

A2 Chemistry Module 4 – Specifications

Part 1 Kinetics

Simple rate equations

You 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 the reactants A and B (m and n will be restricted to values 1, 2 or 0).

Determination of rate equation

You should be able to:

- work out the rate equation for a reaction from data relating initial rate to the concentrations of the different reactants
- explain the qualitative effect of changes in temperature on the rate constant k .

Part 2 Equilibria

Equilibrium constants K_c and K_p for homogeneous systems

You should:

- 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, and
 - be able to perform calculations involving such expressions.

Qualitative effects of changes of pressure, temperature and concentration

You should:

- 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.

Part 3 Acids and bases

Brønsted-Lowry acid–base equilibria in aqueous solution

You should:

- 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.

Definition and determination of pH

You should:

- know that $\text{pH} = -\log_{10}[\text{H}^+]$, 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.

The ionic product of water, K_w

You should:

- know that water is weakly dissociated.
- know that $K_w = [\text{H}^+][\text{OH}^-] = 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ at 25°C
- be able to calculate the pH of a strong base from its molar concentration.

Weak acids and bases

You should know that weak acids and weak bases dissociate only partially in aqueous solution.

K_a for weak acids

You should:

- be able to construct an expression, with units, for the dissociation constant K_a for a weak acid.
- know that $\text{p}K_a = -\log_{10} K_a$
- 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 $\text{p}K_a$ for weak acids.

pH curves, titrations and indicators

You should:

- understand the typical shape of pH curves for acid–base titrations in all combinations of weak and strong monoprotic acids and bases; and
 - be able to perform calculations for these titrations.
- understand the shape of the pH curves for the titration of sodium carbonate with monoprotic acids (e.g. HCl) and of diprotic acids (e.g. ethanedioic acid) with NaOH; and
 - be able to perform 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.

Buffer action

You should be able to:

- explain the action of acidic and basic buffers both qualitatively and quantitatively.
- calculate the pH of buffer solutions.

Part 4 Nomenclature and Isomerism in Organic Chemistry

Naming organic compounds

You should 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 and in AS3.

Isomerism

You should:

- 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.

Part 5 Compounds containing the carbonyl group

Aldehydes and ketones

You should:

- 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 Tollen's reagent).
- recall that aldehydes can be reduced to primary alcohols, and ketones to secondary alcohols, using reducing agents such as NaBH₄ (mechanisms showing :H⁻ are required, and 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.

Carboxylic acids and esters

You should:

- know that carboxylic acids are weak acids, but they *will* liberate CO₂ 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.

Acylation

You should:

- 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.

Part 6 Aromatic chemistry

Bonding

You should understand the nature of the bonding in a benzene ring, limited to planar structure and bond length intermediate between single and double.

Delocalisation stability

You should understand that delocalisation confers stability to the molecule, and be able to use thermochemical evidence from enthalpies of hydrogenation to illustrate this principle.

Electrophilic substitution

You should understand that electrophilic attack in arenes results in substitution (mechanisms limited to the monosubstitutions given below).

Nitration

You should:

- 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.

Friedel–Crafts reactions

You should:

- 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 ethylbenzene is an important intermediate in the manufacture of polystyrene (details of processes not required).

Part 7 Amines

Base properties (Brønsted–Lowry)

You should 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.

Nucleophilic properties

You should:

- 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 quaternary ammonium salts as cationic surfactants.

Preparation

You should:

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.

Part 8 Amino Acids

Acid and base properties

You should understand that amino acids have both acidic and basic properties.

Proteins

You should understand:

- that proteins are sequences of amino acids joined by peptide links.
- that hydrolysis of the peptide link produces the constituent amino acids.
- the importance of hydrogen bonding in proteins (detailed structures **not** required).

Part 9 Polymers

Addition polymers

You should:

- that proteins are sequences of amino acids joined by peptide links.
- 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.

Condensation polymers

You should:

- understand that condensation polymers may be formed by reactions between:
 - dibasic acids and diols;
 - dicarboxylic acids and diamines;
 - 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).

Part 10 Organic synthesis and analysis

Applications

You should 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).

Part 11 Structure Determination

Data sources

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

Mass spectrometry

You should:

- 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 $M^{+\bullet} \rightarrow X^+ + Y^{\bullet}$ 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.

Infra-red spectroscopy

You should:

- 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.

Nuclear magnetic resonance spectroscopy

You should:

- 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.