by the centre-assessed coursework alternative.

These are

- Planning
- Implementing
- Analysing evidence and drawing conclusions
- Evaluating evidence and procedures

Candidates will not be permitted to use books and laboratory notebooks during the examination.

Candidates will be required to carry out a Planning exercise which will be set in the context of the two A2 modules, A2 Module 4 Further Physical and Organic Chemistry and A2 Module 5 Thermodynamics and Further Inorganic Chemistry.

The remaining three skills, Skill 2 Implementing, Skill 3 Analysing evidence and drawing conclusions and Skill 4 Evaluating evidence and procedures will be assessed by a practical exercise(s) which will be set in the same general context as that for the planning exercise although it is unlikely that the practical exercise will be the same task.

The mark scheme for the practical examination will be based on the coursework mark descriptors for the four skills which are the same for both the AS and A2.

The difference in standard of the AS and A2 depends upon related scientific knowledge and understanding and the complexity and demand of the practical activity set. For A2 practical activities will be more sophisticated and complex and will require candidates to apply knowledge, understanding and skills from the A2 part of the specification in planning experimental work and in the analysis and evaluation of data.

The guidance material for practical work which is published separately will provide examples of practical activities appropriate for AS, and for A2, and guidance on the application of the mark descriptors for the four skills. These exemplars will provide a guide to the type and complexity of the exercises that may be set in the practical examination.

Details of the apparatus and materials required for the practical examination will be sent to centres in advance of the date of the examination.

Candidates choosing the coursework alternative or the practical examination at AS do not have to follow the same form of assessment at A2.

Key Skills and Other Issues

16

Key Skills – Teaching, Developing and Providing Opportunities for Generating Evidence

16.1 Introduction

The Key Skills Qualification requires candidates to demonstrate levels of achievement in the Key Skills of *Application of Number*, *Communication* and *Information Technology*.

The units for the 'wider' Key Skills of *Improving own Learning and Performance*, *Working with Others* and *Problem Solving* are also available. The acquisition and demonstration of ability in these 'wider' Key Skills is deemed highly desirable for all candidates, but they do not form part of the Key Skills Qualification.

Copies of the Key Skills Units may be downloaded from the QCA web site (www.qca.org.uk/keyskills).

The units for each Key Skill comprises three sections:

A. What you need to know.

B. What you must do.

C. Guidance.

Candidates following a course of study based on this specification for Chemistry can be offered opportunities to develop and generate evidence of attainment in aspects of all of the Key Skills of *Communication, Application of Number, Information Technology, Improving own Learning and Performance, Working with Others* and *Problem Solving*. Areas of study and learning that can be used to encourage the acquisition and use of Key Skills, and to provide opportunities to generate evidence for Part B of the units, are signposted below. More specific guidance on integrating the delivery of Key Skills in courses based upon this specification is given in the AQA specification support material.

16.2 Key Skills Opportunities in Chemistry

The progressive development of knowledge and understanding throughout this Chemistry specification, and the requirement for candidates to be able to apply their knowledge and understanding of chemistry to new and unfamiliar problems, provides an ideal opportunity for candidates to develop their Key Skills and to show evidence of their application. The matrices below signpost the opportunities for the acquisition, development and production of evidence for Part B of the Key Skills units at *Level 3,* in the teaching and learning modules of this specification. The degree of opportunity in any one module will depend upon a number of centre-specific factors, including teacher strategies and level of resources.

Communication

What you must do:	Signposting of Opportunities for Generating Evidence in Modules					
	1	2	3	4	5	6
C3.1a Contribute to discussions	✓	✓	✓	✓	✓	✓
C3.1b Make a presentation	✓	✓	✓	✓	✓	✓
C3.2 Read and synthesise information	✓	✓	✓	✓	✓	✓
C3.3 Write different types of documents	✓	✓	✓	✓	✓	✓

Application of Number

What you must do:	Signposting of Opportunities for Generating Evidence in Modules					
	1	2	3	4	5	6
N3.1 Plan and interpret Information from different sources	✓	✓	✓	✓	✓	✓
N3.2 Carry out multi-stage calculations	✓	✓	✓	✓	✓	✓
N3.3 Present findings, explain results and justify choice of methods	✓	✓	✓	✓	✓	✓

Information Technology

What you must do:	Signposting of Opportunities for Generating Evidence in Modules					
	1	2	3	4	5	6
IT3.1 Plan and use different sources to search for and select information	✓	✓	✓	✓	✓	✓
IT3.2 Explore, develop and exchange information, and derive new information	✓	✓	✓	✓	✓	✓
IT3.3 Present information including text, numbers and images	✓	✓	✓	✓	✓	✓

Working with Others

What you must do:	Signposting of Opportunities for Generating Evidence in Modules					
	1	2	3	4	5	6
WO3.1 Plan the activity	✓	✓	✓	✓	✓	✓
WO3.2 Work towards agreed objectives	✓	✓	✓	✓	✓	✓
WO3.3 Review the activity	✓	✓	✓	✓	✓	✓

Improving own Learning and Performance

What you must do:	Signposting of Opportunities for Generating Evidence in Modules					
	1	2	3	4	5	6
LP3.1 Agree and plan targets	✓	✓	✓	✓	✓	✓
LP3.2 Seek feedback and support	✓	✓	✓	✓	✓	✓
LP3.3 Review progress	✓	✓	✓	✓	✓	✓

Problem Solving

What you must do:	Signposting of Opportunities for Generating Evidence in Modules					
	1	2	3	4	5	6
PS3.1 Recognise, explain and describe the problem	✓	✓	✓	✓	✓	✓
PS3.2 Generate and compare different ways of solving problems	✓	✓	✓	✓	✓	✓
PS3.3 Plan and implement options	✓	✓	✓	✓	✓	✓
PS3.4 Agree and review approaches to tackling problems	✓	✓	✓	✓	✓	✓

N.B. The signposting in the six tables above represents opportunities to acquire, and produce evidence of the Key Skills which are possible through this specification. There may be other opportunities to achieve these and other aspects of Key Skills, but these are dependent on the detailed course of study delivered within centres.

16.3 Key Skills in the Assessment of Chemistry

Key Skills are not assessed in the context of this specification with the exception of the quality of written communication which is an intrinsic part of all four Assessment Objectives.

16.4 Further Guidance

More specific guidance and examples of tasks that can provide evidence of one or more Key Skills are given in the AQA specification support material.

17 Spiritual, Moral, Ethical, Social, Cultural and Other Issues

17.1 Spiritual, Moral, Ethical, Social and Cultural Issues

The study of Chemistry can contribute to an understanding of ethical issues, including recognising and valuing the world, and taking responsibility for one's actions. Within this specification, there is scope for candidates to discern, consider and discuss values and attitudes, explore dilemmas and effects of change within society. The following topics provide opportunities for candidates to make judgements and decisions on the contribution that chemistry makes to society.

- Uses of chlorine 11.5.4
- Recycling of metals 11.6.4
- Catalytic converters 12.2.3
- Uses of epoxyethane 12.3.3
- Ethanol 12.5.1
- Esters, plasticisers and food flavourings 13.5.2
- Explosives and dyestuffs 13.6.4
- Biodegradable polymers 13.9.2
- Anticancer drugs and photography 14.4.7

17.2 Environmental Education

AQA has taken account of the 1988 Resolution of the Council of the European Community and the Report *"Environmental Responsibility: An Agenda for Further and Higher Education"* 1993 in preparing this specification and associated specimen papers. This specification has been designed to foster responsible attitudes towards the preservation, and improvement of the environment. The following topics provide appropriate opportunities for the consideration of environmental issues.

- Uses of chlorine 11.5.4
- Extraction and recycling of metals 11.6.1, 11.6.4
- Petroleum: fuels, plastics, detergents and drugs 12.2.3, 12.3.3, 13.5.3
- Alcohols: solvent and raw material 12.5.1
- Polymers: production and biodegradability 13.9.1, 13.9.2
- Transition elements as industrial catalysts 14.4.6

17.3 Avoidance of Bias

AQA has taken great care in the preparation of this specification and associated specimen papers to avoid bias of any kind.

17.4 Mathematical Requirements

In order to be able to develop the knowledge, understanding and skills in Section 6 above, candidates need to have been taught and to have acquired competence in the areas of mathematics set out below. Material relevant only to the full A Level is given in bold type.

Arithmetic and computation

Candidates should be able to:

- recognise and use expressions in decimal and standard form;
- use ratios, fractions and percentages;
- make estimates of the results of calculations (without using a calculator);
- **use calculators to find and use x^n, $1/x$, e^x, $\log_{10} x$, $\sqrt{x}$**

Handling data

Candidates should be able to:

- use an appropriate number of significant figures;
- find arithmetic means.

Algebra

Candidates should be able to:

- change the subject of an equation;
- substitute numerical values into algebraic equations using appropriate units for physical quantities;
- **use logarithms in relation to quantities which range over several orders of magnitude.**

Geometry

Candidates should be able to:

- appreciate angles and shapes in regular 2-D and 3-D structures;
- visualise and represent 2-D and 3-D forms including two dimensional representations of 3-D objects;
- understand the symmetry of 2-D **and 3-D shapes.**

Graphs

Candidates should be able to:

- translate information between graphical, numerical and algebraic forms;
- plot two variables from experimental or other data;
- understand that y = mx + c represents a linear relationship;
- determine the slope and intercept of a linear graph;
- **draw and use the slope of a tangent to a curve as a measure of rate of change.**

17.5 Terminology

The terminology used in the written papers will be that described in the AQA (NEAB) leaflet *GCE Chemistry: Nomenclature, units and conventions to be used in question papers* (Chem. 5B, May 1987). The overriding consideration in setting papers will continue to be clarity and lack of ambiguity rather than adherence to strict rules; alternative names or formulae will be given whenever ambiguity might otherwise arise. The use in a candidate's answer of names, formulae or units other than those recommended in the AQA (NEAB) leaflet will not be penalised, provided that the essential chemical information is correctly supplied in the answer.

17.6 Periodic Table

At the beginning of the course, candidates should be supplied with the AQA version of the Periodic Table/Data Sheet printed on white card (CHEM/PT). Copies of this are available from the Publications Department.

Additionally, a version of the AQA Periodic Table/Data Sheet will be provided as a perforated sheet in each question paper, including the Practical Examinations.

A Sample of the Periodic Table/Data Sheet is provided in Appendix D.

17.7 Health and Safety

Attention is drawn to the hazards associated with many materials and processes referred to in the specification. Detailed information may be found in the pamphlets on safety issued by the Department for Education and Skills. Centres are reminded of the requirements to make their own risk assessments under the COSHH regulations.

Centre-Assessed Coursework

18

Nature of Centre-Assessed Coursework

Within the Schemes of Assessment, assessment unit 3(b) of the AS and assessment unit 6(b) of the A2, form the coursework elements. Unit 3(b) will contribute 15% to the AS and 7½% to the A Level. Unit 6(b) will contribute 5% to the A Level. Overall, coursework contributes 12½% to the A Level examination and centres should apportion a commensurate amount of time for learning opportunities and assessment of practical skills. In each of AS and A2, the time required for the assessment of practical work is normally expected to be approximately 15 hours in total, most of which will be supervised laboratory time.

The skills to be assessed during coursework are listed in the Assessment Objectives (Section 6) and Schemes of Assessment (Sections 7 and 8) of the specification. These are:

- Planning
- Implementing
- Analysing evidence and drawing conclusions
- Evaluating evidence and procedures

It is intended that the internal assessment of candidates' performance in the four skills is made during normal coursework and should be an integral part of the scheme of work for both the AS and the A2. It is a continuous process and not separate or additional to the normal teaching programme. It is important therefore that the teaching programme should include activities designed to develop the skills and that assessments should arise naturally from coursework activities rather than from a series of practical tests.

Centres must advise AQA of their intention to enter candidates on form, *Estimated Entries* so that early contact can be made with new centres.

19

Guidance on Setting Centre-Assessed Coursework

It is important that teachers consider carefully the types of activities which will provide valid evidence of positive achievement for the purpose of assessment. The activities in which candidates are involved should be chosen to make reasonable demands and to enable positive achievements to be demonstrated in relation to the assessment criteria.

Guidance on suitable activities appropriate for AS and for A2, and on the application of the mark descriptors, is provided in the support material accompanying this specification and will be available at standardising meetings (see Section 22.1) and on request from AQA. Centres are encouraged to seek advice as to whether their proposed activities are appropriate by contacting AQA or their Coursework Adviser.

The assessment criteria allow the four skills to be assessed individually, or for them to be assessed together. This approach allows for the assessment of **planning** in an activity in which, for example, spectroscopy might be suggested but where it is not possible actually to implement the plan in most centres. It is also important to realise that not all candidates need to be assessed on any one activity. Where more than one skill is assessed in an activity, care must be taken to ensure that a candidate's performance in one skill does not adversely affect the scope to demonstrate attainment in another. For example, having been assessed on planning an experiment, a candidate may be given help to modify or plan before proceeding to the implementation part of the experiment. Similarly, if a candidate fails to obtain satisfactory results from an experiment, additional data may be provided for analysing evidence and drawing conclusions.

The nature of such guidance should be clearly shown on the candidate's work. No help should be given **during** assessment of a particular skill (unless it is to prevent unsafe, unethical or environmentally unacceptable practices), and should only occur so that assessment of other skills is not adversely affected. Guidance must be limited to the minimum required in order to demonstrate the other skills.

Candidates are not permitted to use books and laboratory notebooks during practical assessments.

The AQA does not intend to specify the number, type and length of activities; individual activities will depend on the scheme of work adopted by a centre. However, it is expected that the range of assessment exercises will reflect and emphasise the scientific approach to the study of the subject content of both the AS and the A2 specification. The links between the coursework skills and the knowledge, skills and understanding described in the subject content are fundamental in designing the activities.

20 Assessment Criteria

20.1 Introduction

Marks should be awarded for the four skills listed below for both the AS and the A2. The mark descriptors for the four skills are the same for both AS and A2. The difference in standard of AS and A2 depends upon the related scientific knowledge and understanding and the complexity and demand of the practical activity set. Standards are set by the use of mark criteria which describe the performance expected for a particular mark in each skill area. The marks submitted to AQA should be awarded using only the scales defined by the mark criteria printed in Section 20.2 of this specification.

The skills to be assessed are:

- Skill 1 Planning
- Skill 2 Implementing
- Skill 3 Analysing evidence and drawing conclusions
- Skill 4 Evaluating evidence and procedures

It is not expected that candidates will satisfy all the attributes of a mark descriptor in order for the mark to be awarded. The descriptors are written to guide the professional judgement of teachers in awarding marks for a particular skill. Depending on the experimental activity chosen, some attributes will be more significant than others.

For the AS specification, practical assessments should be based on the subject content of at least two of the three AS modules. The final total mark must be obtained from each of the four skill areas and be based on the subject content of at least two of the three AS modules. The number of occasions on which skills are assessed is left to the discretion of individual centres. If a skill is assessed more than once the best mark should contribute to the final total mark provided that the final total mark is obtained from at least two of the three AS modules.

For the A2 specification, practical assessments should be based on the subject content of the two A2 modules. The final total mark must be obtained from each of the four skill areas and be based on the subject content of the two A2 modules. The number of occasions on which skills are assessed is left to the discretion of individual centres. If a skill is assessed more than once the best mark should contribute to the final total mark provided that the final total mark is obtained from the two A2 modules.

Centres should be aware that if an assessment, set in the context of AS, is submitted for A2, access to the highest marks will be limited.

20.2 Criteria for each skill area

Skill 1 Planning

Candidates are expected to

- identify and define a problem and/or formulate a plan to carry out an experiment or a multi-stage activity using available information and knowledge of Chemistry;
- retrieve and evaluate information from multiple sources, where appropriate, possibly including computer databases;
- organise the procedure to be followed, selecting appropriate technique(s), reagents and apparatus, with due regard to precision of measurement, purity of reagents and products, safety and scale of working and, where appropriate, the control of variables.

Skill 2 Implementing

Candidates are expected to

- demonstrate the manipulative skills needed for specific chemical techniques used in the laboratory showing a due regard for safety;
- make and record accurate and detailed observations and/or measurements to a degree of precision allowed by the apparatus used, including, where appropriate, the logging and processing of data using information technology;
- carry out experimental work in appropriate contexts involving specific chemical techniques such as separation, purification, measurement of physical properties, qualitative and quantitative exercises and/or an ability to obtain the product of a multi-stage preparative activity in appropriate quantity and quality.

Skill 3 Analysing evidence and drawing conclusions

Candidates are expected to

- present their work appropriately in written, graphical or other forms using chemical nomenclature and terminology;
- interpret information obtained from experimental activities including the manipulation of data, the recognition of patterns and trends in a set of data or information, the identification of sources of error and recognition of the limitations of experimental measurements;
- draw valid conclusions in quantitative activities by applying their knowledge and understanding of Chemistry, reporting quantitative data to an appropriate number of significant figures;

OR

- draw valid conclusions in qualitative activities by applying their knowledge and understanding of Chemistry to both positive and negative inferences from information or data gathered;

OR

- prove the purity and/or structure of the product obtained from a multi-stage preparative activity by appropriate analytical technique(s) which may include the application of data from instrumental techniques.

Skill 4 Evaluating evidence and procedures

Candidates are expected to

- assess the reliability of their data and the conclusions drawn from them, taking into account the errors in the data obtained in quantitative work;

OR

- consider whether the evidence collected in qualitative work is sufficient to enable firm conclusions to be drawn;

OR

- consider whether the quantity and/or purity of the product obtained in a multi-stage preparative activity is adequate for the technique(s) used;
- evaluate the techniques used in experimental activity, recognising their limitations and suitability, and accounting for any anomalous results obtained;

OR

evaluate the technique(s) used in a multi-stage preparative activity and account for any deficiencies in the quantity and purity of the product obtained.

20.3 Specific marking criteria for each skill area

The marking criteria for each skill area are recorded on a four-point scale at 2, 4, 6 and 8 marks for each of skills 1, 2 and 3 and on a three-point scale at 2, 4 and 6 marks for skill 4. The performance needed to gain 6 marks in skill area 4 is commensurate with that for 8 marks in each of the other three skill areas. The mark descriptors should be used to judge which mark best fits the candidate's performance. The statements should not be taken as discrete and literal hurdles, all of which must be fulfilled for a mark to be awarded. Opportunities are provided for intermediate marks to be awarded when performance exceeds one description and only partially satisfies the next. A candidate who fails to meet the requirements for 2 marks, but who has made a creditworthy attempt in the skill area should be given 1 mark for that skill.

A mark of zero should not normally be awarded since it would indicate that the candidate had displayed no skill whatsoever in the ability being assessed on a particular occasion. It may be necessary, however, on rare occasions to award zero but even candidates who receive such a mark on one or two occasions are unlikely to be given a final mark of zero for a particular skill.

Skill 1 Planning

The candidate

8 marks

- can identify and define a problem and/or formulate a clear and complete plan independently to carry out an experiment or a multi-stage activity;
- is able to make a full evaluation of the information given to inform the planning process and, where appropriate, can retrieve all necessary information from other sources;
- can describe the method or procedure to be used in great detail; techniques, reagents and apparatus are appropriately selected with full appreciation of scale and precision; takes all necessary safety aspects into account.

6 marks

- can identify and define a problem and/or formulate a plan to carry out an experiment or a multi-stage activity with little assistance except with detail;
- is able to make a good evaluation of the information given to inform the planning process and, where appropriate, can retrieve some information from other sources;
- can describe the method or procedure to be used in detail; techniques, reagents and apparatus are mainly appropriate, but scale or precision are not fully appreciated; takes into account most necessary safety aspects.

4 marks

- can identify and define a problem and/or formulate a plan to carry out an experiment or a multi-stage activity given some assistance;
- is able to make some evaluation of information given to inform the planning process;
- can describe the method or procedure to be used in some detail; techniques, reagents and apparatus are mainly appropriate, but with little appreciation of scale or precision; takes some account of necessary safety aspects.

2 marks

- can identify and define a problem and/or formulate a plan to carry out an experiment or a multi-stage activity only with a great deal of assistance;
- is able to make only a limited evaluation of information given to inform the planning process;
- can describe the method or procedure to be used but gives little detail; techniques, reagents and apparatus are mainly appropriate, but with no appreciation of scale or precision; takes little account of necessary safety aspects.

Although centres will wish to review a candidate's plan as part of the teaching process, a candidate's mark for a planning exercise cannot be improved during this review. Centres wishing to improve candidates' marks for this skill must provide candidates with another, different planning exercise.

Skill 2 Implementing

The candidate

8 marks

- can demonstrate a range of manipulative skills with considerable dexterity, taking into account all necessary safety aspects;
- can make all of the required observations with due regard to accuracy and detail and/or can take most measurements with a precision within that of the apparatus. The recording is complete and presented in an appropriate form;
- can carry out experimental work and complete the activity without guidance.

6 marks

- can demonstrate a range of manipulative skills with dexterity, making only occasional mistakes and taking into account most necessary safety aspects;
- can make all of the required observations in a methodical and organised way, but some are inaccurate and/or can take many measurements with a precision within that of the apparatus. The recording is mostly complete and presented in an appropriate form;
- can carry out experimental work and complete the activity with only occasional guidance.

4 marks

- can demonstrate a range of manipulative skills with limited dexterity and has some regard for safety;
- can make an adequate number of the required observations but some are inaccurate and/or can take some measurements with a precision within that of the apparatus. The recording is mostly complete but presented in an inappropriate form;
- can carry out experimental work and complete the activity when given some guidance.

2 marks

- can use apparatus and chemicals but lacks dexterity and shows little regard for safety;
- can make a few of the required observations and most are accurate and/or can take some measurements but with a precision well below that of the apparatus. The recording is incomplete or presented in an inappropriate form, but with at least some of the information (e.g. some of the units) given correctly;
- can carry out experimental work and complete the activity only when given considerable guidance.

Skill 3 Analysing evidence and drawing conclusions

The candidate

8 marks

- can make a good use of all necessary chemical nomenclature and terminology when presenting work;
- is able to interpret the main information obtained from experimental activities successfully without assistance; can perform calculations correctly, if appropriate to the activity, reporting all of the values to an appropriate number of significant figures, can recognise patterns and trends in a set of data or information and, where appropriate, has a good qualitative and good quantitative appreciation for errors in the values obtained or limitations in the observations made;
- is able to use chemical knowledge to draw conclusions which are correct from data or information, without assistance OR can use chemical knowledge to make a correct analysis of the purity and structure of the product obtained from a multi-stage preparative activity independently.

6 marks

- can make use of almost all necessary chemical nomenclature and terminology when presenting work;
- is able to interpret the main information obtained from experimental activities successfully with little assistance; can perform calculations correctly, if appropriate to the activity, but makes minor mistakes and/or reports only some of the values to an appropriate number of significant figures, can recognise patterns and trends in a set of data or information and, where appropriate, has a good qualitative and some quantitative appreciation for errors in the values obtained or limitations in the observations made;
- is able to use chemical knowledge to draw conclusions which are essentially correct from data or information, with little assistance OR can use chemical knowledge to make an essentially correct analysis of the purity and structure of the product obtained from a multi-stage preparative activity with little assistance, but makes minor mistakes.

4 marks

- can make some use of chemical nomenclature and terminology when presenting work;
- is able to make some interpretation of information obtained from experimental activities but some help is required; can make reasonable progress in calculations, if appropriate to the activity, can recognise patterns and trends in a set of data or information and, where appropriate, has some qualitative appreciation for errors in the values obtained or limitations in the observations made;
- is able to use chemical knowledge to draw conclusions which are mainly appropriate from data or information, but some help is required OR can use chemical knowledge to make a comment on the purity and/or structure of the product obtained in a multi-stage preparative activity, but some help is required.

2 marks

- can make only a limited use of chemical nomenclature and terminology when presenting work;
- is able to make a limited interpretation of information obtained from experimental activities only with considerable assistance; can make some progress with calculations, if appropriate to the activity, can recognise simple patterns and trends in a set of data or information and, where appropriate, has little appreciation for errors in the values obtained or limitations in the observations made;
- is able to use some chemical knowledge to draw simple conclusions from data or information only with considerable assistance OR can make a limited comment on the purity and/or structure of the product obtained in a multi-stage preparative activity.

Skill 4 Evaluating evidence and procedures

The candidate

6 marks

- is able to make a good evaluation of the reliability of the evidence or the data collected and can judge whether firm conclusions can be drawn from it OR has a good understanding that there are deficiencies in both the quantity and the purity of the product obtained in a multi-stage preparative activity and that these result from either side reactions or from handling losses in the technique(s) used;
- is able to make a good evaluation of the limitations and suitability of the technique(s) used in experimental activity, can comment upon and account for anomalous results or observations and can identify almost all areas for improvement OR has a good qualitative and some quantitative understanding why there are deficiencies in both the quantity and purity of the product obtained in a multi-stage preparative activity and whether the technique(s) used is adequate for the activity and can identify almost all areas for improvement of the technique(s) used.

4 marks

- is able to make some evaluation of the reliability of the evidence or the data collected and is able to comment on the validity of the conclusions drawn from it OR has some understanding that there are deficiencies in both the quantity and the purity of the product obtained in a multi-stage preparative activity;
- is able to make some evaluation of the limitations and suitability of the technique(s) used in experimental activity, can make some useful comment on anomalous results or observations and can identify several areas for improvement OR has a good qualitative understanding why there are deficiencies in the quantity and/or purity of the product obtained in a multi-stage preparative activity and whether the technique(s) used is adequate for the activity and can identify several areas for improvement of the technique(s) used.

2 marks

- is able to make only a limited evaluation of the reliability of the evidence or the data collected and the conclusions drawn from it OR has little understanding that there are deficiencies in the quantity and/or purity of the product obtained in a multi-stage preparative activity;
- is able to make only a limited evaluation of the limitations and suitability of the technique(s) used in experimental activity, can make little comment on anomalous results or observations and can identify few areas for improvement OR has little appreciation whether the quantity and/or purity of the product obtained in a multi-stage preparative activity is adequate for the technique(s) used and can identify few areas for improvement of the technique(s) used.

20.4 Evidence to Support the Award of Marks

When the assessments are complete, the final marks awarded under each of the assessment criteria must be entered on the Candidate Record Form, with supporting information given in the spaces provided. Specimen Candidate Record Forms appear in Appendix B; the exact design may be modified before the operational version is issued. The Candidate Record Form must be attached to the candidate's work.

Coursework must be presented in a clear and helpful way for the moderator. It must be annotated to identify, as precisely as possible, where in the work the relevant assessment criteria have been satisfied so that the reasons why marks have been awarded are clear. An indication must also be given at the appropriate point in the work, or in accompanying information, of any further guidance given by the teacher (or other person) which has significant assessment implications.

21 Supervision and Authentication

21.1 Supervision of Candidates' Work

Candidates' work for assessment must be undertaken under conditions which allow the teacher to supervise the work and enable the work to be authenticated. As much coursework as possible must be conducted in the laboratory under the direct supervision of teachers. If it is necessary for candidates to undertake assessed activities outside this supervision, sufficient work must be undertaken under direct supervision to allow the teacher to authenticate each candidate's whole coursework with confidence.

21.2 Guidance by the Teacher

The work assessed must be solely that of the candidate concerned. Any assistance given to an individual candidate which is beyond that given to the group as a whole must be recorded on the Candidate Record Form.

It is perfectly acceptable for parts of a candidate's coursework to be taken from other sources as long as all such cases are clearly identified in the text and fully acknowledged either on the Candidate Record Form or in the supporting evidence. Where phrases, sentences or longer passages are quoted directly from a source, candidates should use quotation marks.

21.3 Unfair Practice

At the start of the course, the supervising teacher is responsible for informing candidates of the AQA Regulations concerning malpractice. Candidates must not take part in any unfair practice in the preparation of coursework to be submitted for assessment, and must understand that to present material copied directly from books or other sources without acknowledgement will be regarded as deliberate deception. Centres must report suspected malpractice to AQA. The penalties for malpractice are set out in the AQA Regulations.

21.4 Authentication of Candidates' Work

Both the candidate and the teacher are required to sign declarations on the Candidate Record Form, confirming that the work submitted for assessment is the candidate's own. The teacher declares that the work was conducted under the specified conditions, and records details of any additional assistance.

22 Standardisation

22.1 Standardising Meetings

Annual standardising meetings will usually be held in the autumn term. Centres entering candidates for the first time must send a representative to the meetings. Attendance is also mandatory in the following cases:

- where there has been a serious misinterpretation of the specification requirements;
- where the nature of coursework tasks set by a centre has been inappropriate;
- where a significant adjustment has been made to a centre's marks in the previous year's examination.

Otherwise, attendance is at the discretion of centres. At these meetings support will be provided for centres in the development of appropriate coursework tasks and assessment procedures.

22.2 Internal Standardisation of Marking

The centre is required to standardise the assessments across different teachers and teaching groups to ensure that all candidates at the centre have been judged against the same standards. If two or more teachers are involved in marking a component, one teacher must be designated as responsible for internal standardisation. Common pieces of work must be marked on a trial basis and differences between assessments discussed at a training session in which all teachers involved must participate. The teacher responsible for standardising the marking must ensure that the training includes the use of reference and archive materials, such as work from a previous year or examples provided by AQA. The centre is required to send to the moderator a signed Centre Declaration Sheet confirming that the marking of centre-assessed work at the centre has been standardised. If only one teacher has undertaken the marking, that person must sign this form.

22.3 Centre Consortium

Where candidates from different centres have been taught together, and standardisation of marking has been carried out, candidates should be treated as a single group for the purposes of moderation. In this case the Processing - Examining Department at AQA must be informed in advance of the moderation period.

23 Administrative Procedures

23.1 Recording Assessments

The candidates' work must be marked according to the assessment criteria set out in Section 20.2 It is important that during the course teachers keep records of a candidate's progress in all four skill areas, of the activities on which assessments have been made, and of the specific skill areas assessed, in a form which facilitates the complete and accurate submission of the final overall assessments at the end of the course.

The candidates' records of coursework carried out for the purposes of assessment are to be kept in a loose-leaf A4 size folder. These records are to be prefaced by a completed Candidate Record Form. A sample of these experimental records will be required from each centre to assist in the moderation process. They should also be available on request to the moderator.

At the beginning of the course, centres must inform AQA on Form A (*Estimated Entries*) of the approximate number of candidates to be entered for the examination so that the appropriate number of Candidate Record Forms and Centre Declaration Sheets may be sent.

23.2 Submitting Marks and Sample Work for Moderation

The total component mark for each candidate must be submitted to AQA on the *Centre Mark Sheet* provided or by Electronic Data Interchange (EDI) by 10 January (January series) or 15 May (June series. At the same time the moderator should be sent the second and third copies of the *Centre Mark Sheet*. For EDI centres, two copies of a printout of candidates' marks should be sent. Centres will be informed which candidates' work is required in the sample to be submitted to the moderator.

23.3 Problems with Individual Candidates

Teachers should be able to accommodate the occasional absence of candidates by ensuring that the opportunity is given for them to make up missed assessments.

The marks for candidates where no assessment can be made for one or more skills should be aggregated in the normal way, using a zero mark where no assessment is possible. Where it is not possible to make any assessment for a candidate for the coursework as a whole, no mark should be awarded and "ABS" should be recorded on the mark sheets.

Special consideration should be requested for candidates whose work has been affected by illness or other exceptional circumstances. Details are available from AQA and centres should ask for a copy of *Regulations and Guidance relating to Candidates with Particular Requirements.*

If work is lost, AQA should be notified immediately of the date of the loss, how it occurred, and who was responsible for the loss. AQA will advise on the procedures to be followed in such cases.

Where special help which goes beyond normal learning support is given, AQA must be informed so that such help can be taken into

account when assessment and moderation take place.

Candidates who move from one centre to another during the course sometimes present a problem for a scheme of internal assessment. Possible courses of action depend on the stage at which the move takes place. If the move occurs early in the course the new centre should take responsibility for assessment. If it occurs late in the course it may be possible to accept the assessments made at the previous centre. Centres should contact AQA at the earliest possible stage for advice about appropriate arrangements in individual cases.

23.4 Retaining Evidence and Re-Using Marks

The centre must retain the work of all candidates, with *Candidate Record Forms* attached, under secure conditions, from the time it is assessed, to allow for the possibility of an enquiry upon results. The work may be returned to candidates after the issue of results provided that no enquiry upon result is to be made which will include re-moderation of the coursework component. If an enquiry upon result is to be made, the work must remain under secure conditions until requested by AQA.

Candidates who wish to re-sit a unit containing coursework may carry forward the moderated coursework mark under the conditions outlined in the *AQA Administrative Procedures* booklet. Marks for the Practical Examination may not be carried forward.

Candidates re-taking Unit 3 or Unit 6 may wish to submit new coursework. In this case the requirements outlined in Section 20.1 must be fulfilled and, in addition, the new marks must be obtained from different investigations from those used in the original assessment. If the work of such a candidate is requested by the moderator, all of the work supporting the new total mark must be sent. Centres should be aware that the marks submitted for all skills (both old and new) will be moderated.

24 Moderation

24.1 Moderation Procedures

Moderation of the coursework is by inspection of a sample of candidates' work, sent by post from the centre to a moderator appointed by AQA. The centre marks must be submitted to AQA by 10 January (January series) or 15 May (June series) in the year in which the qualification is awarded on the *Centre Mark Sheet* provided by AQA.

Following the re-marking of the sample work, the moderator's marks are compared with the centre marks to determine whether any adjustment is needed in order to bring the centre's assessments into line with standards generally. In some cases it may be necessary for the moderator to call for the work of other candidates. In order to meet this possible request, centres must have available the coursework and Candidate Record Forms of every candidate entered for the examination and be prepared to submit it on demand. Mark adjustments will normally preserve the centre's order of merit, but where major discrepancies are found, AQA reserves the right to alter the order of merit.

24.2 Post-Moderation Procedures

On publication of the GCE results, the centre is supplied with details of the final marks for the coursework component.

The candidates' work is returned to the centre after the examination. The centre receives a report form from the moderator giving feedback to the centre on the appropriateness of the tasks set, the accuracy of the assessments made, and the reasons for any adjustments to the marks.

Some candidates' work may be retained by AQA for archive purposes.

Awarding and Reporting

25 Grading, Shelf-Life and Re-Sits

25.1 Qualification Titles

The qualifications based on these specifications have the following titles:

AQA Advanced Subsidiary GCE in Chemistry

AQA Advanced Level GCE in Chemistry

25.2 Grading System

Both the AS and the full A Level qualifications will be graded on a five-grade scale: A, B, C, D and E. Candidates who fail to reach the minimum standard for grade E will be recorded as U (unclassified) and will not receive a qualification certificate.

Individual assessment unit results will be certificated.

25.3 Shelf-Life of Unit Results

The shelf-life of individual unit results, prior to certification of the qualification, is limited only by the shelf-life of the specification.

25.4 Assessment Unit Re-Sits

Each assessment unit may be re-taken an unlimited number of times within the shelf-life of the specification. The best result will count towards the final award. Candidates who wish to repeat an award must enter for at least one of the contributing units and also enter for certification (cash-in). There is no facility to decline an award once it has been issued.

25.5 Carrying Forward of Coursework Marks

Candidates re-taking a unit containing coursework may carry forward the moderated coursework marks. These marks have a shelf-life which is limited only by the shelf-life of the specification, and they may be carried forward an unlimited number of times within this shelf-life. Marks for the Practical Examination may not be carried forward.

25.6 Minimum Requirements

Candidates will be graded on the basis of work submitted for assessment. Zero marks rather than absent will be recorded where no work for a component has been submitted.

25.7 Awarding and Reporting

This specification complies with the grading, awarding and certification requirements of the current GCSE, GCSE in vocational subjects, GCE, VCE, GNVQ and AEA Code of Practice 2006/7 and will be revised in the light of any subsequent changes for future years.

Appendices

A Grade Descriptions

The following grade descriptors indicate the level of attainment characteristic of the given grade at A Level. They give a general indication of the required learning outcomes at each specific grade. The descriptors should be interpreted in relation to the content outlined in the specification; they are not designed to define that content.

The grade awarded will depend in practice upon the extent to which the candidate has met the assessment objectives (as in Section 6) overall. Shortcomings in some aspects of the examination may be balanced by better performances in others.

Grade A Candidates recall and use chemical knowledge from the whole specification with few significant omissions and show good understanding of the principles and concepts they use. They are thoroughly conversant with the construction of chemical equations and use them quantitatively in a range of contexts. They select chemical knowledge relevant to most situations and present their ideas clearly and logically, making use of appropriate chemical terminology.

Candidates carry out calculations in a logical manner even when little guidance is given. They demonstrate good understanding of principles, applying them in familiar and new contexts, *for example, in determining the order of reaction from empirical results, in predicting the conditions which might be used in an industrial process, in using knowledge of the periodic table to predict reactions of unfamiliar elements or compounds or in predicting the reactions of organic compounds containing specific functional groups.* They bring together and use knowledge and understanding from more than one area of the specification, *for example, in suggesting a method of synthesising a particular compound or in interpreting evidence relating to the structure of a molecule or ion.*

In experimental activities, candidates independently formulate a clear and accurate plan. They use a range of manipulative techniques safely and skilfully, making and recording observations with appropriate precision. They interpret, explain and evaluate results, using appropriate chemical knowledge and terminology.

Grade C Candidates recall chemical knowledge from many parts of the specification and show good understanding of some fundamental principles and concepts. They routinely represent most reactions, *for example, those for inorganic redox processes,* by chemical equations and use them quantitatively. They frequently select chemical knowledge relevant to a particular situation or context and present their ideas clearly and logically, making use of chemical terminology.

Candidates carry out a range of calculations, making progress in some where little guidance is given. They show knowledge of fundamental principles in applying these in some new contexts*, for example, in using information about reactions to distinguish between compounds containing different functional groups.* They bring together information from more than one area of the specification in interpreting information, *for example, in explaining trends in K_a for a range of organic acids.*

In experimental activities, candidates formulate a plan which may need some modification. They use a range of techniques safely, making and recording observations and measurements which are adequate for the task. They interpret and explain experimental results, relating these to chemical knowledge and understanding and, with help, evaluate how good their results are.

Grade E

Candidates recall chemical knowledge from some parts of the specification and demonstrate some understanding of fundamental principles and concepts, *for example, in relating the properties of some compounds to the bonding found in them.* They write chemical equations for straightforward, frequently-encountered chemical reactions and use simple equations quantitatively. They select discrete items of knowledge in response to structured questions and use basic chemical terminology.

Candidates carry out straightforward calculations where guidance is given. They apply knowledge and chemical principles contained within the specification to material presented in a familiar or closely related context, *for example, in using information about reactions to identify the functional groups in some organic compounds.* They use some fundamental chemical skills in contexts which bring together different areas of the subject.

In experimental activities, candidates formulate some elements of a practical approach when provided with guidance. They carry out frequently encountered practical procedures in a reasonably skilful manner, recognising the risks in familiar procedures and obtain some appropriate results. They interpret and explain some experimental results but need assistance to relate these to chemical knowledge and understanding.

The Candidate Record Forms have been deleted from this specification because of changed requirements. The latest version of the forms are on the Coursework Administration pages of the Website.

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C

Overlaps with Other Qualifications

GCE Qualifications

Biology

There are no overlaps with Biology.

Environmental Science

There is a minimal overlap with Section 14.4. Acid rain caused by fossil fuels.

Physics

There are no overlaps with Physics.

Science for Public Understanding

There is a marginal overlap with Section 10.3. Air Quality.

AVCE Qualifications

Science

There are some overlaps with the following units.

Unit 3	Controlling Chemical Processes
Unit 5	Synthesising Organic and Biochemical Compounds
Unit 6	Carrying out Scientific Investigations
Unit 12	Colour Chemistry