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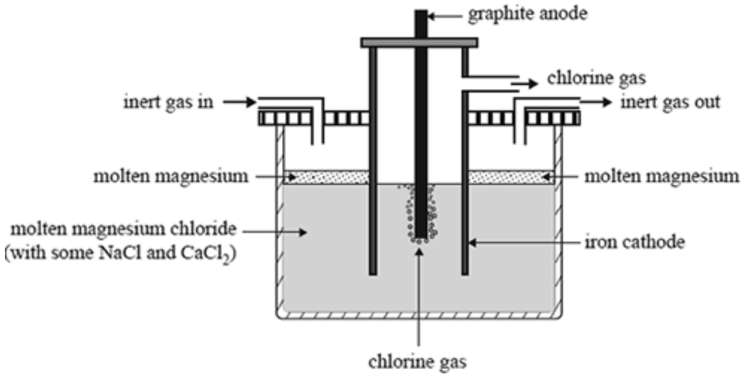
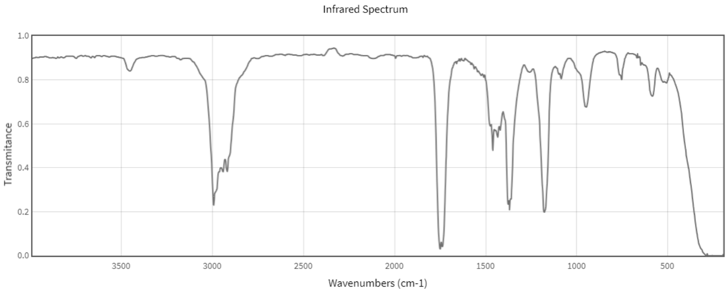
Units 3&4 Chemistry Trial Exam 2024 (Trial 1) – Assessment Guide

Section A

VCAA Key Knowledge	Question	Answer Guide	
the definition of a fuel, including the distinction between fossil fuels (coal, natural gas, petrol) and biofuels (biogas, bioethanol, biodiesel) with reference to their renewability (ability of a resource to be replaced by natural processes within a relatively short period of time)	**Question 1** Renewable fuels A. form over millions of years in the earth's crust. B. are produced in a relatively short period of time. C. do not produce greenhouse gas emissions during combustion. D. do not produce greenhouse gas emissions during production.	*B*	*Renewable fuels can be produced at a rate faster than they are consumed, in a relatively short period of time. Carbon emissions are not considered when evaluating renewability.*
fuel sources for the body measured in kJ g^{-1}: carbohydrates, proteins and lipids (fats and oils)	**Question 2** Fats and oils have a higher energy content than carbohydrates because A. carbohydrate molecules have a higher degree of oxidation than fats and oils. B. fats and oils are more easily broken down during digestion. C. foods generally contain more fats than carbohydrates per gram. D. fats and oils are composed of triglycerides with long hydrocarbon chains.	*A*	*The amount of energy released depends on the degree of oxidation of molecules. Carbohydrates have a higher degree of oxidation than fats and oils per unit mass, therefore releasing less energy on combustion.*
photosynthesis as the process that converts light energy into chemical energy and as a source of glucose and oxygen for respiration in living things: $6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(aq)+ 6O_2(g)$	**Question 3** The thermochemical equation for photosynthesis is A. $6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(aq) + 6O_2(g)$ $\Delta H = +2803$ kJ/g B. $C_6H_{12}O_6(aq) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$ $\Delta H = -2803$ kJ/g C. $6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(aq) + 6O_2(g)$ $\Delta H = +2803$ kJ D. $C_6H_{12}O_6(aq) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$ $\Delta H = -2803$ kJ	*C*	$6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(aq) + 6O_2(g)$ $\Delta H = +2803$ kJ *Endothermic with correct units.*

changes in enzyme function in terms of structure and bonding as a result of increased temperature (denaturation), decreased temperature (lowered activity)	**Question 4** Fermentation of glucose to produce bioethanol is shown by the equation: $C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(l) + 2CO_2(g)$ The process is carried out at 35°C because A. the reaction rate decreases as the temperature increases. B. the enzyme catalysts will be destroyed at higher temperatures. C. ethanol has a very low boiling point and must be kept in the liquid state. D. the reaction is exothermic and an increase in temperature favours the reverse reaction.	*B*	*Fermentation involves protein enzymes for a fast reaction rate. At high temperatures, these enzymes will be denatured.*
enthalpy changes (ΔH) measured in kJ, molar enthalpy changes measured in kJ mol^{-1} and enthalpy changes for mixtures measured in kJ g^{-1}	**Question 5** The amount of energy released when 10.0 kg of liquid butane undergoes complete combustion in a portable stove is equal to A. 497 kJ B. 4.97 x 10^2 J C. 497000 J D. 4.97 x 10^5 kJ	*D*	*n (butane) = m/M* *= 10000/58.0* *= 172.4 mol* *ΔH Butane = -2880 kJ mol^{-1}* *E = 2880 x 172.4* *= 4.97 x 10^5 kJ*
the common design features and general operating principles of commercial electrolytic cells (including, where practicable, the removal of products as they form), and the selection of suitable electrode materials, the electrolyte (including its state) and any chemical additives that result in a desired electrolysis product (no specific cell is required)	**Question 6** The diagram below shows a commercial, electrolytic cell, used in the production of magnesium metal. Which option shows the correct half equation and electrode combination for the cell when it is in operation?  Source: Mg_by_electrolysis.png A. $2Cl^-(l) \rightarrow 2e^- + Cl_2(g)$ at the positive electrode B. $2e^- + Cl_2(g) \rightarrow 2Cl^-(l)$ at the cathode C. $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$ at the anode D. $Mg^{2+}(aq) + 2e^- \rightarrow Mg(s)$ at the negative electrode	*A*	*Chlorine gas is produced at the anode, the positive electrode, during electrolysis. Chloride ions in the molten electrolyte are reduced during the reaction.* *No water is present in the cell, so H_2O is not oxidised and magnesium ions are not in the aqueous state.*

calculations related to the application of stoichiometry to reactions involving the combustion of fuels, including mass-mass, mass-volume and volume-volume stoichiometry, to determine heat energy released, reactant and product amounts and net volume or mass of major greenhouse gases (CO_2, CH_4 and H_2O), limited to standard laboratory conditions (SLC)	**Question 7** The steel tank shown in the image below contains 9.1 kg of propane. What volume of carbon dioxide will be released into the atmosphere if this mass of propane undergoes complete combustion at SLC?  Source: https://upload.wikimedia.org/wikipedia/commons/f/fe/Propane_tank_20lb.jpg A. 1.7×10^3 L B. 1.8×10^3 L C. 1.5×10^4 L D. 1.6×10^4 L	*C*	$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$ $n(C_3H_8) = m/M$ $= 9.1 \times 1000/(3\times12.0 + 8\times1.0)$ $= 206.8$ mol $n(CO_2) = n(C_3H_8) \times 3/1$ $= 620.5$ mol $V = n \times Vm$ $= 620.5 \times 24.8$ $= 15387L$ or 1.5×10^4 L
identification of bond types by qualitative infrared spectroscopy (IR) data analysis using characteristic absorption bands	**Question 8** Which organic compound could have produced the infrared spectrum shown below?  Source: 2-Butanone (nist.gov) A. ethanol B. propanoic acid C. 2-butanone D. ethanamine	*C*	*The bonds present in the molecule are likely to be:* *C=O (ketone) at* $\sim1700cm^{-1}$ *C-H at* $\sim2850\text{-}3090cm^{-1}$ *This is characteristic of a ketone. 2-butanone is the only ketone molecule in the list of responses.*

Use the following information to answer Questions 9 and 10.

The chemical equation for the complete combustion of methane, at constant temperature and pressure, is shown below:

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$$

redox reactions as simultaneous oxidation and reduction processes, and the use of oxidation numbers to identify the reducing agent, oxidising agent and conjugate redox pairs

Question 9

Which option correctly identifies the species being reduced and the oxidation number of the oxidant during the complete combustion of methane?

	Species being reduced	Oxidant oxidation number
A.	$CH_4(g)$	-2
B.	$CH_4(g)$	+1
C.	$O_2(g)$	0
D.	$O_2(g)$	-4

C

Fuels are oxidised during combustion, so O_2 is being reduced. The oxidant is the species that is reduced (O_2) which has an oxidation number of 0 as it is a free element.

determination of limiting reactants or reagents in chemical reactions

Question 10

100 g of methane undergoes complete combustion in 600 g of oxygen at SLC. Calculate the volume of carbon dioxide produced during the reaction.

A. 155 L

B. 233 L

C. 465 L

D. 620 L

A

$n((CH_4) = 100/(12.0 + 4.0)$
$= 6.25$ mol
$n(O_2) = 600/(16.0 + 16.0)$
$= 18.75$ mol
Oxygen reacts in a 2:1 ratio so methane is limiting.
$n(CH_4) = n(CO_2)$
$V(CO_2) = n \times Vm$
$= 6.25 \times 24.8$
$= 155$ L

the writing of balanced half-equations (including states) for oxidation and reduction reactions, and the overall redox cell reaction in both acidic and basic conditions

Question 11

Consider the unbalanced redox equation shown below:

$$Fe^{2+}(aq) + Cr_2O_7^{2-}(aq) \rightarrow Fe^{3+}(aq) + Cr^{3+}(aq)$$

The balanced, overall equation for this reaction in acidic conditions is

A. $14H^+(aq) + 6Fe^{2+}(aq) + Cr_2O_7^{2-}(aq) \rightarrow 6Fe^{3+}(aq) + 2Cr^{3+}(aq)+7H_2O(l)$

B. $14H^+(aq) + 8Fe^{2+}(aq) + Cr_2O_7^{2-}(aq) \rightarrow 8Fe^{3+}(aq) + 2Cr^{3+}(aq)+7H_2O(l)$

C. $14H^+(aq) + 9Fe^{2+}(aq) + Cr_2O_7^{2-}(aq) \rightarrow 9Fe^{3+}(aq) + 2Cr^{3+}(aq)+7H_2O(l)$

D. $14H^+(aq) + 11Fe^{2+}(aq) + Cr_2O_7^{2-}(aq) \rightarrow 11Fe^{3+}(aq) + 2Cr^{3+}(aq)+7H_2O(l)$

A

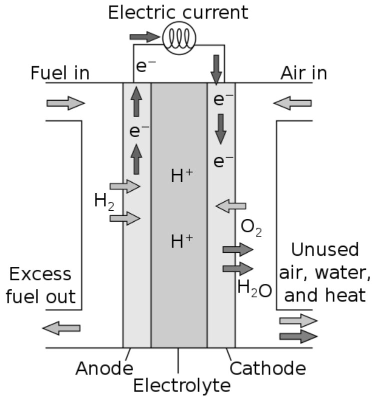
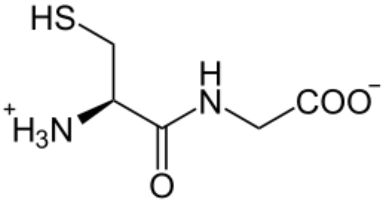
Half equations:

$14H^+(aq) + Cr_2O_2^{-7}(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$

$Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^-$ (multiply by 6 to balance electrons)

Overall equation:

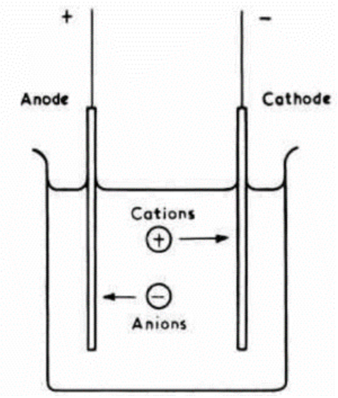
$14H^+(aq) + 6Fe^{2+}(aq) + Cr_2O_7^{2-}(aq) \rightarrow 6Fe^{3+}(aq) + 2Cr^{3+}(aq)+7H_2O(l)$

the common design features and general operating principles of fuel cells, including the use of porous electrodes for gaseous reactants to increase cell efficiency	**Question 12** The diagram below shows a typical hydrogen fuel cell setup. Which statement correctly describes the processes occurring in the fuel cell?  Source: File:Proton Exchange Fuel Cell Diagram.svg **A.** hydrogen is reduced and water is produced as a by-product of the reaction **B.** an electric current is supplied to the cell to force the oxidation of hydrogen **C.** electrical energy is transformed into chemical energy as the cell operates **D.** oxidation occurs at the negative electrode and hydrogen ions travel from the anode to the cathode	*D*	*In this cell, the negative electrode is the anode, the site of oxidation. Oxidised hydrogen ions travel through the electrolyte to the cathode.* *The other options are incorrect because:* *Hydrogen gas is oxidised, not reduced, losing electrons at the anode.* *Fuel cells convert chemical energy to electrical energy and therefore do not require the input of electricity.*
hydrolytic reactions of proteins, carbohydrates and fats and oils to break down large biomolecules in food to produce smaller molecules (formation of zwitterions and denaturation)	**Question 13** The structure below shows a zwitterion of a dipeptide in a neutral solution. Identify the two amino acid molecules that would be produced when this molecule undergoes hydrolysis.  Source: https://commons.wikimedia.org/wiki/File:L-Cysteinylglycin.svg **A.** cysteine and glycine **B.** alanine and cysteine **C.** glycine and lysine **D.** valine and methionine	*A*	*The amino acids are identified by their side chains.* *Cysteine R group: CH_2SH* *Glycine R group: H* *Dependent on the Data Book.*

the common design features and general operating principles of commercial electrolytic cells (including, where practicable, the removal of products as they form), and the selection of suitable electrode materials, the electrolyte (including its state) and any chemical additives that result in a desired electrolysis product (no specific cell is required)

Question 14

The diagram below represents a basic cell set-up, with two solid electrodes and an electrolyte solution.



Source: https://commons.wikimedia.org/wiki/File:Coulometer_in_A._Horsfield,_%22The_Faraday_and_Its_Significance_in_Determining_the_Fundamental_Constants%22.jpg

The cell shown in the diagram could be used to

- **A.** provide a sustainable source of energy.
- **B.** convert chemical energy to electrical energy.
- **C.** oxidise an impure metal at the positive electrode.
- **D.** electroplate an object with copper at the positive electrode.

C

The positive electrode is the site of oxidation in this cell (anode). There must be an input of electrical energy to cause non-spontaneous cell reactions – an electrolytic cell. Electrical energy is being transformed into chemical energy and the oxidation of an impure metal at the positive electrode is one use for this type of cell.

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the application of Faraday's Laws and stoichiometry to determine the quantity of electrolytic reactant and product, and the current or time required to either use a particular quantity of reactant or produce a particular quantity of product

Question 15

Two electrolytic cells are constructed to compare the mass of electroplated material that is deposited at the cathode. Both cells operate for 15.0 minutes with a current of 20.0 A under standard conditions.

Cell A contains an object to be plated at the cathode, copper anode and electrolyte containing Cu^{2+} ions.
Cell B contains an object to be plated at the cathode, tin anode and electrolyte containing Sn^{2+} ions.

Which statement is correct regarding the mass of metal plated at the cathode?

- **A.** the mass of tin plated is the same as the mass of copper plated
- **B.** almost 0.2 g more tin than copper is plated
- **C.** just over 5 g more tin than copper is plated
- **D.** just over 10 g more tin than copper is plated

C

In both cells:
$Q = It$
$= 20.0 \times (15 \times 60)$
$= 18000$ C
$n(e^-) = 18000/96500$
$= 0.187$ mol
$n(\text{metal}) = 0.187/2$
$= 0.0933$ mol
$m(Cu) = n \times M$
$= 0.0933 \times 63.5$
$= 5.92$ g
$m(Sn) = n \times M$
$= 0.0933 \times 118.7$
$= 11.1$ g

11.1 – 5.92 = 5.15 g more tin than copper is plated.

characteristics of the carbon atom that contribute to the diversity of organic compounds formed, with reference to valence electron number, relative bond strength, relative stability of carbon bonds with other elements, degree of unsaturation, and the formation of structural isomers	**Question 16** Consider the following statements regarding the structure and bonding of carbon atoms. I Carbon has a valence electron number of six. II The bond energy of a carbon-to-carbon double bond is greater than for a single carbon-to-carbon bond. III Carbon and silicon have the same valence electron number and form a similar range of compounds. IV Carbon can form single and multiple bonds with itself and a range of other elements. Which of the statements above are correct? **A.** I and III only **B.** II and IV only **C.** III and IV only **D.** I, II, III and IV	*B*	*Double bonds have a higher bond energy than single bonds – requiring more energy to break. Bond energies can be found in the Data Book.* *Carbon is able to bond to itself and a range of other elements, resulting in the vast number of organic molecules that exist.* *Carbon's valence number is 4, not 6.* *While silicon has the same valence number, it does not form a similar range of compounds.*
structural determination of organic compounds by low and high resolution proton nuclear magnetic resonance (^{1}H-NMR) spectral analysis, using chemical shift values, integration curves (where the height is proportional to the area underneath a peak) and peak splitting patterns (excluding coupling constants), and application of the n+1 rule (where n is the number of neighbouring protons) to deduce the number and nature of different proton environments	**Question 17** Which of the following pieces of information can be obtained from the high-resolution ^{1}H spectrum of an organic compound? **A.** the number of unique hydrogen environments, based on splitting patterns of the signals **B.** the number of neighbouring hydrogen atoms adjacent to each environment, based on chemical shift data **C.** the length of the molecule, based on the number of signals **D.** the ratio of hydrogen atoms in each environment, based on signal integration	*D*	*Signal integration, or relative peak area, shows the ratio of hydrogen atoms in each unique environment. The higher the integration, or peak area, the more hydrogen atoms are present in the environment that produced the peak.*

the common design features and general operating principles of rechargeable (secondary) cells, with reference to discharging as a galvanic cell and recharging as an electrolytic cell, including the conditions required for the cell reactions to be reversed and the electrode polarities in each mode

Question 18

Select the option that correctly defines the reactions occurring in a secondary cell.

	During discharge	During recharge
A.	galvanic operation, oxidation at negative electrode	electrolytic operation, oxidation at positive electrode
B.	electrolytic operation, oxidation at positive electrode	galvanic operation, oxidation at negative electrode
C.	galvanic operation, oxidation at positive electrode	electrolytic operation, oxidation at negative electrode
D.	electrolytic operation, oxidation at negative electrode	galvanic operation, oxidation at positive electrode

A

Discharge is galvanic – spontaneous reactions with chemical energy being transformed into electrical energy. Oxidation occurs at the negative terminal.

Recharge is electrolytic – non-spontaneous reactions with electrical energy being transformed into chemical energy. Oxidation occurs at the positive electrode.

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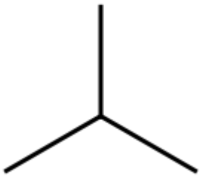
molecular, structural and semi-structural (condensed) formulas and skeletal structures of alkanes (including cyclohexane), alkenes, benzene, haloalkanes, primary amines, primary amides, alcohols (primary, secondary and tertiary), aldehydes, ketones, carboxylic acids and non-branched esters

Question 19

The skeletal structure of an organic compound is shown below.



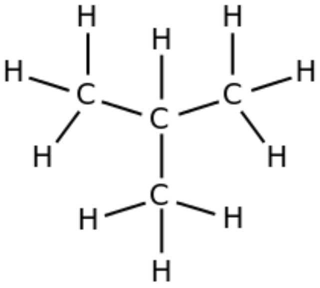
Source: File:I-Butane-2D-Skeletal.svg

What is the IUPAC, systematic name of the compound?

- A. ammonia
- B. methylethane
- C. 2-methylpropane
- D. 1,1-dimethylethane

C

The skeletal formula shows propane with a methyl group on the 2-carbon. Shown in the structure below:



Source: https://commons.wikimedia.org/wiki/File:Isobutane_1.svg

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the reaction quotient (Q) as a quantitative measure of the extent of a chemical reaction: that is, the relative amounts of products and reactants present during a reaction at a given point in time

Question 20

The reaction $Fe^{3+}(aq) + SCN^{-}(aq) \rightarrow FeSCN^{2+}(aq)$ has a value of K equal to 9×10^{2} M^{-1} at 25°C.

At a certain point in time during the reaction, at 25°C, the concentration of each species was found to be:

$[Fe^{3+}] = 0.01$ M

$[SCN^{-}] = 0.01$ M

$[FeSCN^{2+}] = 0.1$ M

The relationship between Q and K, at this point in time, is

- A. Q > K and the forward reaction will be favoured.
- B. Q > K and the reverse reaction will be favoured.
- C. K > Q and the forward reaction will be favoured.
- D. K > Q and the reverse reaction will be favoured.

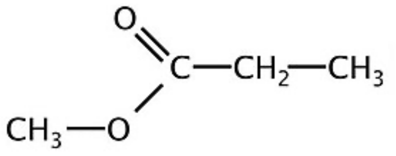
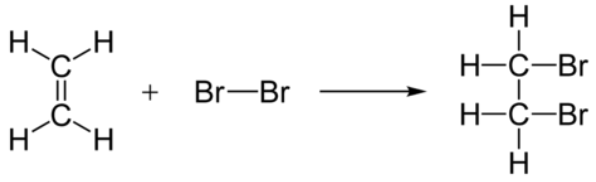
B

$Q = [FeSCN^{2+}] / [Fe^{3+}][SCN^{-}]$

$= 0.1 / 0.01 \times 0.01$

$= 1000\ M^{-1}$

At this point in time, Q is greater than K. The reverse reaction will be favoured to bring the reaction quotient down until equilibrium is established.

trends in physical properties within homologous series (boiling point and melting point, viscosity), with reference to structure and bonding	**Question 21** Select the structure below that is likely to have the lowest viscosity. A. $CH_3(CH_2)_9CH_3$ B. CH_3CH_2COOH C. CH_3COCH_3 D. $CH_3CHCHCH_2CH_3$	*D*	*The more intermolecular bonds that form, the higher the viscosity.* *Option D is the shortest molecule, does not contain polar functional groups and contains a double bond (kink), preventing the formation of intermolecular forces and lowering viscosity.*
organic reactions and pathways, including equations, reactants, products, reaction conditions and catalysts (specific enzymes not required): the esterification between an alcohol and a carboxylic acid	**Question 22** Which two molecules undergo a condensation reaction to produce the larger molecule shown in the diagram below?  Source: https://commons.wikimedia.org/wiki/File:%D8%A7%D9%84%D8%A7%D8%B3%D8%AA%D8%B1%D8%A7%D8%AA_1.jpg A. methanol and propanoic acid B. propan-1-ol and methanoic acid C. methyl propanoate and water D. propyl methanoate and water	*A*	*The ester group (COO) is formed during condensation.* *Breaking the molecule at the COO bond shows that methanol and propanoic acid are the two molecules.*
qualitative tests for the presence of carbon-carbon double bonds, hydroxyl and carboxyl functional groups *addition reactions of alkenes*	**Question 23** The diagram below shows the reaction of ethene with bromine.  Source: File:Bromine-adds-to-ethene.png The reaction is A. an addition reaction and bromine changes from colourless to brown. B. a substitution reaction that tests for the presence of halogen functional groups. C. an addition reaction that tests for the presence of carbon-carbon double bonds. D. a substitution reaction and bromine changes from brown to colourless.	*C*	*The bromine test is used to detect carbon-carbon double bonds. If present, the Br_2 undergoes an addition reaction across the carbon double bond and a colour change is observed from brown to colourless.*

condensation reactions to synthesise large biologically important molecules for storage as proteins, starch, glycogen and lipids (fats and oils)

Question 24

Which of the following is not produced via a condensation reaction?

A. cellulose

B. glucose

C. an ester

D. a triglyceride

B

A condensation reaction involves the formation of a covalent bond between two monomers, with the elimination of a small molecule, usually water. Glucose is a monomer unit and is not formed through condensation with other molecules.

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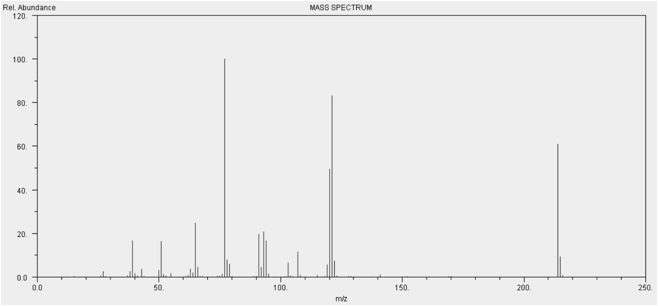
applications of mass spectrometry (excluding features of instrumentation and operation) and interpretation of qualitative and quantitative data, including identification of molecular ion peak, determination of molecular mass and identification of simple fragments

Question 25

The diagram below shows the mass spectrum of an unidentified, organic compound with molecular formula $C_{14}H_{14}O_2$.



Source: File:Difenossi etano spectrum mass.png

From the information provided, it can be assumed that

A. the base peak is at m/z 214 and a $[CH_3CH_2]^+$ fragment is possible.

B. the molar mass of the compound is 215 g mol^{-1} and there are isotopes of carbon-13 in the compound.

C. the m/z 121 peak could be produced by a $[C_8H_9O]^+$ fragment and the molecular mass of the compound is 216 g mol^{-1}.

D. the molecular mass of the compound is 214 g mol^{-1} and a benzene functional group could produce the peak with greatest abundance.

D

From the molecular formula, the molar mass of the organic compound is 214 g mol^{-1}. The base peak at m/z 77 could be produced by a benzene fragment that was bonded to the molecule (C_6H_5).

the roles and applications of laboratory and instrumental analysis, with reference to product purity and the identification of organic compounds or functional groups in isolation or within a mixture

Question 26

Which of the following does not correctly describe an instrumental analysis technique commonly used to determine the purity of commercial products?

A. using reference samples to determine the identity of specific impurities using IR spectroscopy

B. using known standards and NMR spectra to analyse organic samples for substitution of ingredients

C. identifying additional peaks in IR spectra that should not be present according to database records of pure compounds

D. identifying contaminant functional groups from peak splitting patterns produced during mass spectrometry

D

Mass spectrometry does not produce peak splitting patterns. This is a feature of high-resolution ^{1}H NMR spectroscopy.

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extraction and purification of natural plant compounds as possible active ingredients for medicines, using solvent extraction and distillation

Question 27

The solvent extraction process can be used to extract medicinal components from plants. For the process to work effectively

A. both the solvent and the plant matter should be in liquid form.

B. the temperature of the solvent should always be close to boiling point.

C. the leaves should not be blended or shredded as this breaks down their structure.

D. the polarity of the component being extracted should be the same as the solvent.

D

In order for the components to dissolve into the solvent, their polarities should be the same (like dissolves like).

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enzymes as protein-based catalysts in living systems: primary, secondary, tertiary and quaternary structures and changes in enzyme function in terms of structure and bonding as a result of increased temperature (denaturation), decreased temperature (lowered activity), or changes in pH (formation of zwitterions and denaturation)

Question 28

Which option correctly lists specific bonding types present in the primary, secondary and tertiary folding patterns of protein molecules?

	Primary folding	**Secondary folding**	**Tertiary folding**
A.	covalent bonds	covalent bonds	a variety of bond types
B.	hydrogen bonds	hydrogen bonds	a variety of bond types
C.	covalent bonds	a variety of bond types	dipole-dipole forces and ionic bonds
D.	covalent bonds	hydrogen bonds	covalent and hydrogen bonds

D

The primary structure of proteins involves the formation of covalent peptide links between amino acid residues. Secondary folding structures form due to hydrogen bonding between polar peptide link groups. The C=O on one peptide link and the N-H on another peptide link. Tertiary bonding can include a variety of bond types, depending on the R-groups of the amino acids in the protein chain.

the accuracy, precision, repeatability, reproducibility, resolution and validity of measurements

volumetric analysis

Question 29

A group of Year 12 students conducted multiple trials of a volumetric analysis investigation over several days. They noticed that their results fluctuated, depending on the student carrying out the titration each day. The results are shown in the table below:

Day	Conducted by	Volume of acid required to reach the end point (mL)
Mon	Student 1	24.50
Tues	Student 1	24.55
Wed	Student 1	24.55
Thurs	Student 1	24.45
Mon	Student 2	26.25
Tues	Student 2	26.20
Wed	Student 2	26.25
Thurs	Student 2	26.20

From the results, it can be concluded that

A. the method has high repeatability.

B. the method has high reproducibility.

C. results from Student 1 are more accurate than Student 2.

D. results from Student 1 are more precise than Student 2.

A

The method has high repeatability under the same conditions as results show little range (high precision) when conducted by the same student. Both students were able to achieve concordant titres.

The method does not have high reproducibility. When carried out by different students, results varied.

Further testing and modifications to the method would be required before making a judgement on how close the results are to the true value.

Student 2's results show a higher degree of precision than Student 1.

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the principles of chromatography, including high performance liquid chromatography (HPLC) and the use of retention times and the construction of a calibration curve to determine the concentration of an organic compound in a solution (excluding features of instrumentation and operation)

Question 30

High-performance liquid chromatography (HPLC) is an analytical technique used to separate and identify components in a mixture. An increase in the length of the column would

A. increase the peak area.

B. not affect relative retention times of components.

C. reduce overall analysis time if the flow rate remains unchanged.

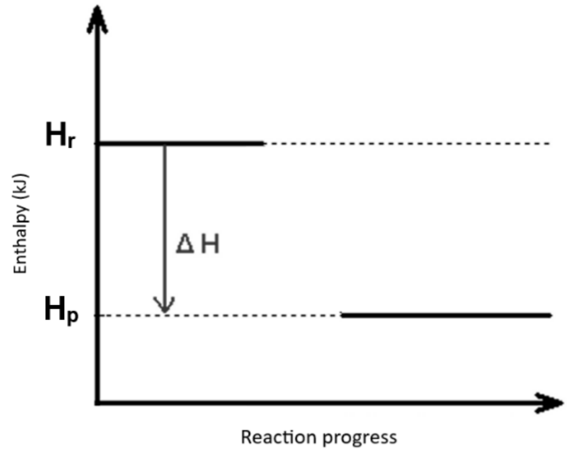
D. increase the separation resolution of the components.

D

Increasing the length of the column allows for clearer separation of the components, reducing the overlap of peaks. The identity of components can be more accurately predicted, particularly when two components have similar retention times.

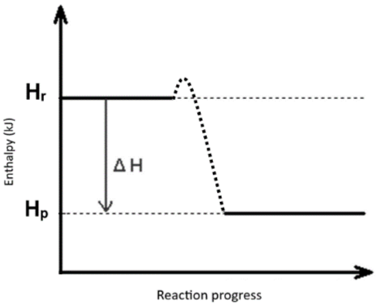
Section B

The diagram below shows an incomplete energy profile diagram for an exothermic chemical reaction. The ΔH for this reaction was found to be -726 $kJ\ mol^{-1}$ at SLC.

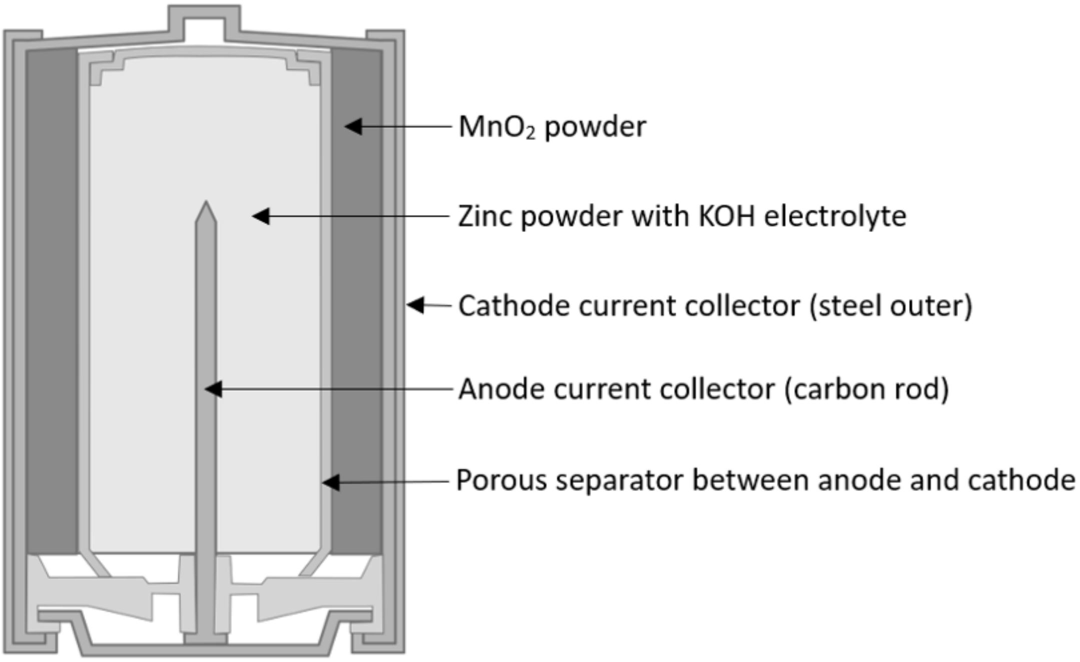


Source: Adapted from https://commons.wikimedia.org/wiki/File:Entalpia_r_exotermica.PNG

VCAA Key Knowledge	Question	Answer Guide
molar enthalpy changes measured in $kJ\ mol^{-1}$ and enthalpy changes for mixtures measured in $kJ\ g^{-1}$, and their representations in energy profile diagrams	**Question 1a** (2 marks) With reference to the diagram, explain why energy is released as the reaction progresses.	**Answer:** • *On the diagram, the energy of the reactants is higher than the energy of the products.* • *As the reaction progresses, excess energy from the reactants is lost as heat to the surroundings.* **Marking Protocol:** One mark for each of the above points.
comparison of exothermic and endothermic reactions, with reference to bond making and bond breaking, including enthalpy changes (ΔH) measured in kJ	**Question 1b** (2 marks) The ΔH for this reaction is -726 $kJ\ mol^{-1}$ at SLC. Explain why exothermic reactions have a negative ΔH value.	**Answer:** • *ΔH is calculated by Hp – Hr.* • *Given that the energy of the reactants is higher than the energy of the products, the value of ΔH will always be negative for an exothermic reaction.* **Marking Protocol:** One mark for each of the above points.
comparison of exothermic and endothermic reactions, with reference to bond making and bond breaking	**Question 1c** (1 mark) Explain the exothermic nature of the reaction with reference to bond breaking and bond forming as the reaction progresses.	**Answer:** • *The amount of energy released when bonds form in the products is greater than the amount of energy absorbed when bonds in the reactants break.* **Marking Protocol:** One mark for the above point.

comparison of exothermic and endothermic reactions, with reference to bond making and bond breaking, including enthalpy changes (ΔH) measured in kJ, molar enthalpy changes measured in kJ mol^{-1} and enthalpy changes for mixtures measured in kJ g^{-1}, and their representations in energy profile diagrams	**Question 1d** (1 mark) The activation energy for the reaction is +100 kJ mol^{-1}. Complete the energy profile by sketching a curve on the diagram to show the magnitude of the activation energy.	**Answer:** •  **Marking Protocol:** One mark for the above point. Note: The activation energy should be approximately 1/8th the height of the ΔH. While students are not expected to draw to scale, an attempt should be made to sketch an activation energy with a magnitude relative to ΔH.
combustion (complete and incomplete) reactions of fuels as exothermic reactions: the writing of balanced thermochemical equations, including states, for the complete and incomplete combustion	**Question 1e** (3 marks) Write the thermochemical equation for the complete combustion of liquid methanol at SLC.	**Answer:** • $CH_3OH(l) + 3/2O_2(g) \rightarrow CO_2(g) + 2H_2O(l) \quad \Delta H = -726\ kJ$ *OR* • $2CH_3OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(l) \quad \Delta H = -1452\ kJ$ **Marking Protocol:** Three marks for either of the above points (either can be accepted but take note of ΔH), including: One mark for correct states (liquid methanol and water should be liquid at SLC). One mark for the correct ΔH including units. One mark for a correctly balanced equation.
including mass-mass, mass-volume and volume-volume stoichiometry, to determine heat energy released, reactant and product amounts and net volume or mass of major greenhouse gases (CO_2, CH_4 and H_2O), limited to standard laboratory conditions (SLC)	**Question 1f** (3 marks) Calculate the volume of CO_2 released into the atmosphere if 1.00 L of pure methanol undergoes complete combustion in excess oxygen at SLC. The density of methanol is 0.791 g mL^{-1}.	**Answer:** • $m(CH_3OH) = 0.791 \times 1000 = 791\ g$ • $n(CH_3OH) = 791/(12.0 + 3.0 + 16.0 + 1.0)$ $= 24.7\ mol$ $n(CO_2) = n(CH_3OH)$ $= 24.7\ mol$ • $V = n \times Vm$ $= 24.7 \times 24.8$ = 613 L *correct to 3 significant figures* **Marking Protocol:** One mark for the density conversion of methanol. One mark for the correct calculation of mole of carbon dioxide. One mark for the correct calculation of the volume of CO_2. Note: Significant figures must be correct for the third mark.

In an alkaline battery, zinc powder reacts at the anode and manganese dioxide powder reacts at the cathode. Potassium hydroxide is used as the electrolyte. The diagram below shows the setup of the cell.



Adapted from: https://commons.wikimedia.org/wiki/File:Alkaline-battery-english.svg

factors affecting the frequency and success of reactant particle collisions and the rate of a chemical reaction in open and closed systems, including temperature, surface area, concentration, gas pressures, presence of a catalyst, activation energy and orientation	**Question 2a** (2 marks) Explain why the solid reactants are present in powdered form.	**Answer:** - *Crushing a solid increases its surface area.* - *The increased surface area allows for a faster rate of reaction at the electrodes/increased efficiency.* **Marking Protocol:** One mark for each of the above points.

The reaction occurring at the cathode during discharge is:

$2MnO_2(s) + H_2O(l) + 2e^- \rightarrow Mn_2O_3(s) + 2OH^-(aq)$

deducing overall equations from redox half-equations and for determining maximum cell voltage under standard conditions redox reactions as simultaneous oxidation and reduction processes, and the use of oxidation numbers to identify the reducing agent, oxidising agent and conjugate redox pairs	**Question 2bi** (2 marks) Use oxidation numbers to show that manganese undergoes reduction during the reaction.	**Answer:** - *Mn in MnO_2 is +4* *Mn in Mn_2O_3 is +3* - *A decrease in oxidation number indicates reduction has taken place.* **Marking Protocol:** One mark for each of the above points.

deducing overall equations from redox half-equations and for determining maximum cell voltage under standard conditions *redox reactions as simultaneous oxidation and reduction processes, and the use of oxidation numbers to identify the reducing agent, oxidising agent and conjugate redox pairs*	**Question 2bii** (1 mark) Write the half-cell equation for the reaction occurring at the anode during discharge, where Zn(s) is oxidised to ZnO(s).	**Answer:** - $Zn(s) + 2OH^{-}(aq) \rightarrow ZnO(s) + H_2O(l) + 2e^{-}$ **Marking Protocol:** One mark for the above point.

deducing overall equations from redox half-equations and for determining maximum cell voltage under standard conditions *redox reactions as simultaneous oxidation and reduction processes, and the use of oxidation numbers to identify the reducing agent, oxidising agent and conjugate redox pairs*	**Question 2biii** (1 mark) Write the overall equation for the alkaline battery during discharge.	**Answer:** - $Zn(s) + 2MnO_2(s) \rightarrow ZnO(s) + Mn_2O_3(s)$ **Marking Protocol:** One mark for the above point.

the common design features and general operating principles of non-rechargeable (primary) galvanic cells converting chemical energy into electrical energy	**Question 2c** (3 marks) Battery technology has improved greatly over the past few years with respect to energy output, charge time and safety. Many of these improvements have been in the development of battery technology for Electric Vehicles (EVs). Compare the energy efficiency of a battery designed for an EV with a traditional petrol combustion engine.	**Answer:** - *Batteries are more efficient than petrol combustion engines.* - *Batteries involve only one transformation of energy, from chemical to electrical. This minimises energy loss to the surroundings.* - *On the other hand, combustion engines involve several transformations of energy. More energy is lost to the surroundings through each transformation.* **Marking Protocol:** One mark for each of the above points.

the common design features and general operating principles of fuel cells, including the use of porous electrodes for gaseous reactants to increase cell efficiency	**Question 2d** (1 mark) Hydrogen fuel cells offer another possibility for electricity generation in EVs. Explain why fuel cells are usually designed with porous electrodes.	**Answer:** - *To increase the surface area of the electrode for the oxidation and reduction of gaseous reactants, increasing efficiency (or rate of reaction).* **Marking Protocol:** One mark for the above point.

contemporary responses to challenges and the role of innovation in the design of fuel cells to meet society's energy needs	**Question 2e** (2 marks) State one advantage and one disadvantage of using hydrogen fuel cell technology to power EVs instead of batteries.	**Answer:** *Advantages* • *Hydrogen is energy dense/low mass so it can improve the range of the car before refuelling compared to a battery range.* • *Short refuelling time compared to recharging a battery.* • *Can be used in the commercial transport industry for long-haul travel due to its increased range.* • *Hydrogen fuel can be produced sustainably with solar power resulting in a zero-emissions fuel source.* *Disadvantages* • *The current infrastructure is set up for battery recharging stations, not hydrogen refuelling.* • *Hydrogen storage tanks take up space and add mass to the vehicle. These are not necessary for battery-powered cars.* • *The production of hydrogen requires the input of energy – which may involve the use of fossil fuels to generate, which is not sustainable.* **Marking Protocol:** One mark for any of the above points (one advantage and one disadvantage), to a maximum of two.

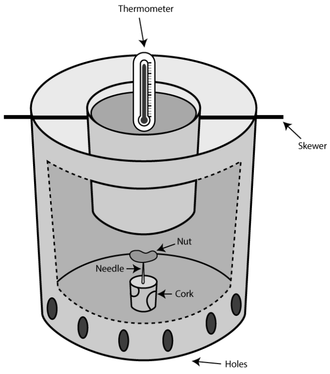
Almonds are considered a nutritious food option with many health benefits, including lowering blood sugar and cholesterol levels. They contain healthy fats, protein, fibre and a range of vitamins and minerals. They are also an excellent source of energy for the body.

The information table below shows some of the nutrient data for raw almonds per 100 g.

	per 100 g
Total Protein (g)	19.7
Total Fat (g)	50.5
Total Carbohydrate (g)	5.4

energy from fuels and food: *comparison and calculations of energy values of foods containing carbohydrates, proteins and fats and oils*	**Question 3a** (2 marks) Use the data in the table to calculate the energy content of almonds in kJ g^{-1}.	**Answer:** • *Protein 19.7 x 17 = 334.9 kJ* *Carbohydrate 5.4 x 16 = 86.4 kJ* *Fat 50.5 x 37 = 1868.5 kJ* *Total in 100 g = 2289.8 kJ* • *2289.8 / 100* *= 23 kJ* g^{-1} **Marking Protocol:** One mark for each of the above points.

A basic calorimeter was set up in a school laboratory to determine the energy content of almonds, as shown in the diagram below.



Source: https://www.education.com/science-fair/article/how-much-potential-energy-do-different/

the use of specific heat capacity of water to approximate the quantity of heat energy released during the combustion of a known mass of fuel and food	**Question 3b** (2 marks) One small almond, with a mass of 0.950 g, underwent complete combustion in the calorimeter. 100 g of water in the suspended cup showed an increase in temperature of 11.3°C after combustion. Calculate the energy content of almonds in kJ g^{-1}.	**Answer:** • $E = m\ \mathrm{x}\ c\ \mathrm{x}\ \Delta T$ $= 100\ \mathrm{x}\ 4.18\ \mathrm{x}\ 11.3$ $= 4723.4\ \text{J}$ $= 4.72\ \text{kJ}$ • *Energy content* $= 4.72/0.950$ $= 4.97\ \text{kJ g}^{-1}$ **Marking Protocol:** One mark for each of the above points.

the principles of solution calorimetry and consideration of the effects of heat loss	**Question 3c** (2 marks) Compare your answers for Questions 3a and 3b. State one likely reason for the difference in calculated values.	**Answer:** • *The data calculation shows a much higher energy content of almonds than the experimental calculation.* • *This could be because:* - *heat was lost to the environment.* - *there was no lid on the calorimeter to trap heat.* - *the can absorbed some of the heat.* - *there was actually more water in the can than 100 g.* - *there was incomplete combustion of the almond.* - *the holes did not provide enough oxygen for complete combustion.* - *the sample of almond did not contain the average amount of nutrients, as stated in the data table.* - *(or any other valid reason why the calculated value is lower in the experimental version)* **Marking Protocol:** One mark for each of the above points. A comparison of values and a valid reason is required. Note: Watch for consequential marks if students calculated an answer to Question 3b to be higher than 3a. Accept any logical reason for why results might be higher, e.g. the thermometer was touching the side of the can, or that there was less than 100 g water in the can.

the principles of solution calorimetry, including determination of calibration factor	**Question 3d** (2 marks) Calorimeters can be calibrated to improve accuracy. Describe how this simple calorimeter could be calibrated before being used in an investigation.	**Answer:** - *Supply a known amount of energy to the water in the suspended can.* - *Determine the calibration factor by dividing the energy provided to the water by the change in temperature of the water during calibration (J $^{\circ}C^{-1}$).* **Marking Protocol:** One mark for each of the above points.

the accuracy, precision, repeatability, reproducibility, resolution and validity of measurements	**Question 3e** (2 marks) Explain why calibrated calorimeters are more accurate than non-calibrated calorimeters.	**Answer:** - *Calibration determines the heat capacity of the specific calorimeter being used in an investigation, taking into account heat loss that may be occurring throughout the process.* - *This brings the experimental value closer to the true value.* **Marking Protocol:** One mark for each of the above points.

combustion (complete and incomplete) reactions of fuels as exothermic reactions	**Question 3f** (1 mark) State the main purpose of the holes in the bottom of the calorimeter.	**Answer:** - *The holes allow oxygen (reactant) to flow into the calorimeter to ensure complete combustion.* **Marking Protocol:** One mark for the above point.

The Haber process is used to produce ammonia from hydrogen gas and nitrogen gas. The equation for the reaction is shown below.

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H = -92.4 kJ$

A summary of operating conditions and processes is shown below.

Condition/Process	Haber Cell
Temperature	High
Pressure	Moderately high
Catalyst	Yes
Recycling of unreacted gases	Yes

the distinction between reversible and irreversible reactions, and between rate and extent of a reaction *factors affecting the frequency and success of reactant particle collisions and the rate of a chemical reaction in open and closed systems, including temperature, surface area, concentration, gas pressures, presence of a catalyst, activation energy and orientation* *the change in position of equilibrium that can occur when changes in temperature or species or volume (concentration or pressure) are applied to a system at equilibrium*	**Question 4ai** (2 marks) Explain the effect of high pressure on the rate of production of ammonia.	**Answer:** - *There are more particles per unit area, resulting in an increase in the frequency of particle collision.* - *An increase in the number of successful collisions increases the rate of reaction.* **Marking Protocol:** One mark for each of the above points.

the distinction between reversible and irreversible reactions, and between rate and extent of a reaction *factors affecting the frequency and success of reactant particle collisions and the rate of a chemical reaction in open and closed systems, including temperature, surface area, concentration, gas pressures, presence of a catalyst, activation energy and orientation* *the change in position of equilibrium that can occur when changes in temperature or species or volume (concentration or pressure) are applied to a system at equilibrium*	**Question 4aii** (2 marks) Explain the effect of low temperatures on the yield of ammonia.	**Answer:** • *The reaction is exothermic so a decrease in temperature favours the forward reaction and therefore the yield of ammonia increases.* • *The system opposes the change by releasing heat through the exothermic pathway (forward reaction).* **Marking Protocol:** One mark for each of the above points.

responses to the conflict between optimal rate and temperature considerations in producing equilibrium reaction products, with reference to the green chemistry principles of catalysis and designing for energy efficiency	**Question 4bi** (1 mark) Manufacturers of ammonia must compromise on the operating conditions and processes to balance the rate, yield and cost of production. State one reason why temperature is set at a moderately high level, rather than low.	**Answer:** • *If the temperature is too low, the rate of reaction will be so slow that very little ammonia is produced in a timely manner.* *OR* • *The specific catalyst used in the Haber process requires a higher temperature to be functional.* **Marking Protocol:** One mark for either of the above points.

responses to the conflict between optimal rate and temperature considerations in producing equilibrium reaction products, with reference to the green chemistry principles of catalysis and designing for energy efficiency	**Question 4bii** (1 mark) Explain why recycling of the unreacted gases leads to a higher yield.	**Answer:** • *Constant input of reactant gases favours the forward reaction, increasing yield.* **Marking Protocol:** One mark for the above point.

the role of catalysts in increasing the rate of specific reactions, with reference to alternative reaction pathways of lower activation energies *responses to the conflict between optimal rate and temperature considerations in producing equilibrium reaction products,*	**Question 4c** (2 marks) Describe the role of the catalyst in the Haber process, with reference to the temperature stated in the operating conditions table.	**Answer:** • *The catalyst increases the rate of reaction by providing a reaction pathway with lower activation energy.* • *The temperature can be kept lower to help with cost and poor yield.* **Marking Protocol:** One mark for each of the above points.

calculations involving equilibrium expressions (including units) for a closed homogeneous equilibrium system and the dependence of the equilibrium constant (K) value on the system temperature and the equation used to represent the reaction

Question 4d (4 marks)

30.0 mol of N_2 gas and 90.0 mol of H_2 gas are added to a 10.0 L tank at a particular temperature and pressure. At equilibrium, 10.0 mol of ammonia, NH_3, is present. Calculate the equilibrium constant, K, for the reaction under these conditions.

Answer:

Equation	$N_2(g)$ +	$3H_2(g)$ ⇌	$2NH_3(g)$
I	30.0 mol	90.0 mol	0.00 mol
C	-x	-3x	+2x
E	25.0 mol	75.0 mol	10.0 mol
mol L^{-1}	25.0/10.0 = 2.50 M	75.0/10.0 = 7.50 M	10.0/10.0 = 1.00 M

$K = [NH_3]^2 / [N_2][H_2]^3$
$= 1.00^2 / 2.50 \times 7.50^3$
$= 9.48 \times 10^{-4}\ M^{-2}$

OR (Students may also complete the calculations without an ICE table)

$n(NH_3)$ produced = 10.0 mol
$c(NH_3)$ at equilibrium = 10.0/10.0 = 1.00 M

$n(N_2)$ reacting (stoichiometry) = 10.0/2 = 5.0 mol
$n(N_2)$ at equilibrium = 30.0 – 5.0 = 25.0 mol
$c(N_2)$ at equilibrium = 25.0/10.0 = 2.50 M

$n(H_2)$ reacting = 10.0 x 3/2 = 15.0 mol
$n(H_2)$ at equilibrium = 90.0 – 15.0 = 75.0 mol
$c(H_2)$ at equilibrium = 75.0/10.0 = 7.50 M

$K = [NH_3]^2 / [N_2][H_2]^3$
$= 1.00^2 / 2.50 \times 7.50^3$
$= 9.48 \times 10^{-4}\ M^{-2}$

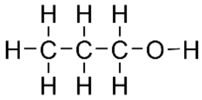
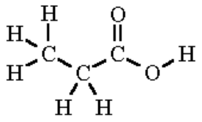
Marking Protocol:

One mark for all three correct equilibrium mole calculations. One mark for all three conversions to molar concentration shown. One mark for correct equilibrium expression.
One mark for correct calculation of the equilibrium constant with correct units.
Note: Award consequential marks for correct molar concentration conversions and/or use of the equilibrium expression with incorrect values.
I is 'Initial', C is 'Change' and E is 'Equilibrium'.

responses to the conflict between optimal rate and temperature considerations in producing equilibrium reaction products, with reference to the green chemistry principles of catalysis and designing for energy efficiency	**Question 4e** (2 marks) State two ways the processes and operating conditions associated with the industrial production of ammonia are designed to meet the green chemistry principle of 'designing for energy efficiency'.	**Answer:** • *Unreacted gases are recycled, reducing waste and improving efficiency.* • *The catalyst reduces the amount of energy required for a fast reaction rate.* • *Ammonia production is exothermic – the heat generated can be recycled to other processes.* • *Temperatures are kept moderately high, instead of high, reducing the overall energy consumption.* **Marking Protocol:** One mark for any of the above points, to a maximum of two.

The table below compares some of the common properties and structural features of two organic compounds, propan-1-ol and propanoic acid.

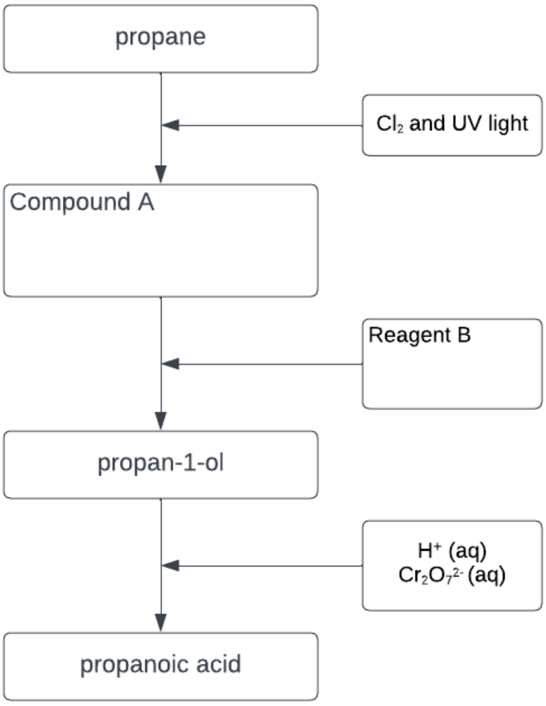
Property/Structure at SLC	**propan-1-ol**	**propanoic acid**
Molecular formula	C_3H_8O	$C_3H_6O_2$
Boiling point	97.2 °C	141.1 °C
Flash point	23 °C	53 °C

molecular, structural and semi-structural (condensed) formulas and skeletal structures of alkanes (including cyclohexane), alkenes, benzene, haloalkanes, primary amines, primary amides, alcohols (primary, secondary and tertiary), aldehydes, ketones, carboxylic acids and non-branched esters	**Question 5a** (2 marks) Draw the full, structural formulas of propan-1-ol and propanoic acid into the boxes below. propan-1-ol propanoic acid	**Answer:** • ***propan-1-ol*** Source: https://commons.wikimedia.org/wiki/File:Propanol_flat_structure.png  ***propanoic acid*** Source: Propanoic Acid Formula & Structure (purdue.edu)  **Marking Protocol:** One mark for the structural formula of propan-1-ol – all bonds should be shown. One mark for the structural formula of propanoic acid – all bonds should be shown.

trends in physical properties within homologous series (boiling point and melting point, viscosity), with reference to structure and bonding	**Question 5b** (2 marks) Explain why the boiling point of propanoic acid is higher than the boiling point of propan-1-ol.	**Answer:** • *There are stronger intermolecular bonds between propanoic acid molecules than between propan-1-ol molecules.* • *These require more energy to break, so the boiling point is higher.* **Marking Protocol:** One mark for each of the above points.

the health, safety and ethical guidelines relevant to the selected scientific investigation	**Question 5c** (2 marks) The 'flash point' is the lowest temperature of a liquid at which the vapours forming above a substance can ignite in the presence of an ignition source. Use the data to explain why a Safety Data Sheet for propan-1-ol lists 'Use only non-sparking tools' as a precautionary measure.	**Answer:** • *The flash point of propan-1-ol is below standard laboratory conditions/room temperature.* • *Therefore, any source of ignition could cause the vapours to ignite.* **Marking Protocol:** One mark for each of the above points.

Propanoic acid can be synthesised in a laboratory from propane, a constituent of crude oil. The reaction pathway is shown below.



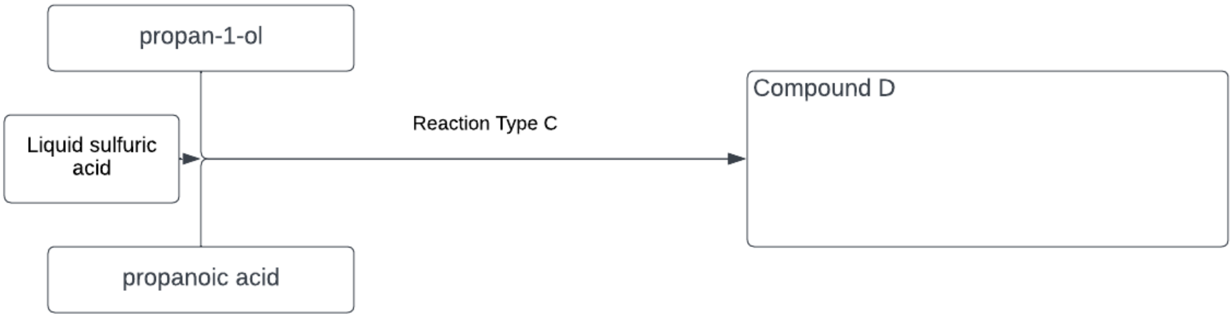
the International Union of Pure and Applied Chemistry (IUPAC) systematic naming of organic compounds up to C8, with no more than two functional groups for a molecule, limited to non-cyclic hydrocarbons, haloalkanes, primary amines, alcohols (primary, secondary and tertiary), aldehydes, ketones, carboxylic acids and non-branched esters *organic reactions and pathways, including equations, reactants, products, reaction conditions and catalysts (specific enzymes not required):* *applications and principles of laboratory analysis techniques in verifying components and purity of consumer products, including melting point determination and distillation (simple and fractional)*	**Question 5di** (1 mark) Write the IUPAC name of Compound A into the box provided on the diagram.	**Answer:** • *1-chloropropane* **Marking Protocol:** One mark for the above point.

the International Union of Pure and Applied Chemistry (IUPAC) systematic naming of organic compounds up to C8, with no more than two functional groups for a molecule, limited to non-cyclic hydrocarbons, haloalkanes, primary amines, alcohols (primary, secondary and tertiary), aldehydes, ketones, carboxylic acids and non-branched esters *organic reactions and pathways, including equations, reactants, products, reaction conditions and catalysts (specific enzymes not required):* *applications and principles of laboratory analysis techniques in verifying components and purity of consumer products, including melting point determination and distillation (simple and fractional)*	**Question 5dii** (1 mark) In the box provided on the diagram, write the formula of the ionic species that acts as Reagent B.	**Answer:** • *NaOH* **Marking Protocol:** One mark for the above point.

the International Union of Pure and Applied Chemistry (IUPAC) systematic naming of organic compounds up to C8, with no more than two functional groups for a molecule, limited to non-cyclic hydrocarbons, haloalkanes, primary amines, alcohols (primary, secondary and tertiary), aldehydes, ketones, carboxylic acids and non-branched esters *organic reactions and pathways, including equations, reactants, products, reaction conditions and catalysts (specific enzymes not required):* *applications and principles of laboratory analysis techniques in verifying components and purity of consumer products, including melting point determination and distillation (simple and fractional)*	**Question 5diii** (2 marks) The reaction pathway leads to the production of a significant amount of propan-2-ol. Explain why this isomer does not undergo further synthesis to produce propanoic acid.	**Answer:** - *Carbon forms 4 bonds with other atoms in a molecule.* - *The carboxyl group does not form on a central carbon atom as it would require carbon to form 5 bonds.* **Marking Protocol:** One mark for each of the above points.

the International Union of Pure and Applied Chemistry (IUPAC) systematic naming of organic compounds up to C8, with no more than two functional groups for a molecule, limited to non-cyclic hydrocarbons, haloalkanes, primary amines, alcohols (primary, secondary and tertiary), aldehydes, ketones, carboxylic acids and non-branched esters *organic reactions and pathways, including equations, reactants, products, reaction conditions and catalysts (specific enzymes not required):* *applications and principles of laboratory analysis techniques in verifying components and purity of consumer products, including melting point determination and distillation (simple and fractional)*	**Question 5div** (1 mark) Propan-1-ol and propan-2-ol have similar boiling points. Explain how fractional distillation could be used to separate the two isomers.	**Answer:** • *Fractional distillation involves multiple distillation and condensation cycles, resulting in more complete separation/purification of components with similar boiling points.* **Marking Protocol:** One mark for the above point.

The diagram below shows the reaction pathway for the production of Compound D.

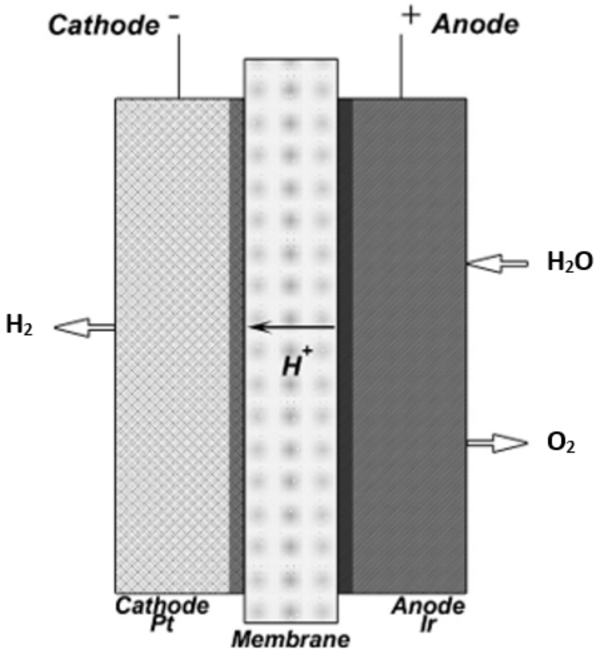


organic reactions and pathways, including equations, reactants, products, reaction conditions and catalysts (specific enzymes not required) *the esterification between an alcohol and a carboxylic acid* *calculations of percentage yield and atom economy of single-step or overall reaction pathways, and the advantages for society and for industry of developing chemical processes with a high atom economy*	**Question 5ei** (1 mark) State the name of Reaction Type C.	**Answer:** - *Oxidation, condensation or esterification.* **Marking Protocol:** One mark for the above point.

organic reactions and pathways, including equations, reactants, products, reaction conditions and catalysts (specific enzymes not required) *the esterification between an alcohol and a carboxylic acid* *calculations of percentage yield and atom economy of single-step or overall reaction pathways, and the advantages for society and for industry of developing chemical processes with a high atom economy*	**Question 5eii** (1 mark) Write the IUPAC name of the product of this reaction, Compound D, in the box provided on the diagram.	**Answer:** - *Propyl propanoate.* **Marking Protocol:** One mark for the above point.

organic reactions and pathways, including equations, reactants, products, reaction conditions and catalysts (specific enzymes not required) the esterification between an alcohol and a carboxylic acid *calculations of percentage yield and atom economy of single-step or overall reaction pathways, and the advantages for society and for industry of developing chemical processes with a high atom economy*	**Question 5eiii** (2 marks) Calculate the atom economy of Reaction Type C to produce Compound D.	**Answer:** • *Molar masses of reactants and products* *M(propan-1-ol) = 60.0 g mol*$^{-1}$ *M(propanoic acid) = 74.0 g mol*$^{-1}$ *M(propyl propanoate = 116.0 g mol*$^{-1}$ • *M(Compound D)/M(All reactants) x 100* *= 116/(60 + 74) x100* *= 86.6%* **Marking Protocol:** One mark for each of the above points.

The diagram below shows the basic operation of a PEM electrolyser.



Source: https://commons.wikimedia.org/wiki/File:PEMelectrolysis.jpg#/media/File:PEMelectrolysis.jpg

the common design features and general operating principles of commercial electrolytic cells (including, where practicable, the removal of products as they form), and the selection of suitable electrode materials, the electrolyte (including its state)	**Question 6a** (2 marks) Other than allowing the passage of hydrogen ions from the anode to the cathode, state two purposes of the membrane in the electrolyser.	**Answer:** • *Separation of the product gases* H_2 *and* O_2 *that would spontaneously react if they came in contact.* • *Completion of the internal circuit.* • *Prevention of the direct flow of electrons/direct reaction of reactants.* **Marking Protocol:** One mark for any of the above points, to a maximum of two.

the writing of balanced equations (with states) for the reactions occurring at the anode and cathode and the overall redox reaction for the cell	**Question 6b** (1 mark) Write the half equation for the reaction occurring at the cathode while the cell is in operation.	**Answer:** • $2H^+ + 2e^- \rightarrow H_2(g)$ **Marking Protocol:** One mark for the above point.

the role of innovation in designing cells to meet society's energy needs in terms of producing 'green' hydrogen (including equations in acidic conditions) using the following methods: polymer electrolyte membrane electrolysis powered by either photovoltaic (solar) or wind energy	**Question 6c** (1 mark) Green chemistry principles require new technologies to be developed with the use of renewable feedstocks where possible. Describe how the PEM electrolyser can produce hydrogen, required as a reactant in hydrogen fuel cells, renewably.	**Answer:** • *The energy for the electrolysis of water can be obtained from renewable biofuels or solar/wind generators, reducing the need for fossil fuels.* **Marking Protocol:** One mark for the above point.

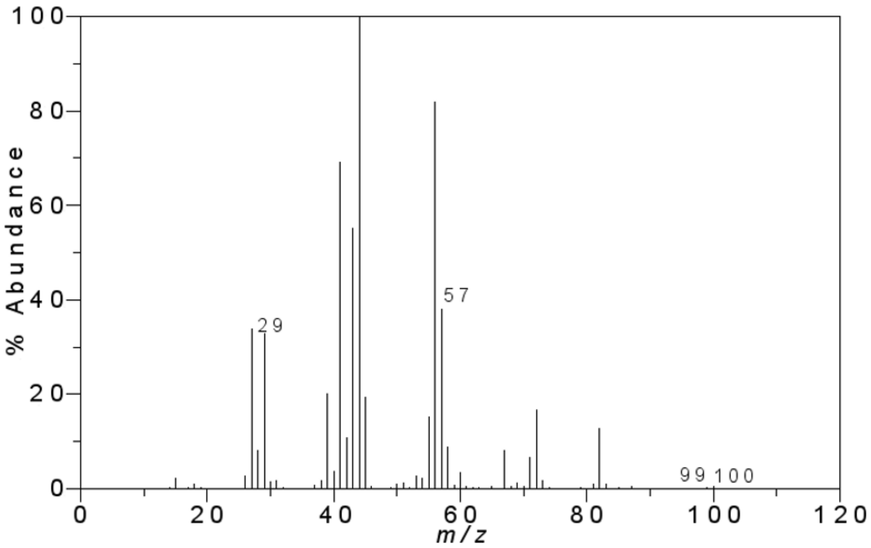
the role of innovation in designing cells to meet society's energy needs in terms of producing 'green' hydrogen (including equations in acidic conditions) using the following methods: artificial photosynthesis using a water oxidation and proton reduction catalyst system	**Question 6d** (2 marks) Hydrogen can also be produced using a process known as artificial photosynthesis, with a photoelectrochemical cell. Compare artificial photosynthesis to natural photosynthesis, referencing one similarity and one difference between the two processes.	**Answer:** • *Both processes use solar energy/sunlight to directly provide the energy for the production of a 'fuel'.* • *Natural photosynthesis uses sunlight to produce glucose ('fuel' for cellular respiration) whereas artificial photosynthesis uses sunlight to produce hydrogen (fuel for fuel cells).* **Marking Protocol:** One mark for each of the above points.

The following organic compounds were purified and then used to develop reference data and spectra for the identification of unknown contaminants in consumer products.

hexane	**hex-2-ene**	**hexan-2-ol**	**hexanal**

the principles of chromatography, including high performance liquid chromatography (HPLC) and the use of retention times	**Question 7a** (2 marks) A mixture of hexene and hex-2-ene was purified using high-performance liquid chromatography (HPLC). A non-polar, silica, stationary phase was set up for the separation of the two components. Explain why these two components can be separated using HPLC.	**Answer:** • *Hexane and hexene will be attracted to the stationary phase to different extents.* • *The double bond in hex-2-ene molecules prevents them from forming as many dispersion forces with the stationary phase as hexane molecules, therefore hex-2-ene will have a shorter Rt and will be eluted first.* **Marking Protocol:** One mark for each of the above points.

The mass spectrum of one of the compounds is shown below.



Source: https://commons.wikimedia.org/wiki/File:Hexanal_edited.gif

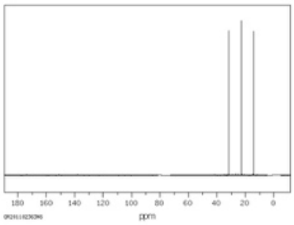
applications of mass spectrometry (excluding features of instrumentation and operation) and interpretation of qualitative and quantitative data, including identification of molecular ion peak, determination of molecular mass and identification of simple fragments	**Question 7bi** (1 mark) Identify the fragment, producing a peak at m/z 43, that is common to all four organic compounds.	**Answer:** - *$[CH_3CH_2CH_2]^+$* **Marking Protocol:** One mark for the above point.

applications of mass spectrometry (excluding features of instrumentation and operation) and interpretation of qualitative and quantitative data, including identification of molecular ion peak, determination of molecular mass and identification of simple fragments	**Question 7bii** (2 marks) The mass spectrum was produced by hexanal. State two reasons why this spectrum could not be that of hex-2-ene.	**Answer:** - *Hex-2-ene has a molar mass of 84 g mol^{-1}. The molecular ion peak in this spectrum is too high.* - *Hex-2-ene is unlikely to produce a fragment at m/z 57.* **Marking Protocol:** One mark for each of the above points.

structural determination of organic compounds by low resolution carbon-13 nuclear magnetic resonance (^{13}C-NMR) spectral analysis, using chemical shift values to deduce the number and nature of different carbon environments

Question 7c (3 marks)

The ^{13}C NMR spectrum below was obtained during the analysis of the organic compounds.



Source: https://www.chemicalbook.com/SpectrumEN_110-54-3_13CNMR.htm

Identify which of the four molecules produced the ^{13}C NMR spectrum. Provide two justifications for your choice.

Answer:

- *Hexane.*

And two justifications:

- *The spectrum shows three signals, indicating three unique carbon environments.*
- *All the other compounds would have produced spectra with 6 signals.*
- *The chemical shift data suggests the presence of carbon atoms in CH_3 and CH_2 groups, rather than C=C carbons.*

Marking Protocol:

One mark for hexane.

One mark for any of the other points, to a maximum of two.

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measurement of the degree of unsaturation of compounds using iodine

trends in physical properties within homologous series (boiling point and melting point, viscosity), with reference to structure and bonding

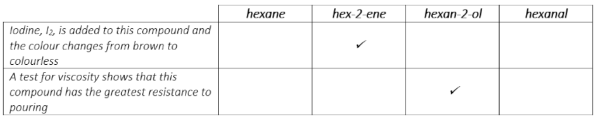
Question 7d (2 marks)

Laboratory tests can be used to identify and distinguish between organic compounds. Next to each test description below, place a tick in the box of the organic molecule it could be used to identify.

	hexane	**hex-2-ene**	**hexan-2-ol**	**hexanal**
Iodine, I_2, is added to this compound and the colour changes from brown to colourless				
A test for viscosity shows that this compound has the greatest resistance to pouring				

Answer:

-



	hexane	*hex-2-ene*	*hexan-2-ol*	*hexanal*
Iodine, I_2, is added to this compound and the colour changes from brown to colourless		✓		
A test for viscosity shows that this compound has the greatest resistance to pouring			✓	

Marking Protocol:

One mark for each of the ticks placed in the correct position of the table.

Catalase is an enzyme that breaks down hydrogen peroxide into water and oxygen gas.
A student-designed an experiment to determine the optimal temperature for catalase activity. A summary of the method is shown below.

1. Set up four water baths at 10°C, 30°C, 50°C and 70°C. Use thermometers to monitor the temperature of each water bath.
2. Measure 2.0 mL of 10% hydrogen peroxide solution into four, separate test tubes.
3. Place a thermometer in each test tube.
4. Put test tube 1 into the 10°C water bath. Wait until the contents of the test tube cool to 10°C.
5. Add one catalase tablet to the test tube and immediately start timing. Stop the timer when oxygen gas stops being produced.
6. Repeat steps 4 and 5 for the other three test tubes in water baths at 30°C, 50°C and 70°C. Record all times and observations in the results table.

Experimental Results

Water Bath Temperature (°C)	**Time for bubbles to stop (sec)**	**Observations**
10°C	205	Bubbles produced slowly
30°C	45	Vigorous fizzing
50°C	95	Bubbles consistently but at a slower rate than at 30°C
70°C	10	Very few bubbles produced

enzymes as protein-based catalysts in living systems: primary, secondary, tertiary and quaternary structures and changes in enzyme function in terms of structure and bonding as a result of increased temperature (denaturation), decreased temperature (lowered activity)	**Question 8a** (1 mark) Suggest why the enzyme in the 10°C water bath produced bubbles of oxygen for the longest period of time.	**Answer:** • *At colder temperatures, enzymes operate at a slower rate due to decreased kinetic energy and fewer particle collisions.* **Marking Protocol:** One mark for the above point.

assumptions and limitations of investigation methodology and/or data generation and/or analysis methods	**Question 8b** (2 marks) Explain why the 'time for bubbles to stop' data could be misleading at 70°C.	**Answer:** • *The bubbles stopped after 10 seconds, indicating a fast rate of reaction compared with the 10°C trial.* • *However, the observations state that there were very few bubbles produced, suggesting that there was very little catalysis of the hydrogen peroxide.* **Marking Protocol:** One mark for each of the above points.

enzymes as protein-based catalysts in living systems: changes in enzyme function in terms of structure and bonding as a result of increased temperature (denaturation)	**Question 8c** (2 marks) Based on your understanding of enzyme function, explain why the catalase and hydrogen peroxide reaction lasted for 95 seconds at 50°C but only 10 seconds at 70°C.	**Answer:** • *At 50 ℃, the rate of reaction is high, but the increased temperature is enough to start the breakdown of the enzyme, leading to a loss in 3D shape and function.* • *At 70 ℃, the enzyme is fully denatured and does not catalyse the reaction because the active site/3D shape is lost.* **Marking Protocol:** One mark for each of the above points.

The development and identification of chiral molecules in medicines have been an important part of the drug manufacturing process since Louis Pasteur discovered molecular chirality in the mid-1800s. Over 50% of the medicines in current circulation consist of chiral molecules. Some drugs are unichiral, with only one enantiomer present, and others are racemic mixtures, consisting of both enantiomers.

significance of isomers and the identification of chiral centres (carbon atom surrounded by four different groups) in the effectiveness of medicines	**Question 9** (5 marks) Use your understanding of chiral chemistry to explain why chirality has become such a strong focus in the drug development and manufacturing industry. In your response: - provide a definition of chirality and how chiral molecules are identified, - explain the significance of chirality in the production of pharmaceutical medicines, and - describe specific challenges faced by manufacturers of new medicines due to molecule chirality.	**Answer:** • *Chiral molecules are optical isomers, whose mirror images cannot be superimposed on top of each other.* • *Chiral molecules are identified through chiral centres; usually a carbon atom with four different atom groups bonded to it.* • *The two enantiomers of a drug can have different biological effects. Sometimes the two enantiomers have different therapeutic effects and sometimes one enantiomer could have a detrimental effect.* *The challenges faced by manufacturers could include (require two):* • *Increased testing of enantiomer drugs is required to check for biological effects and safety.* • *Separation and purification of the enantiomers can be difficult and costly.* • *Increased length of time between development and availability to the public.* • *Working within government regulations that require single enantiomer drugs due to possible negative side effects.* • *New technologies may need to be developed to allow for greater separation and purification of enantiomers, increasing the cost and time required.* **Marking Protocol:** One mark for each of the first three points, and one mark for any of the other points, to a maximum of two.

aced

VCE UNITS 3&4
CHEMISTRY
Written Examination
ANSWER SHEET – 2024

Student name:

Use a **PENCIL** for **ALL** entries. For each question, shade the box which indicates your answer.

Marks will **NOT** be deducted for incorrect answers.

NO MARK will be given if more than **ONE** answer is completed for any question.

If you make a mistake, **ERASE** the incorrect answer – **DO NOT** cross it out.

1	A	[✓ B]	C	D
2	[✓ A]	B	C	D
3	A	B	[✓ C]	D
4	A	[✓ B]	C	D
5	A	B	C	[✓ D]
6	[✓ A]	B	C	D
7	A	B	[✓ C]	D
8	A	B	[✓ C]	D
9	A	B	[✓ C]	D
10	[✓ A]	B	C	D
11	[✓ A]	B	C	D
12	A	B	C	[✓ D]
13	[✓ A]	B	C	D
14	A	B	[✓ C]	D
15	A	B	[✓ C]	D
16	A	[✓ B]	C	D
17	A	B	C	[✓ D]
18	[✓ A]	B	C	D
19	A	B	[✓ C]	D
20	A	[✓ B]	C	D
21	A	B	C	[✓ D]
22	[✓ A]	B	C	D
23	A	B	[✓ C]	D
24	A	[✓ B]	C	D
25	A	B	C	[✓ D]
26	A	B	C	[✓ D]
27	A	B	C	[✓ D]
28	A	B	C	[✓ D]
29	[✓ A]	B	C	D
30	A	B	C	[✓ D]