AS and A LEVEL

Content guide

H032/H432

CHEMISTRY A

Specification content additional to the GCE AS and A Level common subject criteria

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OCR
Oxford Cambridge and RSA

SPECIFICATION CONTENT ADDITIONAL TO THE GCE AS AND A LEVEL COMMON SUBJECT CRITERIA FOR CHEMISTRY

The OCR AS and A Level GCE qualifications in Chemistry follow the subject level conditions and requirements for the subject as set by the regulator, Ofqual. These requirements include the core content and skills that must be included in the specification. According to the requirements, this core content must comprise approximately 60% of the overall specification, for both AS and A Level. This 60% of specification content is therefore common to all awarding organisations.

This document sets out the content within the OCR AS and A Level Chemistry A specifications that is **additional** to the core content.

The approach to creating the additional content in GCE Chemistry A has been to require a more detailed and in-depth understanding of the topics covered in the common content. So, while the specifications do contain topics that are not included in the common content (for example Markownikoff's rule, the concept of half-life in rates, the Arrhenius equation) much of the additional content lies in requiring not just an appreciation but also an explanation of certain phenomena, as well as application of certain principles in different contexts. Illustrative examples include:

- application of principles of covalent bonding to the geometry of organic molecules
- explanation of trends in reactivity of elements in terms of attraction, atomic radius and shielding
- understanding of the functional principle of IR spectroscopy.

AS AND A LEVEL CONTENT

MODULE 2: FOUNDATIONS IN CHEMISTRY

2.1 Atoms and reactions

2.1.2(a) the writing of formulae of ionic compounds from ionic charges, including:

- (i) prediction of ionic charge from the position of an element in the periodic table
- (ii) recall of the names and formulae for the following ions: NO_3^-, CO_3^{2-}, SO_4^{2-} , OH^-, NH_4^+, Zn^{2+} and Ag^h

2.1.3(d) the terms *anhydrous, hydrated* and *water of crystallisation* and calculation of the formula of a hydrated salt from given percentage composition, mass composition or based on experimental results

2.2 Electrons, bonding and structure

2.1.3(f) the ideal gas equation

$pV = nRT$

2.2.2(m) explanation of anomalous properties of H_2O resulting from hydrogen bonding, e.g.:

- (i) the density of ice compared with water
- (ii) its relatively high melting and boiling points

MODULE 3: PERIODIC TABLE AND ENERGY

3.1 The periodic table

3.1.3(d) explanation of the trend in reactivity shown in (c), from the decreasing ease of forming 1– ions, in terms of attraction, atomic radius and electron shielding

3.1.3(e) explanation of the term *disproportionation* as oxidation and reduction of the same element, illustrated by:

- (i) the reaction of chlorine with water as used in water purification
- (ii) the reaction of chlorine with cold, dilute aqueous sodium hydroxide, as used to form bleach
- (iii) reactions analogous to those specified in (i) and (ii)

3.1.3(f) the benefits of chlorine use in water treatment (killing bacteria) contrasted with associated risks (e.g. hazards of toxic chlorine gas and possible risks from formation of chlorinated hydrocarbons)

3.1.4(a) qualitative analysis of ions on a test-tube scale;

processes and techniques needed to identify the following ions in an unknown compound:

- (i) anions:
  - CO_3^{2-}, by reaction with $H^+(aq)$ forming $CO_2(g)$
  - SO_4^{2-}, by precipitation with $Ba^{2+}(aq)$
  - Cl^-, Br^-, I^-
- (ii) cations: NH_4^+, by reaction with warm NaOH(aq) forming NH_3.

3.2 Physical chemistry

3.2.1(b) construction of enthalpy profile diagrams to show the difference in the enthalpy of reactants compared with products

3.2.1(e) determination of enthalpy changes directly from appropriate experimental results, including use of the relationship: $q = mc\Delta T$

3.2.1(f) (ii) explanation of exothermic and endothermic reactions in terms of enthalpy changes associated with the breaking and making of chemical bonds

3.2.1(h) the techniques and procedures used to determine enthalpy changes directly and indirectly

3.2.2(b) calculation of reaction rate from the gradients of graphs measuring how a physical quantity changes with time

3.2.2(e) the techniques and procedures used to investigate reaction rates including the measurement of mass, gas volumes and time

3.2.3(c) explanation that a catalyst increases the rate of both forward and reverse reactions in an equilibrium by the same amount resulting in an unchanged position of equilibrium

3.2.3(d) the techniques and procedures used to investigate changes to the position of equilibrium for changes in concentration and temperature

3.2.3(e) explanation of the importance to the chemical industry of a compromise between chemical equilibrium and reaction rate in deciding the operational conditions

MODULE 4: CORE ORGANIC CHEMISTRY

4.1 Basic concepts and hydrocarbons

4.1.1(a) application of IUPAC rules of nomenclature for systematically naming organic compounds

4.1.1(d) use of the general formula of a homologous series to predict the formula of any member of the series

4.1.1(f) the different types of covalent bond fission:
  (i) homolytic fission (in terms of each bonding atom receiving one electron from the bonded pair, forming two radicals)
  (ii) heterolytic fission (in terms of one bonding atom receiving both electrons from the bonded pair)

4.1.1(g) the term *radical* (a species with an unpaired electron) and use of 'dots' to represent species that are radicals in mechanisms

4.1.1(h) a 'curly arrow' described as the movement of an electron pair, showing either heterolytic fission or formation of a covalent bond

4.1.1(i) reaction mechanisms, using diagrams, to show clearly the movement of an electron pair with 'curly arrows' and relevant dipoles.

4.1.2(b) explanation of the tetrahedral shape and bond angle around each carbon atom in alkanes in terms of electron pair repulsion

4.1.2(e) complete combustion of alkanes, as used in fuels, and the incomplete combustion of alkane fuels in a limited supply of oxygen with the resulting potential dangers from CO

4.1.2(g) the limitations of radical substitution in synthesis by the formation of a mixture of organic products, in terms of further substitution and reactions at different positions in a carbon chain

4.1.3(b) explanation of the trigonal planar shape and bond angle around each carbon in the C=C of alkenes in terms of electron pair repulsion

4.1.3(c) (ii) use of Cahn–Ingold–Prelog (CIP) priority rules to identify the E and Z stereoisomers

4.1.3(d) determination of possible *E/Z* or *cis–trans* stereoisomers of an organic molecule, given its structural formula

4.1.3(g) definition and use of the term *electrophile* (an electron pair acceptor)

4.1.3(i) use of Markownikoff's rule to predict formation of a major organic product in addition reactions of H–X to unsymmetrical alkenes, e.g. H–Br to propene, in terms of the relative stabilities of carbocation intermediates in the mechanism

4.2 Alcohols, haloalkanes and analysis

4.2.1(a) (i) the polarity of alcohols and an explanation, in terms of hydrogen bonding, of the water solubility and the relatively low volatility of alcohols compared with alkanes
  (ii) classification of alcohols into primary, secondary and tertiary alcohols

4.2.1(b) combustion of alcohols

4.2.2(b) definition and use of the term *nucleophile* (an electron pair donor)

4.2.3(a) the techniques and procedures for:
  (i) use of Quickfit apparatus including for distillation and heating under reflux
  (ii) preparation and purification of an organic liquid including:
    - use of a separating funnel to remove an organic layer from an aqueous layer
    - drying with an anhydrous salt (e.g. $MgSO_4$, $CaCl_2$)
    - redistillation

4.2.3(b) synthetic routes for an organic molecule containing several functional groups:
  (i) identification of individual functional groups
  (ii) prediction of properties and reactions

4.2.4(a) infrared (IR) radiation causes covalent bonds to vibrate more and absorb energy

4.2.4(b) absorption of infrared radiation by atmospheric gases containing C=O, O–H and C–H bonds (e.g. H_2O, CO_2 and CH_4), the suspected link to global warming and resulting changes to energy usage

A LEVEL ONLY CONTENT

MODULE 5: PHYSICAL CHEMISTRY AND TRANSITION ELEMENTS

5.1 Rates, equilibrium and pH

5.1.1(d) from a concentration–time graph:
  (i) deduction of the order (0 or 1) with respect to a reactant from the shape of the graph
  (ii) calculation of reaction rates from the measurement of gradients

5.1.1(e) from a concentration–time graph of a first order reaction, measurement of constant half-life, $t_{1/2}$

5.1.1(f) for a first order reaction, determination of the rate constant, *k*, from the constant half-life, $t_{1/2}$, using the relationship: $k = \ln 2/t_{1/2}$

5.1.1(g) from a rate–concentration graph:
  (i) deduction of the order (0, 1 or 2) with respect to a reactant from the shape of the graph
  (ii) determination of rate constant for a first order reaction from the gradient

5.1.1(h) the techniques and procedures used to investigate reaction rates by the initial rates method and by continuous monitoring, including use of colorimetry

5.1.1(j) a qualitative explanation of the effect of temperature change on the rate of a reaction and hence the rate constant

5.1.1(k) the Arrhenius equation:
  (i) the exponential relationship between the rate constant, *k* and temperature, *T* given by the Arrhenius equation, $k = Ae^{-\mathrm{Ea/RT}}$
  (ii) determination of E_a and *A* graphically using: $\ln k = -E_a/RT + \ln A$ derived from the Arrhenius equation

5.1.2(a) use of the terms *mole fraction* and *partial pressure*

5.1.2(c) the techniques and procedures used to determine quantities present at equilibrium

5.1.2(d) expressions for K_c and K_p for homogeneous and heterogeneous equilibria

5.1.2(g) explanation of how an equilibrium constant controls the position of equilibrium on changing concentration, pressure and temperature

5.1.2(h) application of the above principles in 5.1.2 How far? for K_c, K_p to other equilibrium constants, where appropriate

5.1.3(b) the role of H^+ in the reactions of acids with metals and bases (including carbonates, metal oxides and alkalis), using ionic equations

5.1.3(h) limitations of using approximations to K_a related calculations for 'stronger' weak acids

5.1.3(m) explanation of the control of blood pH by the carbonic acid–hydrogencarbonate buffer system

5.1.3(o) the techniques and procedures used when measuring pH with a pH meter

5.2 Energy

5.2.1(a) explanation of the term lattice enthalpy (formation of 1 mol of ionic lattice from gaseous ions, $\Delta_{LE}H$) and use as a measure of the strength of ionic bonding in a giant ionic lattice

5.2.1(b) use of the lattice enthalpy of a simple ionic solid (i.e. $\mathrm{NaC}\ell$, $\mathrm{MgC}\ell_2$) and relevant energy terms for:
  (i) the construction of Born–Haber cycles
  (ii) related calculations

5.2.1(c) explanation and use of the terms:
  (i) *enthalpy change of solution* (dissolving of 1 mol of solute, $\Delta_{sol}H$)
  (ii) *enthalpy change of hydration* (dissolving of 1 mol of gaseous ions in water, $\Delta_{hyd}H$)

5.2.1(d) use of the enthalpy change of solution of a simple ionic solid (i.e. $\mathrm{NaC}\ell$, $\mathrm{MgC}\ell_2$) and relevant energy terms (*enthalpy change of hydration and lattice enthalpy*) for:
  (i) the construction of enthalpy cycles
  (ii) related calculations

5.2.1(e) qualitative explanation of the effect of ionic charge and ionic radius on the exothermic value of a lattice enthalpy and enthalpy change of hydration

5.2.2(a) explanation that entropy is a measure of the dispersal of energy in a system which is greater, the more disordered a system

5.2.2(b) explanation of the difference in magnitude of the entropy of a system:
  (i) of solids, liquids and gases
  (ii) for a reaction in which there is a change in the number of gaseous molecules

5.2.3(a) explanation and use of the terms *oxidising agent* and *reducing agent*

5.2.3(g) the techniques and procedures used for the measurement of cell potentials of:
  (i) metals or non-metals in contact with their ions in aqueous solution
  (ii) ions of the same element in different oxidation states in contact with a Pt electrode

5.2.3(i) prediction of the feasibility of a reaction using standard cell potentials and the limitations of such predictions in terms of kinetics and concentration

5.3 Transition elements

5.3.1(f) types of stereoisomerism shown by complexes, including those associated with bidentate and multidentate ligands:
  (i) *cis–trans* isomerism e.g. $\mathrm{Pt(NH_3)_2C}\ell_2$
  (ii) optical isomerism e.g. $[\mathrm{Ni(NH_2CH_2CH_2NH_2)_3}]^{2+}$

5.3.1(g) use of *cis*-platin as an anti-cancer drug and its action by binding to DNA preventing cell division

5.3.1(j) reactions, including ionic equations, and the accompanying colour changes of aqueous Cu^{2+}, Fe^{2+}, Fe^{3+}, Mn^{2+} and Cr^{3+} with aqueous sodium hydroxide and aqueous ammonia, including:
  (i) precipitation reactions
  (ii) complex formation with excess aqueous sodium hydroxide and aqueous ammonia

5.3.1(l) interpretation and prediction of unfamiliar reactions including ligand substitution, precipitation, redox

5.3.2(a) qualitative analysis of ions on a test-tube scale: processes and techniques needed to identify the following ions in an unknown compound:
  (i) anions: CO_3^{2-}, $C\ell^-$, Br^-, I^-, SO_4^{2-}
  (ii) cations: NH_4^+; Cu^{2+}, Fe^{2+}, Fe^{3+}, Mn^{2+}, Cr^{3+}

MODULE 6: ORGANIC CHEMISTRY AND ANALYSIS

6.1 Aromatic compounds, carbonyls and acids

6.1.1(c) use of IUPAC rules of nomenclature for systematically naming substituted aromatic compounds

6.1.1(f) the explanation of the relative resistance to bromination of benzene, compared with alkenes, in terms of the delocalised electron density of the π-system in benzene compared with the localised electron density of the π-bond in alkenes

6.1.1(g) the interpretation of unfamiliar electrophilic substitution reactions of aromatic compounds, including prediction of mechanisms

6.1.1(h) the weak acidity of phenols shown by the neutralisation reaction with NaOH but absence of reaction with carbonates

6.1.1(i) the electrophilic substitution reactions of phenol:
  (i) with bromine to form 2,4,6-tribromophenol
  (ii) with dilute nitric acid to form 2-nitrophenol

6.1.1(j) the relative ease of electrophilic substitution of phenol compared with benzene, in terms of electron pair donation to the π-system from an oxygen p-orbital in phenol

6.1.1(k) the 2- and 4-directing effect of electron-donating groups (OH, NH_2) and the 3-directing effect of electron-withdrawing groups (NO_2) in electrophilic substitution of aromatic compounds

6.1.1(l) the prediction of substitution products of aromatic compounds by directing effects and the importance to organic synthesis

6.1.3(a) explanation of the water solubility of carboxylic acids in terms of hydrogen bonding

6.1.3(e) the formation of acyl chlorides from carboxylic acids using $SOCl_2$

6.1.3(f) use of acyl chlorides in synthesis in formation of esters, carboxylic acids and primary and secondary amides

6.2 Nitrogen compounds, polymers and synthesis

6.2.2(b) structures of primary and secondary amides

6.2.4(a) the use of C–C bond formation in synthesis to increase the length of a carbon chain

6.2.4(b) formation of $C{-}C{\equiv}N$ by reaction of:
  (i) haloalkanes with CN^- and ethanol, including nucleophilic substitution mechanism
  (ii) carbonyl compounds with HCN, including nucleophilic addition mechanism

6.2.4(d) formation of a substituted aromatic C–C by alkylation (using a haloalkane) and acylation (using an acyl chloride) in the presence of a halogen carrier (Friedel–Crafts reaction)

6.2.5(a) the techniques and procedures used for the preparation and purification of organic solids involving use of a range of techniques (see also 4.2.3 a) including:
  (i) organic preparation
    - use of Quickfit apparatus
    - distillation and heating under reflux
  (ii) purification of an organic solid
    - filtration under reduced pressure
    - recrystallisation
    - measurement of melting points

6.3 Analysis

6.3.1(c) qualitative analysis of organic functional groups on a test-tube scale;

processes and techniques needed to identify the following functional groups in an unknown compound:
  (i) alkenes by reaction with bromine
  (ii) haloalkanes by reaction with aqueous silver nitrate in ethanol
  (iii) phenols by weak acidity but no reaction with CO_3^{2-}
  (iv) carbonyl compounds by reaction with 2,4-DNP
  (v) aldehydes by reaction with Tollens' reagent
  (vi) primary and secondary alcohols and aldehydes by reaction with acidified dichromate
  (vii) carboxylic acids by reaction with CO_3^{2-}

6.3.2(a) analysis of a carbon-13 NMR spectrum of an organic molecule to make predictions about:
  (i) the number of carbon environments in the molecule
  (ii) the different types of carbon environment present, from chemical shift values
  (iii) possible structures for the molecule

6.3.2(d) (i) the use of tetramethylsilane, TMS, as the standard for chemical shift measurements
  (ii) the need for deuterated solvents, e.g. $CDCl_3$, when running an NMR spectrum
  (iii) the identification of O–H and N–H protons by proton exchange using D_2O

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