Please read in conjunction with the information provided in the introductory section above.

CHEMISTRY TEST SPECIFICATION

1 AIMS

The AEA in chemistry should encourage candidates to:

- bring together knowledge of ways in which different areas of chemistry relate to each other;
- demonstrate their depth of knowledge and understanding of the material within the Advanced GCE through:
  - applying chemical concepts in novel contexts;
  - critical analysis of chemical information, such as experimental methods or data;
  - proposing solutions to chemical problems; and
  - evaluating information and evidence about how chemistry is used and applied in society.

2 CONTENT

The AEA in chemistry will be based on the following sections taken from the Advanced Subsidiary and Advanced GCE level subject criteria for chemistry.

The AEA in chemistry will require students to demonstrate:

- knowledge and understanding set out in sections 1.1 to 1.10 of Appendix 1;
- the skills of analysing and evaluating evidence included within section 2 of Appendix 1;
- the mathematical techniques included within section 3 of Appendix 1;
- other content identified and agreed as common to all Advanced GCE chemistry specifications.

The content of these sections is listed fully in Appendix 1.

3 ASSESSMENT OBJECTIVE

The AEA in chemistry will assess candidates' abilities to apply and communicate effectively their understanding of chemistry, using the skills of critical analysis, evaluation, synthesis and by applying mathematical techniques to chemical contexts.

4 SCHEME OF ASSESSMENT

Supervision and duration of assessment

External assessment should be a timed written examination of three hours taken under normal examination conditions. It should contain 4 to 6 questions adopting different approaches. Questions should use contexts which interest and stimulate candidates.

There should be a choice of one out of two alternatives in at least one of the questions. Where there are alternatives within a question, these should be based on the same approach, should be of a similar style, and assess similar skills.

There should be a balance within the paper across the main areas of chemistry.

In some problem solving questions, including those requiring quantitative work, candidates should be given no guidance about approach. When guidance is given, it should be kept to a minimum.

The paper should include questions, using the following or similar approaches:

i) candidates are provided with unfamiliar information, for example, spectra, reaction sequences, details of properties, and are asked to apply existing knowledge and understanding to the context of the material, for example, to predict products, identify compounds, suggest mechanisms, evaluate uses of products;

ii) candidates are provided with data related to laboratory work or from other sources, asked to analyse and evaluate this critically and to use the analysis, for example, to propose a solution to a problem, to propose additional data to be collected to overcome weaknesses in the data available or to verify the validity of conclusions drawn. This could be linked to part of a question on planning investigative procedures;

iii) candidates are asked to give an extended structured account of an area of chemistry in which they draw together, select appropriate knowledge and understanding, and demonstrate an ability to marshal an argument, for example, in evaluating a statement about chemical processes, principles, group of reactions; candidates should be given a choice of one out of two alternatives which should be based on the same approach and of a similar style;

iv) candidates are provided with material (either one source or several sources) from which they select information to evaluate, illustrate or develop principles, patterns or hypotheses, or to solve a problem;

v) candidates are asked to solve short chemical problems, for example, work out a formula using titrimetric data, suggest organic synthetic routes, involving several steps, identify inorganic unknowns from reaction data;

vi) candidates are asked questions which involve solving multi-step problems.

Candidates should be given guidance on the number of marks allocated to each question and, if appropriate, the times to be allocated to each question.

Use of resources

In common with Advanced GCE examinations, the use of dictionaries will not be permitted. The use of any other resources must take full account of the need to ensure fairness to all candidates and the rigour of the assessment. Candidates should be allowed access to calculators. Data needed (including a periodic table) should be provided as part of the examination paper.

Options within individual modes of assessment

Optional questions, based on the content of different specifications, should not be set. In some questions, candidates should be asked to illustrate and exemplify points with examples of their choice, enabling them to draw more widely on the content of the specification studied.

5 PERFORMANCE LEVEL DESCRIPTORS

Distinction

Candidates:

- use and apply the specified chemical knowledge, with no significant omissions;
- select and use the relevant chemical information, principles and concepts, recognise information that is not relevant, and bring together principles and concepts from different areas of the subject in seeking a solution, demonstrating a clear and deep understanding of the relationships between these;
- apply principles and concepts in a range of familiar and new contexts proficiently and sometimes innovatively;
- communicate their ideas with clarity and precision, selecting a form appropriate to the context, and make effective use of appropriate chemical and mathematical terminology, concepts, data and techniques in constructing arguments and solving problems;
- carry out calculations in a logical and concise manner, even when no guidance is given;
- are thoroughly conversant with the use of chemical equations and use them in a range of contexts, including quantitative contexts, and will select ways of presenting and using chemical equations appropriate to the context;

- interpret, analyse and evaluate qualitative information and quantitative data from a range of sources, identifying weaknesses and strengths, and suggest improvements, and draw inferences and, where appropriate, relate these to other contexts.

Merit

Candidates:

- use and apply the specified chemical knowledge, with few significant omissions;
- select the relevant chemical information, principles and concepts and bring together principles and concepts from different areas of chemistry in seeking a solution, demonstrating a clear understanding of relationships between these;
- demonstrate good understanding of principles and concepts, applying them to familiar and new contexts;
- communicate their ideas clearly and logically, making use of appropriate chemical and mathematical terminology;
- carry out calculations in a logical manner, even when little guidance is given;
- are thoroughly conversant with the use of chemical equations and use them in a range of contexts, including quantitative contexts;
- interpret, analyse and evaluate qualitative information and quantitative data from a range of sources, identifying weaknesses and strengths, and drawing appropriate inferences.

APPENDIX 1

The AEA in chemistry will be based on an assessment of the following knowledge, understanding and skills.

Additional content identified and agreed as common to all Advanced GCE chemistry specifications is shown in bold type.

1 KNOWLEDGE, UNDERSTANDING AND SKILLS

	AREA OF STUDY	AMPLIFICATION
1.1	Formulae, equations and amounts of substance	Empirical and molecular formulae. Balanced chemical equations (full and ionic). Avogadro constant and the concept of amount of substance. Relative atomic mass and relative formula mass. The calculation of reacting masses, mole concentrations and volumes of gases. Simple acid-base titrations.
1.2	Atomic structure	The structure of atoms in terms of electrons, neutrons and protons. Formation of ions by electron transfer. Existence of isotopes. Relative isotopic mass. Use of mass spectrometer in determining relative atomic mass and relative abundance of isotopes. The electronic configuration of atoms (up to Z = 36) in terms of main energy levels and *s, p* and *d* atomic orbitals. Classification of elements into *s, p* and *d* blocks.
1.3	Bonding and structure	The interpretation of states of matter and changes of state in terms of the types, motion and arrangement of particles (atoms, molecules and ions) present. The interpretation of ionic and covalent bonding in terms of electron arrangements when atoms combine in compound formation. Existence of the following types of structure: giant covalent; simple molecular; ionic and metallic. The concept of electronegativity and its application to bond type. The existence of interactions between one molecule and another: permanent and induced dipole-dipole interaction, including hydrogen bonding. The interpretation of the physical properties of materials in terms of structure and bonding. The shapes of simple molecules and ions with up to four outer pairs of electrons (any combination of bonding pairs and lone pairs). Interpretation in terms of electron pair repulsion theory.
1.4	Energetics	The concept of an enthalpy change. Standard enthalpy changes of reaction, formation and combustion. Average bond enthalpies. The use of Hess's Law to calculate enthalpy changes. The concept of lattice enthalpy and the construction and use of the Born-Haber cycle for simple ionic compounds.
1.5	Kinetics	A qualitative understanding of the collision theory of chemical reaction. The concept of activation energy and its relationship to the

		qualitative effect of temperature changes on rate of reaction. The role of catalysts in providing alternative routes of lower activation energy. Determination and use of empirical rate equations of the form: *Rate* = $k[A]^m[B]^n$, where *m* and *n* are integers.
1.6	Equilibria	The dynamic nature of equilibria. For homogeneous reactions, the qualitative effects of changes of temperature, pressure and concentration on the position of equilibrium. For homogeneous reactions, the concept of an equilibrium constant, K_c and K_p. Calculations of equilibrium constants and reacting quantities. The way in which changes of temperature and pressure affect the magnitude of the equilibrium constant. The Bronsted-Lowry theory of acid-base reactions occurring in aqueous solution and use of the concept of equilibrium to describe proton transfer in acid-base equilibria. The ionic product of water, K_w. The concept of pH and its calculation for strong acids and strong bases. Dissociation constants of weak acids, K_a. Calculation of pH for weak acids. The nature of buffer solutions and their applications. Calculation of the pH of buffer solutions.
1.7	Redox	Concept of an oxidation state. Oxidation and reduction as electron transfer reactions applied to reactions of *s, p* and *d* block elements. Simple redox titrations.
1.8	Inorganic chemistry and the periodic table	The organisation of elements in the periodic table according to their proton number and electronic structures. The characteristic reactions of the elements and compounds of Group II and Group VII. Trends in properties of elements and compounds within these groups. Trends in properties of elements across a period including: a) melting point and boiling point; b) electrical conductivity; c) ionisation energy.

Trends in reactions of elements and properties of compounds across a period including:

a) the reactions of elements with oxygen, chlorine and water;
b) the acid-base character of oxides;
c) the behaviour of chlorides towards water.

Wherever possible, trends should be interpreted in terms of structure and bonding.

The transition metals as *d* block elements forming one or more stable ions which have incompletely filled *d* orbitals. At least two transition metals, chosen from titanium to copper, to illustrate, as appropriate:

a) the existence of more than one oxidation state for each element in its compounds;
b) the formation of coloured ions in solution and simple precipitation reactions of these;
c) reactions with ligands to form complexes and reactions involving ligand substitution; **shapes of complex ions (tetrahedral and octahedral);**
d) the catalytic behavour of the elements and compounds.

1.9 Organic chemistry

The concepts of homologous series and functional group. The existence of structural isomers and of *cis-trans* isomers illustrated by the alkenes.

Reactions classified as:

a) free radical, electrophilic addition, nucleophilic substitution **and elimination**;
b) hydrolysis, oxidation;

illustrated, as appropriate, by reactions of alkanes, alkenes, halogenoalkanes and alcohols.

Oxidation of primary and secondary alochols only.

The mechanism of the chlorination of alkanes.

The environmental effects of the combustion of petroleum products.

The industrial production of ethanol from ethene.

Single and double covalent bonds, bond polarity and bond enthalpy as factors influencing reactivity, illustrated by reference to appropriate reactions of alkanes, alkenes and halogenoalkanes.

The structure of, and the bonding in, benzene.

Reactions classified as: reduction, electrophilic substitution, nucleophilic addition, polymerisation (addition and condensation) illustrated, as appropriate, by reactions of arenes **(including nitration)**, aldehydes, ketones, carboxylic acids, esters, amines and amino acids.

The existence of stereo isomers (limited to *cis-trans* isomerism as a result of restricted rotation about a carbon-carbon double bond and optical isomerism as a result of chirality in molecules with a single asymmetric carbon atom).

Organic synthesis and analysis, including the characteristic reactions of the functional groups included in the specification.

1.10	Modern analytical techniques	The use of ultraviolet and visible spectrometry, mass spectrometry, infrared spectroscopy and nuclear magnetic resonance in analysis, including techniques for the elucidation of structure.

2 EXPERIMENT AND INVESTIGATION

2.1 Analysing evidence and drawing conclusions

Students should:

a) present work appropriately in written, graphical or other forms, using chemical nomenclature and terminology;

b) interpret information gathered from experimental activities including:
   - i) manipulation of data;
   - ii) recognition of patterns and trends in a set of data or information;
   - iii) identification of sources of error and recognition of the limitations of experimental measurements;

c) draw valid conclusions by applying their knowledge and understanding of chemistry, reporting quantitative data to an appropriate number of significant figures.

2.2 Evaluating evidence and procedures

Students should:

a) assess the reliability of their data and the conclusions drawn from it;

b) evaluate the techniques used in the experimental activity, recognising the limitations of these.

3 MATHEMATICAL REQUIREMENTS FOR THE MATERIAL CONTAINED IN THE CRITERIA

In order to be able to develop the knowledge, understanding and skills in sections 1.1 to 1.10 and 2.1 to 2.2 above, which are taken from the Advanced Subsidiary and Advanced GCE level subject criteria for chemistry, students need to have been taught and to have acquired competence in the areas of mathematics set out below.

3.1 Arithmetic and computation

Students should be able to:

a) recognise and use expressions in decimal and standard form;

b) use ratios, fractions and percentages;

c) make estimates of the results of calculations (without using a calculator);

d) use calculators to find and use x^n, $1/x$, e^x, $\log_{10} x$.

3.2 Handling data

Students should be able to:

a) use an appropriate number of significant figures;

b) find arithmetic means.

3.3 Algebra

Students should be able to:

a) change the subject of an equation;

b) substitute numerical values into algebraic equations using appropriate units for physical quantities;

c) use logarithms in relation to quantities which range over several orders of magnitude.

3.4 Geometry

Students should be able to:

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

3.5 Graphs

Students should be able to:

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