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| A2 Chemistry Checklist | **Notes** | **R** | **A** | **G** | **Revision** |
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| **Module 5: Physical chemistry and transition elements** | | | | | |
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| **5.1 Rates, equilibria and pH** |  |  |  |  |  |
| 5.1.1 How fast |
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| Explain and use of the terms: rate of reaction, order, overall order, rate constant, half-life, rate-determining step |  |  |  |  |  |
| Deduction of: orders from experimental data; a rate equation from orders of the form: rate = k[A]m[B]n, where m and n are 0, 1 or 2 |  |  |  |  |  |
| Calculate the rate constant, k, and related quantities, from a rate equation including determination of units |  |  |  |  |  |
| From a concentration–time graph: deduct the order (0 or 1) with respect to a reactant from the shape of the graph |  |  |  |  |  |
| Using a concentration–time graph: calculate reaction rates from the measurement of gradients |  |  |  |  |  |
| Using a concentration–time graph of a first order reaction, measurement of constant half-life, t1/2 |  |  |  |  |  |
| Determine, for a first order reaction, the rate constant, k, from the constant half-life, t1/2, using the relationship: k = ln 2/t1/2 |  |  |  |  |  |
| Using a rate–concentration graph: deduct the order (0, 1 or 2) with respect to a reactant from the shape of the graph |  |  |  |  |  |
| Describe techniques and procedures used to investigate reaction rates by the initial rates method and by continuous monitoring, including use of colorimetry |  |  |  |  |  |
| Predict, for a multi-step reaction, a rate equation that is consistent with the rate-determining step |  |  |  |  |  |
| Predict, for a multi-step reaction, possible steps in a reaction mechanism from the rate equation and the balanced equation for the overall reaction |  |  |  |  |  |
| Explain qualitatively, the effect of temperature change on the rate of a reaction and hence the rate constant |  |  |  |  |  |
| Exponential relationship between the rate constant, k and temperature, T given by the Arrhenius equation, k = Ae–Ea/RT |  |  |  |  |  |
| Determine Ea and A graphically using: ln k = –Ea/RT + ln A derived from the Arrhenius equation. |  |  |  |  |  |
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| 5.1.2 How far? |  |  |  |  |  |
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| Use of the terms mole fraction and partial pressure |  |  |  |  |  |
| Calculate quantities present at equilibrium, given appropriate data |  |  |  |  |  |
| Techniques and procedures used to determine quantities present at equilibrium |  |  |  |  |  |
| Expressions for Kc and Kp for homogeneous and heterogeneous equilibria |  |  |  |  |  |
| Calculate Kc and Kp, or related quantities, including determination of units |  |  |  |  |  |
| Describe qualitative effect on equilibrium constants of changing temperature for exothermic and endothermic reactions |  |  |  |  |  |
| Understand constancy of equilibrium constants with changes in concentration, pressure or in the presence of a catalyst |  |  |  |  |  |
| Explain how an equilibrium constant controls the position of equilibrium on changing concentration, pressure and temperature |  |  |  |  |  |
| Application of these principles for Kc, Kp to other equilibrium constants |  |  |  |  |  |

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| 5.1.3 Acids, bases and buffers |  |  |  |  |  |
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| Define a Brønsted–Lowry acid |  |  |  |  |  |
| Use of the terms: conjugate acid-base pairs, monobasic, dibasic and tribasic acids |  |  |  |  |  |
| Role of H+ in the reactions of acids with metals and bases (including carbonates, metal oxides and alkalis), using ionic equations |  |  |  |  |  |
| Acid dissociation constant, Ka, for the extent of acid dissociation and the relationship between Ka and pKa |  |  |  |  |  |
| Use the expression for pH as: pH = –log[H+] [H+] = 10–pH; and the expression for the ionic product of water, Kw |  |  |  |  |  |
| Calculate pH, or related quantities, for: strong monobasic acids; strong bases, using Kw |  |  |  |  |  |
| Calculate pH, Ka or related quantities, for a weak monobasic acid using approximations |  |  |  |  |  |
| Limitations of using approximations to Ka related calculations for ‘stronger’ weak acids |  |  |  |  |  |
| Define the term buffer solution |  |  |  |  |  |
| Formation of a buffer solution from: a weak acid and a salt of the weak acid; excess of a weak acid and a strong alkali |  |  |  |  |  |
| Explain the role of the conjugate acid–base pair in an acid buffer solution |  |  |  |  |  |
| Calculate the pH of a buffer solution, from the Ka value of a weak acid and the equilibrium concentrations of the conjugate acid–base pair |  |  |  |  |  |
| Explain the control of blood pH by the carbonic acid–hydrogencarbonate buffer system |  |  |  |  |  |
| Sketch and interpret the shapes of pH titration curves for combinations of strong and weak acids with strong and weak bases |  |  |  |  |  |
| Explain the choice of suitable indicators, given the pH range of the indicator |  |  |  |  |  |
| Explain indicator colour changes in terms of equilibrium shift between the HA and A– forms of the indicator |  |  |  |  |  |
| Techniques and procedures used when measuring pH with a pH meter. |  |  |  |  |  |

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| **5.2 Energy** |  |  |  |  |  |
| 5.2.1 Lattice enthalpy |
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| Explain the term lattice enthalpy |  |  |  |  |  |
| Use the lattice enthalpy of a simple ionic solid and relevant energy terms for: the construction of Born–Haber cycles and related calculations |  |  |  |  |  |
| Explain and use the terms enthalpy change of solution and enthalpy change of hydration |  |  |  |  |  |
| Use the enthalpy change of solution of a simple ionic solid and relevant energy terms for: the construction of enthalpy cycles and related calculations |  |  |  |  |  |
| Explain qualitatively the effect of ionic charge and ionic radius on the exothermic value of a lattice enthalpy and enthalpy change of hydration. |  |  |  |  |  |
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| 5.2.2 Enthalpy and entropy |  |  |  |  |  |
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| Explain entropy is a measure of the dispersal of energy in a system which is greater, the more disordered a system |  |  |  |  |  |
| Explain the difference in magnitude of the entropy of a system: of solids, liquids and gases |  |  |  |  |  |
| Explain the difference in magnitude of the entropy of a system for a reaction in which there is a change in the number of gaseous molecules |  |  |  |  |  |
| Calculate the entropy change of a system, ΔS, and related quantities for a reaction given the entropies of the reactants and products |  |  |  |  |  |
| Explain the feasibility of a process depends upon TΔS, and ΔH |  |  |  |  |  |
| Explain, and calculate, the free energy change, ΔG, as: ΔG = ΔH – TΔS; and that a process is feasible when ΔG has a negative value |  |  |  |  |  |
| Limitations of predictions made by ΔG about feasibility, in terms of kinetics. |  |  |  |  |  |
| 5.2.3 Redox and electrode potentials |  |  |  |  |  |
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| Explain and use the terms oxidising agent and reducing agent |  |  |  |  |  |
| Construct redox equations using half equations and oxidation numbers |  |  |  |  |  |
| Interpret and predict reactions involving electron transfer |  |  |  |  |  |
| Techniques and procedures used when carrying out redox titrations |  |  |  |  |  |
| Structured and non-structured titration calculations, based on experimental results of redox titrations |  |  |  |  |  |
| Use the term standard electrode (redox) potential, Eθ including its measurement using a hydrogen electrode |  |  |  |  |  |
| Techniques and procedures used for the measurement of cell potentials |  |  |  |  |  |
| Calculate a standard cell potential by combining two standard electrode potentials |  |  |  |  |  |
| Predict the feasibility of a reaction using standard cell potentials and the limitations of such predictions |  |  |  |  |  |
| Apply principles of electrode potentials to modern storage cells |  |  |  |  |  |
| Explain how fuel cells create voltage and the changes that take place at each electrode |  |  |  |  |  |

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| **5.3 Transition elements** |  |  |  |  |  |
| 5.3.1 Transition elements |
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| Electron configuration of atoms and ions of the d-block elements of Period 4 (Sc–Zn), given the atomic number and charge |  |  |  |  |  |
| Elements Ti–Cu d-block elements that have an ion with an incomplete d-sub-shell (Transition elements) |  |  |  |  |  |
| Use at least two transition to demonstrate: the existence of more than one oxidation state for each element in its compounds |  |  |  |  |  |
| Use at least two transition to demonstrate: the formation of coloured ions |  |  |  |  |  |
| Use at least two transition to demonstrate: the catalytic behaviour of the elements and their compounds and their industrial importance |  |  |  |  |  |
| Explain and use the term ligand |  |  |  |  |  |
| Use the terms complex ion and coordination number and examples of complexes with: octahedral shape and either a planar or tetrahedral shape |  |  |  |  |  |
| Types of stereoisomerism shown by complexes: cis–trans isomerism; optical isomerism |  |  |  |  |  |
| Use of cis-platin as an anti-cancer drug and its action by binding to DNA preventing cell division |  |  |  |  |  |
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| 5.3.2 Qualitative analysis |  |  |  |  |  |
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| Ligand substitution reactions and the accompanying colour changes |  |  |  |  |  |
| Explain the biochemical importance of iron in haemoglobin, including ligand substitution involving O2 and CO |  |  |  |  |  |
| Reactions, including ionic equations, of transition ions with aqueous sodium hydroxide and aqueous ammomia |  |  |  |  |  |
| Redox reactions and accompanying colour changes for: interconversions between Fe2+ and Fe3+ |  |  |  |  |  |
| Redox reactions and accompanying colour changes for: interconversions between Cr3+ and Cr2O72– |  |  |  |  |  |
| Redox reactions and accompanying colour changes for: reduction of Cu2+ to Cu+ and disproportionation of Cu+ to Cu2+ and Cu |  |  |  |  |  |
| Interpret and predict unfamiliar reactions including ligand substitution, precipitation, redox. |  |  |  |  |  |
| Qualitative analysis of ions on a test-tube scale: processes and techniques needed to identify the following ions in an unknown compound |  |  |  |  |  |

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| **Module 6: Organic chemistry and analysis** | | | | | |
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| **6.1 Aromatic compounds** |  |  |  |  |  |
| 6.1.1 Aromatic compounds |
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| Compare the Kekulé model of benzene with the subsequent delocalised models for benzene; including an examination of the experimental evidence |  |  |  |  |  |
| Use IUPAC rules of nomenclature for systematically naming substituted aromatic compounds |  |  |  |  |  |
| Electrophilic substitution of aromatic compounds with: concentrated nitric acid in the presence of concentrated sulfuric acid |  |  |  |  |  |
| Electrophilic substitution of aromatic compounds with: a halogen in the presence of a halogen carrier |  |  |  |  |  |
| Electrophilic substitution of aromatic compounds with: a haloalkane or acyl chloride in the presence of a halogen carrier |  |  |  |  |  |
| Mechanism of electrophilic substitution in arenes for nitration and halogenation |  |  |  |  |  |
| Explain the relative resistance to bromination of benzene, compared with alkenes |  |  |  |  |  |
| Interpret unfamiliar electrophilic substitution reactions of aromatic compounds, including prediction of mechanisms |  |  |  |  |  |
| Weak acidity of phenols shown by the neutralisation reaction with NaOH but absence of reaction with carbonates |  |  |  |  |  |
| Electrophilic substitution reactions of phenol: with bromine to form 2,4,6-tribromophenol; with dilute nitric acid to form 2-nitrophenol |  |  |  |  |  |
| Compare the relative ease of electrophilic substitution of phenol with benzene |  |  |  |  |  |
| The effect of electron donating groups and of electron-withdrawing groups in electrophilic substitution of aromatic compounds |  |  |  |  |  |
| Predict substitution products of aromatic compounds by directing effects and the importance to organic synthesis |  |  |  |  |  |
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| 6.1.2 Carbonyl Compounds |  |  |  |  |  |
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| Oxidation of aldehydes to form carboxylic acids |  |  |  |  |  |
| Nucleophilic addition reactions of carbonyl compounds to form alcohols and hydroxynitriles |  |  |  |  |  |
| Mechanism for nucleophilic addition reactions of aldehydes and ketones NaBH4 and HCN |  |  |  |  |  |
| Uses of 2,4-dinitrophenylhydrazine when identifying carbonyl groups or compounds |  |  |  |  |  |
| Use of Tollens’ reagent to: detect the presence of an aldehyde group; distinguish between aldehydes and ketones |  |  |  |  |  |
| Explain how Tollens' reagent distinguishes between aldehydes and ketones |  |  |  |  |  |

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| 6.1.3 Carboxylic acids and esters |  |  |  |  |  |
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| Explain the water solubility of carboxylic acids in terms of hydrogen bonding |  |  |  |  |  |
| Reactions in aqueous conditions of carboxylic acids with metals and bases |  |  |  |  |  |
| Esterification of: carboxylic acids with alcohols in the presence of an acid catalyst; acid anhydrides with alcohols |  |  |  |  |  |
| Hydrolysis of esters: to form carboxylic acids and alcohols; to form carboxylate salts and alcohols |  |  |  |  |  |
| Formation of acyl chlorides from carboxylic acids |  |  |  |  |  |
| Use of acyl chlorides in synthesis in formation of esters, carboxylic acids and primary and secondary amides |  |  |  |  |  |

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| **6.2 Nitrogen compounds, polymers and synthesis** |  |  |  |  |  |
| 6.2.1 Amines |
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| Basicity of amines in terms of proton acceptance by the nitrogen lone pair and the reactions of amines with dilute acids to form salts |  |  |  |  |  |
| Preparation of: aliphatic amines by substitution of haloalkanes |  |  |  |  |  |
| Preparation of: aromatic amines by reduction of nitroarenes |  |  |  |  |  |
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| 6.2.2 Amino acids, amides and chirality |  |  |  |  |  |
|  |  |  |  |  |  |
| General formula for an α-amino acid as RCH(NH2)COOH |  |  |  |  |  |
| Reactions of amino acids: carboxylic acid group with alkalis and in the formation of esters; amine group with acids |  |  |  |  |  |
| Structures of primary and secondary amides |  |  |  |  |  |
| Define optical isomerism and use it to draw 3-D diagrams |  |  |  |  |  |
| Identify chiral centres in a molecule of any organic compound |  |  |  |  |  |

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| 6.2.3 Polyesters and polyamides |  |  |  |  |  |
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| Condensation polymerisation to form polyesters and polyamides |  |  |  |  |  |
| Acid and base hydrolysis of: the ester groups in polyesters; the amide groups in polyamides |  |  |  |  |  |
| Predict from addition and condensation polymerisation: the repeat unit from a given monomer(s) |  |  |  |  |  |
| Predict from addition and condensation polymerisation: the monomer(s) required for a given section of a polymer molecule |  |  |  |  |  |
| Predict from addition and condensation polymerisation: the type of polymerisation. |  |  |  |  |  |

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| 6.2.4 Carbon-Carbon bond formation |  |  |  |  |  |
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| Use of C–C bond formation in synthesis to increase the length of a carbon chain |  |  |  |  |  |
| Formation of C–C=N by reaction of: haloalkanes with CN– and ethanol, including nucleophilic substitution mechanism |  |  |  |  |  |
| Formation of C–C=N by reaction of: carbonyl compounds with HCN, including nucleophilic addition mechanism |  |  |  |  |  |
| Reaction of nitriles: by reduction to form amines; by acid hydrolysis to form carboxylic acids |  |  |  |  |  |
| Formation of a substituted aromatic C–C by alkylation and acylation |  |  |  |  |  |

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| 6.2.5 Organic synthesis |  |  |  |  |  |
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| Techniques and procedures used for the preparation and purification of organic solids involving use of a range of techniques |  |  |  |  |  |
| Identify the functional groups and predict the properties and reactions for an organic molecule containing several functional groups |  |  |  |  |  |
| Multi-stage synthetic routes for preparing organic compounds. |  |  |  |  |  |

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| **6.3 Analysis** |  |  |  |  |  |
| 6.3.1 Chromatography and qualitative analysis |
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| Interpret one-way TLC chromatograms in terms of Rf values |  |  |  |  |  |
| Interpret gas chromatograms in terms of: retention times; the amounts and proportions of the components in a mixture. |  |  |  |  |  |
| Qualitative analysis of organic functional groups on a test-tube scale to identify the functional groups in an unknown compound |  |  |  |  |  |
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| 6.3.2 Spectroscopy |  |  |  |  |  |
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| Analyse a carbon-13 NMR spectrum of an organic molecule to make predictions about: the number of carbon environments in the molecule |  |  |  |  |  |
| Analyse a carbon-13 NMR spectrum of an organic molecule to make predictions about: the different types of carbon environment present |  |  |  |  |  |
| Analyse a carbon-13 NMR spectrum of an organic molecule to make predictions about: possible structures for the molecule |  |  |  |  |  |
| Analyse a high resolution proton NMR spectrum to make predictions about: the number and type of proton environments in the molecule |  |  |  |  |  |
| Analyse a high resolution proton NMR spectrum to make predictions about: relative numbers of each type of proton present |  |  |  |  |  |
| Analyse a high resolution proton NMR spectrum to make predictions about: the number of non-equivalent protons adjacent to a given proton |  |  |  |  |  |
| Analyse a high resolution proton NMR spectrum to make predictions about: possible structures for the molecule |  |  |  |  |  |
| Predict a carbon-13 or proton NMR spectrum for a given molecule |  |  |  |  |  |
| Use of tetramethylsilane, TMS, as the standard for chemical shift measurements |  |  |  |  |  |
| The need for deuterated solvents when running an NMR spectrum |  |  |  |  |  |
| The identification of O–H and N–H protons by proton exchange |  |  |  |  |  |
| Deduce the structures of organic compounds from different analytical data |  |  |  |  |  |