Topic 3: Organic and biological chemistry

Subtopic 3.1: Introduction

This subtopic continues the work on organic chemistry introduced in Stage 1 subtopic 3.3, and discussion of physical properties throughout this topic draws on concepts introduced in Stage 1 subtopics 2.2, 3.2, and 4.1.

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| Organic compounds can be represented by molecular and structural formulae.   * Determine the molecular formula of an organic compound given its extended, condensed, or skeletal structural formula.   Organic compounds are named systematically to provide unambiguous identification.  Condensation reactions occur when two organic molecules combine to form a larger molecule, also releasing another small molecule, such as water. |
| The physical properties of organic compounds are influenced by the molar masses of the molecules, and the number and polarity of functional groups.   * Predict, explain, and compare the melting points, boiling points, and solubilities in water and in non-polar solvents of organic compounds, given their structural formulae. |

Subtopic 3.2: Alcohols

This subtopic builds upon the concept of oxidation introduced in Stage 1 subtopic 6.1, and the production and use of ethanol as a fuel is considered in subtopic 4.1.

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| Alcohols are classified as primary, secondary, or tertiary.   * Identify, name systematically, and draw structural formulae of alcohols containing: * up to eight carbon atoms in the main chain, with side chains limited to a maximum of two carbon atoms * one or more hydroxyl groups.   Primary, secondary, and tertiary alcohols behave differently with oxidising agents.   * Describe how primary and secondary alcohols can be distinguished from tertiary alcohols by their reaction with acidified dichromate solution. * Predict the structural formula(e) of the product(s) of oxidation of a primary or secondary alcohol, given its structural formula. |
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Subtopic 3.3: Aldehydes and ketones

This subtopic builds upon the concept of oxidation introduced in Stage 1 subtopic 6.1.

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| Aldehydes and ketones are produced by the oxidation of the corresponding primary and secondary alcohols respectively.   * Identify, name systematically, and draw structural formulae of aldehydes and ketones containing: * up to eight carbon atoms in the main chain, with side chains limited to a maximum of two carbon atoms * one or more aldehyde or ketone groups.   Aldehydes can be readily oxidised; ketones cannot.   * Draw the structural formula of the oxidation product of a given aldehyde in either acidic or alkaline conditions. * Describe how acidified dichromate solution and Tollens’ reagent (ammoniacal silver nitrate solution) can be used to distinguish between aldehydes and ketones. |
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Subtopic 3.4: Carbohydrates

This subtopic builds upon the concept of repeating units introduced in Stage 1 subtopic 3.4.

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| Carbohydrates are naturally occurring sugars and their polymers. They are defined as either polyhydroxy aldehydes or polyhydroxy ketones, or substances that form these compounds on hydrolysis.   * Given its structural formula, determine whether a molecule is a carbohydrate.   Disaccharides and polysaccharides are produced by the condensation of monosaccharide units linked in chains by covalent bonds.   * Write molecular formulae for glucose, and for disaccharides and polysaccharides, based on glucose monomers. * Draw the structural formulae of the monosaccharide(s), given the structural formula of a disaccharide. * Identify the repeating unit and draw the structural formula of the monomer, given the structural formula of a section of a polysaccharide.   In aqueous solution there is an equilibrium between a ring form and a chain form of glucose.   * Explain the ability of glucose to react as an aldehyde when in chain form but not when in ring form. |

Subtopic 3.5: Carboxylic acids

*This subtopic builds upon the concepts introduced in Stage 1 subtopics 4.2 and 5.2.*

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| Carboxylic acids can be produced by the oxidation of aldehydes or primary alcohols.   * Identify, name systematically, and draw structural formulae of carboxylic acids containing: * up to eight carbon atoms in the main chain, with side chains limited to a maximum of two carbon atoms * one or two carboxyl groups.   Carboxylic acids are weak acids and, to a small extent, ionise in water.   * Write equations for the reactions of carboxylic acids with bases, including hydroxides, carbonates, and hydrogencarbonates, to form carboxylate salts, and describe changes that accompany these reactions. * Explain why sodium and potassium carboxylate salts are more soluble in water than their parent carboxylic acids. |
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Subtopic 3.6: Amines

This subtopic builds upon the concepts introduced in Stage 1 subtopics 4.2 and 5.2.

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| Amines are classified as primary, secondary, or tertiary.   * Identify, name systematically, and draw structural formulae of primary amines containing: * up to eight carbon atoms in the main chain, with side chains limited to a maximum of two carbon atoms * one or more amino groups.   Amines act as bases.   * Draw the structural formula of the protonated form of an amine, given the structural formula of its molecular form, and vice versa. * Explain why the protonated form of an amine is more soluble in water than its parent molecular amine. |
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Subtopic 3.7: Esters

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| Carboxylic acids undergo condensation reactions with alcohols to form esters.   * Identify, name systematically, and draw structural formulae of methyl and ethyl esters of acids containing up to eight carbon atoms in the main chain, with side chains limited to a maximum of two carbon atoms. * Draw the structural formula of the ester that could be produced by the condensation reaction between a carboxylic acid and an alcohol, given their structural formulae or vice versa. * Draw the structural formula of a polyester, given the structural formula(e) of the monomer(s) or vice versa.   Condensation reactions are slow at 25°C.   * Explain the use of heating under reflux, and the use of a trace of concentrated sulfuric acid in the laboratory preparation of esters.   Esters may be hydrolysed under acidic or alkaline conditions.   * Identify the products of acidic or alkaline hydrolysis of an ester or polyester, given the appropriate structural formula. |
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Subtopic 3.8: Amides

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| Carboxylic acids undergo condensation reactions with amines to form amides.   * Draw the structural formula of the amide formed from a carboxylic acid and an amine, given their structural formulae or vice versa. * Draw the structural formula of a polyamide, given the structural formula(e) of the monomer(s) or vice versa.   Amides may be hydrolysed under acidic or alkaline conditions.   * Identify the products of acidic or alkaline hydrolysis of an amide or polyamide, given the appropriate structural formula. |
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Subtopic 3.9: Triglycerides

This subtopic builds upon concepts introduced in Stage 1 subtopics 3.3 and 4.1.

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| Edible oils and fats are esters of propane-1,2,3-triol (glycerol) and various carboxylic acids.   * Draw the structural formula of an edible oil or fat, given the structural formula(e) of the carboxylic acid(s) from which it is derived.   Triglycerides can be hydrolysed to produce propane-1,2,3-triol and various carboxylic acids.   * Identify and draw the structural formulae of the alcohol and acid(s) from which a triglyceride is derived, given its structural formula.   Triglycerides may be saturated or unsaturated.   * Describe and explain the use of a solution of bromine or iodine to determine the degree of unsaturation of a compound. Draw the structural formula of the reaction product. * Explain how the degree of unsaturation causes differences in the melting points of edible oils and fats.   Liquid triglycerides can be converted into triglycerides of higher melting point.   * Explain the role of pressure, temperature, and a catalyst in the hydrogenation of liquid triglycerides to form triglycerides of higher melting point.   Alkaline hydrolysis of triglycerides produces carboxylate ions, which have both hydrophilic and hydrophobic regions.   * Explain how such particles form micelles in solutions. * Explain how micelles can dissolve and move non-polar substances through an aqueous medium or vice versa. |
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Subtopic 3.10: Proteins

This subtopic revisits concepts introduced in Stage 1 subtopics 3.1, 3.2, and 4.2, and in Stage 2 subtopics 3.5 and 3.6.

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| Proteins are polymers of amino acids.  Amino acids contain a carboxyl group and an amino group.   * Write the general formula of amino acids and recognise their structural formulae.   Amino acids have both acidic and basic properties.   * Draw the structural formula of the product formed when an amino acid self-ionises, given its structural formula.   Amino acids can undergo condensation to form protein chains.  The amide groups within proteins are also known as ‘peptide links’.   * Draw the structural formula of a section of a protein chain that could be formed from amino acids, given their structural formulae or vice versa.   The unique spatial arrangement of a protein depends on secondary interactions between sections of the chain and, in aqueous environments, between the chain and water.   * Identify where secondary interactions can occur, given the structural formula of a section of a protein chain.   The biological function of a protein is a consequence of its spatial arrangement.   * Explain why the biological function of a protein (e.g. an enzyme) may be affected by changes in pH and temperature. |
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