Units 3&4 Chemistry Trial Exam 2024 (Trial 2) – Assessment Guide

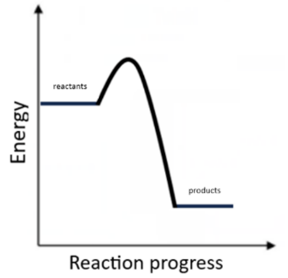
Section A

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** Biofuels **A.** do not require energy to produce. **B.** can be found trapped between rocks in gas reservoirs. **C.** are unable to be replenished at a rate faster than they are consumed. **D.** release carbon dioxide into the atmosphere during combustion.	*D* *Biofuels, like fossil fuels, do release CO_2 into the atmosphere during combustion. Biofuels like ethanol and biodiesel require energy to be produced from plant and animal matter and are not found in underground gas reservoirs. Biofuels are a renewable resource and are generally produced faster than they are consumed.*

VCAA Key Knowledge	Question	Answer Guide
fuel sources for the body measured in kJ g^{-1}: carbohydrates, proteins and lipids (fats and oils)	**Question 2** The energy released when food undergoes combustion in a lab is often higher than the energy it provides to the body after digestion. This could be due to **A.** high levels of fat in the food sample. **B.** incomplete digestion of food molecules. **C.** the high degree of oxidation of carbohydrate molecules. **D.** the loss of heat energy to the surroundings during combustion.	*B* *Laboratory analysis assumes that the fuel undergoes complete combustion. In reality, food is not completely digested and therefore the theoretical energy content is often higher than the energy available to the body.*

Use the following information to answer Questions 3 and 4.

The energy profile diagram for a particular chemical process is shown below.



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 3

Looking at the energy profile diagram, the forward reaction is

A. endothermic because $E_a < H_r$
B. exothermic because $H_r > H_p$
C. exothermic because $\Delta H > E_a$
D. endothermic because $H_r < H_p$

B — *The energy profile diagram shows that H_r is higher than H_p, therefore excess energy is released in an exothermic reaction.*

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 4

This process does not represent the energy changes associated with

A. fermentation of glucose.
B. cellular respiration.
C. steam reforming of methane.
D. a combustion reaction.

C — *Steam reforming of methane to produce hydrogen gas requires the input of energy, consistent with the definition of an endothermic process. All other reaction types release energy, matching the energy profile diagram.*

combustion (complete and incomplete) reactions of fuels as exothermic reactions: the writing of balanced thermochemical equations, including states, for the complete and incomplete combustion of organic molecules using experimental data and data tables

Question 5

17.5 mol of an unknown fuel undergoes complete combustion, releasing 15.60 MJ of energy. What is the likely identity of the fuel?

A. hydrogen
B. ethane
C. methanol
D. methane

D — *15.60 x 1000 /17.5*
= 891 kJ mol^{-1}
This is consistent with the Data Book value for methane.

the use and limitations of the electrochemical series in designing galvanic cells and as a tool for predicting the products of redox reactions, for deducing overall equations from redox half-equations and for determining maximum cell voltage under standard conditions	**Question 6** A spontaneous redox reaction occurs when solid zinc is placed in a beaker containing a 1.0 M solution of copper(II) ions at 25°C. Which of the following would NOT occur in the beaker? **A.** the temperature of the solution would increase **B.** a dark solid would be deposited at the surface of the zinc electrode **C.** a potential difference of approximately 1.10 V would be recorded **D.** the blue colour of the solution would gradually fade as $Cu^{2+}(aq)$ ions are reduced	*C*	*Given that solid zinc is coming into direct contact with copper ions in solution, the energy released would be thermal, not electrical. The temperature would increase, solid copper would be produced and the blue colour would fade as copper ions are reduced. No voltage would be generated due to the direct contact of reactants.*

oxidation of glucose as the primary carbohydrate energy source, including the balanced equation for cellular respiration: $C_6H_{12}O_6(aq) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$	**Question 7** Which of the following statements about cellular respiration is incorrect? **A.** cellular respiration provides energy for body processes **B.** glucose is oxidised during cellular respiration **C.** cellular respiration occurs in both plant and animal cells **D.** the products of cellular respiration are usually glucose and oxygen gas	*D*	*The products of cellular respiration are CO_2 and H_2O. All other statements are consistent with the process of cellular respiration.*

production of bioethanol by the fermentation of glucose, $C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(l) + 2CO_2(g)$, and subsequent distillation to produce a more sustainable transport fuel	**Question 8** Which flow chart shows a likely processing pathway for the production of bioethanol for use in E10 petrol? **A.** glucose → fermentation → distillation → bioethanol **B.** canola oil → fermentation → distillation → bioethanol **C.** leaf litter → pre-treatment → distillation → fermentation → bioethanol **D.** sugar cane → pre-treatment → distillation → fermentation → bioethanol	*A*	*Raw material should be high in carbohydrate. The more complex the carbohydrate, the more pre-treatment required. Glucose does not require pre-treatment as it is the precursor for fermentation to ethanol. Distillation follows fermentation to purify the final product.*

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 9** Analysis of an unidentified organic substance shows that it has a low melting point range. This information suggests that the substance **A.** has high purity. **B.** starts to melt at a low temperature. **C.** does not contain carbon-carbon double bonds. **D.** has a disorganised arrangement of molecules.	*A*	*A pure substance has a narrower melting point range than a mixture. A low melting point range is an indication of high purity.*

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 10

The balanced half equation for the reduction of permanganate(VII) ions to manganese(II) ions in alkaline conditions is

A. $MnO_4^-(aq) + 8OH^-(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$

B. $MnO_4^-(aq) + 8H_2O(l) + 5e^- \rightarrow Mn^{2+}(aq) + 4OH^-(aq)$

C. $MnO_4^-(aq) + 4H_2O(l) + 5e^- \rightarrow Mn^{2+}(aq) + 8OH^-(aq)$

D. $MnO_4^-(aq) + 4H_2O(l) + 8H^+(aq) \rightarrow Mn^{2+}(aq) + 8OH^-(aq)$

C

The balanced half equation in acidic conditions is $MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$ Add enough OH^- ions to each side to balance the H^+ ions, leaving $8OH^-$ on the right of the equation. Then cancel out the water molecules, leaving 4 on the left of the equation.

the use and limitations of the electrochemical series in designing galvanic cells and as a tool for predicting the products of redox reactions, for deducing overall equations from redox half-equations and for determining maximum cell voltage under standard conditions

Question 11

A student constructs a series of galvanic cells as part of an investigation. Which combination of half cells would be expected to produce the greatest potential difference under standard conditions?

	Half-cell 1		Half-cell 2	
	Electrode	Electrolyte	Electrode	Electrolyte
A.	Fe(s)	$Fe^{2+}(aq)$	Pt(s)	$Pb^{2+}(aq)$
B.	Zn(s)	$Zn^{2+}(aq)$	Ni(s)	$Ni^{2+}(aq)$
C.	Ag(s)	$Ag^+(aq)$	inert electrode	$Mg^{2+}(aq)$
D.	inert electrode	$Mn^{2+}(aq)$	Al(s)	$Al^{3+}(aq)$

D

$Mn^{2+}/Al/Al^{3+}$ cell
Water is the strongest oxidant so -0.83 - - 1.66 = 0.83V

$Fe/Fe^{2+}/Pb^{2+}$ cell
-0.13 - - 0.44 = 0.31V
$Zn/Zn^{2+}/Ni/Ni^{2+}$ cell
-0.25 - - 0.76 = 0.51V
$Ag/Ag^+/Mg^{2+}$ cell
no reaction (non-spontaneous)

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

Question 12

Consider the thermochemical equation for the complete combustion of propane at SLC below:

$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l) \quad \Delta H = -2220$ kJ

Determine the theoretical ΔH value for the following reaction under the same conditions:

$6CO_2(g) + 8H_2O(l) \rightarrow 2C_3H_8(g) + 10O_2(g)$

A. ΔH = +1110 kJ

B. ΔH = +4440 kJ

C. ΔH = -1110 kJ

D. ΔH = -4440 kJ

B

The equation is reversed and doubled. Therefore, the reaction changes from exothermic to endothermic, with the amount of energy doubled.

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 13

For which one of the following substances can energy content be expressed using both kJ g^{-1} and kJ mol^{-1}?

A. biogas

B. palmitic acid

C. E10 petrol

D. sugar cane

B

Only pure substances can have energy content expressed in kJ mol^{-1}. The only pure substance in the list is palmitic acid. The others are all mixtures.

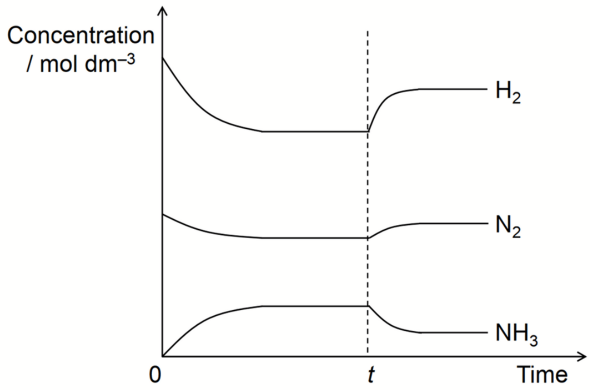
the role of innovation in designing cells to meet society's energy needs in terms of producing 'green' hydrogen (including equations in acidic conditions) using the following methods: polymer electrolyte membrane electrolysis powered by either photovoltaic (solar) or wind energy artificial photosynthesis using a water oxidation and proton reduction catalyst system	**Question 14** A hydrogen production facility at Bell Bay, Tasmania, is aiming to be one of the world's largest producers of renewable hydrogen. The hydrogen will be used in fuel cell technology, drastically reducing carbon emissions in the transport industry. According to green chemistry principles, raw materials and feedstocks should be renewable, rather than depleting. The hydrogen that will be produced at the Tasmanian facility is considered renewable because **A.** a hydrogen fuel cell does not produce carbon emissions. **B.** porous electrodes will allow for increased energy efficiency. **C.** the energy source for hydrogen production will be hydroelectric and wind-based power. **D.** electrolysis of water to produce hydrogen does not require the input of energy.	*C*	*Renewable resources are replenished within a short time frame. Hydrogen produced using hydro and wind power, rather than fossil fuel energy, means that it can be replenished at a rate faster than it is consumed and does not deplete natural resources. The other responses are incorrect (D) or do not link to the concept of renewability (A and B).*

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 15** According to collision theory, which of the following changes will not lead to an increase in the rate of reaction? **A.** increasing the particle size of solid reactants **B.** decreasing the volume of the vessel for gaseous systems **C.** lowering the activation energy of the reaction **D.** increasing the temperature of the system	*A*	*Increasing particle size decreases the surface area available for particle collision and will decrease the rate of reaction. All other options increase the reaction rate.*

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, and the representation of these changes using concentration-time graphs

Question 16

The concentration-time graph below shows that a change was made to a system in equilibrium at time, t.



$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H < 0$

Source: Le Chatelier Principle and Concentration Time Graph (chemistryguru.com.sg)

Which option correctly identifies the change that was made to the system at time, t, with the corresponding effect on the equilibrium constant?

A. increase in volume of the vessel, decrease K
B. increase in volume of the vessel, no change to K
C. increase in temperature, decrease K
D. increase in temperature, no change to K

C

The equation states that ΔH is less than zero, indicating an exothermic reaction. From time, t, the reverse reaction is favoured as hydrogen and nitrogen concentrations increase. Given there is no immediate change to any species at time, t, the change is an increase in temperature, which reduces the value of K.

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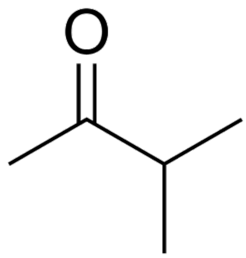
molecular, structural and semi-structural (condensed) formulas and skeletal structures of alkanes (including cyclohexane), alkenes, benzene, haloalkanes, primary amines, primary amides, alcohols (primary, secondary and tertiary), aldehydes, ketones, carboxylic acids and non-branched esters

Question 17

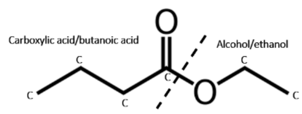
State the IUPAC systematic name of the organic molecule shown in the diagram below.



Source: File:Methyl isopropyl ketone.png

A. 2-methylpropan-3-one
B. 3-methylpropan-2-one
C. 3,3-dimethylpropan-2-one
D. 3-methylbutan-2-one

D

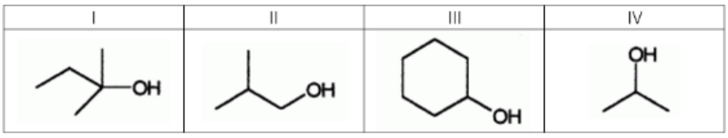


Number the carbon atoms from the end closest to the carbonyl group. The longest chain is 4 carbon atoms in length.

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

Question 18

The images below show the structures of various primary, secondary and tertiary alcohols.



Source: https://commons.wikimedia.org/wiki/File:Alcohol_examples.png

Which structure(s) are classified as secondary alcohols?

A. I only
B. I and III only
C. III and IV only
D. II, III and IV only

C

Secondary alcohols have a hydroxyl group (OH) attached to a saturated carbon, which is bonded to two other carbon atoms. Both III and IV show this arrangement.

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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 19

Which straight chain, hydrocarbon molecule has a degree of unsaturation equal to 2?

A. C_2H_6
B. C_3H_6
C. C_4H_6
D. C_5H_{10}

C

Degree of unsaturation: Maximum H possible, minus actual H present, divided by 2.
C_4H_6
$10-6/2 = 2$

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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 20

Water can be electrolysed to produce hydrogen gas in an electrolytic cell at a rate of 1.8 litres per minute at SLC. Calculate the current required to produce this volume of hydrogen gas.

A. 58 A
B. 117 A
C. 233 A
D. 840 A

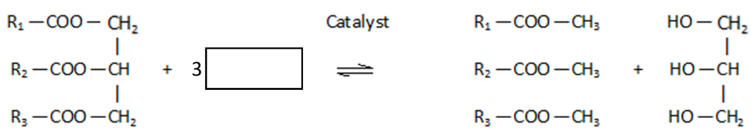
C

$n(H_2) = V/Vm$
$= 1.8/24.8$
$= 0.0726$ mol H_2
$n(e^-) = 0.0726 \times 2$
$= 0.145$ mol e^-
$n(e^-) = Q/F$
$Q = 0.145 \times 96500$
$= 14,008$ C
$Q = It$
$I = 14,008/60$
$= 233$ A

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 21** For a secondary cell, such as a lead-acid battery, to be recharged, the products of the discharge reaction should A. remain in contact with the electrodes. B. be kept separate to avoid a spontaneous reaction. C. be supplied with electrical energy, equal to the potential difference of the cell. D. react spontaneously to reverse the discharge reaction.	*A*	*For recharging to occur, the product of discharge will be the reactants for recharge. In most cells, they should stay in contact with the electrodes for the reverse reaction to occur. If they migrate away from the electrodes, the recharging process will not be efficient. Products of spontaneous discharge will not spontaneously react so do not need to be kept separate. Electrical energy GREATER than the potential difference must be supplied as some energy is lost as heat during the recharge process.*

Use the following information to answer Questions 22 and 23.

The equation below represents the production of a common biofuel via transesterification of plant triglycerides.



R 1, R 2, R 3 = Hydrocarbon chain of 15 to 21 carbon atoms

Source: Adapted from https://commons.wikimedia.org/wiki/File:Transesterification_reaction.png

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 transesterification of plant triglycerides using alcohols to produce biodiesel	**Question 22** What is the identity of the reactant that is missing from the equation? A. $C_3H_8O_3$ B. CH_3OH C. C_2H_5OH D. fatty acids	*B*	*The reaction shows transesterification to produce biodiesel. An alcohol is required for the process. Given the structure of the products (one methyl group on the end of each methyl ester), the reactant must be methanol.*

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 transesterification of plant triglycerides using alcohols to produce biodiesel

Question 23

The methyl esters that are produced during this reaction

A. are non-renewable.

B. can be added to petrol to make E10 fuel.

C. are commonly used as a biofuel in the transport industry.

D. do not produce carbon dioxide emissions during combustion.

C

This process is used to produce biodiesel, a biofuel that can replace diesel fuel, commonly used in the transport industry. Biofuels are renewable sources of energy. Ethanol, not biodiesel, is added to petrol to make E10 petrol. The fuel is high in carbon so would release CO_2 upon combustion.

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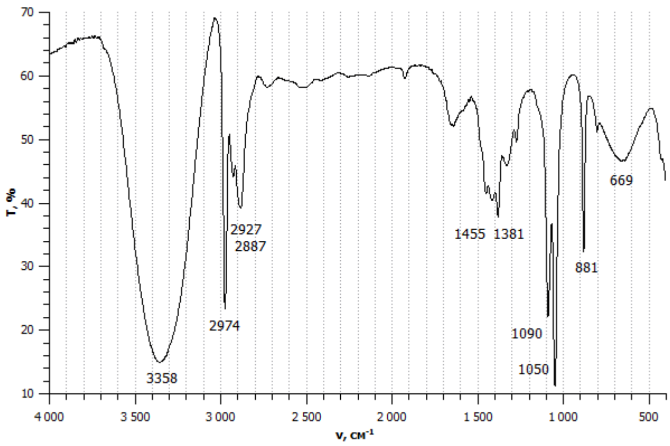
identification of bond types by qualitative infrared spectroscopy (IR) data analysis using characteristic absorption bands

Question 24

The IR spectrum of a simple organic compound is shown below.



Source: File:Ethanol IR Spectrum.png

The likely identity of the molecule is

A. ethanol

B. ethanal

C. ethanoic acid

D. ethanamide

A

The bonds present in the molecule are likely to be 3358 cm^{-1} which could indicate N-H amine/amide or O-H acids/alcohols. The absence of a C=O bond at 1700cm^{-1} and no amine present in the answer options means the molecule is ethanol.

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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 25

What is the correct oxidation number for chromium in $Cr_2O_7^{2-}$?

A. +6

B. +7

C. +12

D. +14

A

2Cr + (-2 x 7) = -2

2Cr = +12

Cr = +6

structural determination of organic compounds by low and high resolution proton nuclear magnetic resonance (^{1}H-NMR) spectral analysis, using chemical shift values, integration and peak splitting patterns (excluding coupling constants), and application of the n+1 rule to deduce the number and nature of different proton environments

Question 26

Low-resolution ^{1}H-NMR analysis can provide information about the

A. presence of carbon-13 isotopes in a molecule.

B. number of unique carbon environments in a molecule.

C. ratio of hydrogen atoms in each hydrogen environment.

D. number of neighbouring hydrogen atoms adjacent to each hydrogen environment.

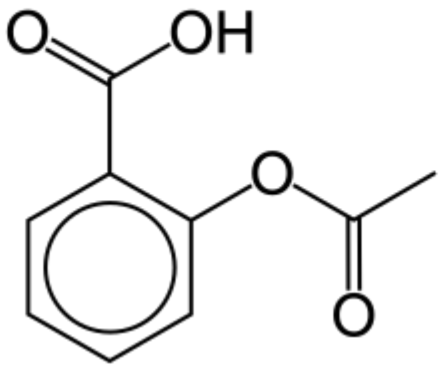
C

Low-resolution ^{1}H-NMR can provide information about the ratio of hydrogen atoms through comparison of peak area (integration). Low resolution does not show signal splitting so cannot provide information about neighbouring H atoms.

identification of the structure and functional groups of organic molecules that are medicines

Question 27

The skeletal formula of an aspirin molecule is shown below.



Source: https://commons.wikimedia.org/wiki/File:Aspirin-skeletal_benzene-circle.svg

Which of the following would NOT be observed when conducting laboratory and instrumental analysis of aspirin?

A. a mass spectrum peak at m/z 15

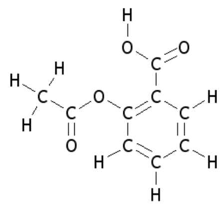
B. a ^{1}H-NMR spectrum with 8 clear signals

C. an IR spectrum showing a broad absorption band at approximately 3000cm^{-1}

D. it is colourless in the presence of phenolphthalein indicator

B

Only 6 hydrogen environments are observed. The hydrogen atoms on the methyl group are equivalent and produce one signal.



The molecule is an acid (COOH group) so would be colourless when tested with a phenolphthalein indicator.

Source: https://commons.wikimedia.org/wiki/File:Aspirin-in-full.png

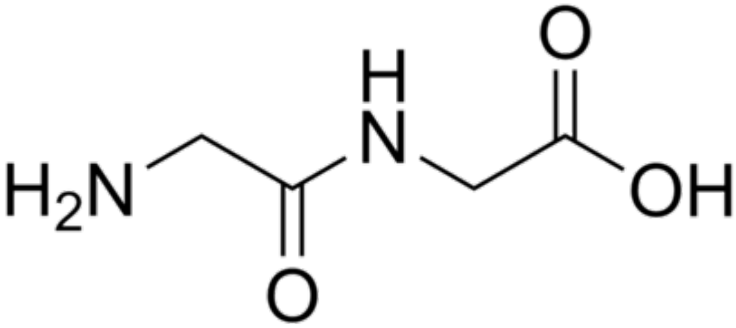
the role of innovation in designing cells to meet society's energy needs in terms of producing 'green' hydrogen (including equations in acidic conditions) using the following methods: polymer electrolyte membrane electrolysis powered by either photovoltaic (solar) or wind energy artificial photosynthesis using a water oxidation and proton reduction catalyst system	**Question 28** Consider the following statements regarding the production of green hydrogen via electrolysis of water in acidic conditions. I The reaction occurring at the negative electrode is $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$ II Hydrogen ions are reduced to $H_2(g)$ during electrolysis III The process produces green hydrogen when the electrical energy required is obtained from renewable sources IV Electrical energy is not required for this process, so the hydrogen is classified as a green fuel Which of the statements above are correct? **A.** I and IV only **B.** II and III only **C.** I, II and IV only **D.** I, II and III only	***B***	*Hydrogen ions gain electrons and are reduced to H_2 during cell operation. During electrolysis, oxidation occurs at the positive electrode, not negative. Electrical energy is required to drive the non-spontaneous reactions involved in the electrolysis of water. If this energy is derived from renewable resources, the hydrogen can be considered 'green'.*

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 29** Hydrogen iodide is produced from a reversible reaction between hydrogen gas and iodine gas according to the equation: $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$ At a particular temperature, 1.0 mol of H_2 and 1.0 mol of I_2 are present at equilibrium in a 2.0 L, closed vessel. If the equilibrium constant, K, is 50 at this temperature, the equilibrium concentration of hydrogen iodide would be closest to **A.** 3.5 M. **B.** 3.5 no units. **C.** 12.5 M. **D.** 12.5 no units.	***A***	*$c(H_2)$ and (I_2) = n/V* *= 1.0/2.0* *= 0.50 M* *$K = [HI]^2 / [H_2] [I_2]$* *$50 = [HI]^2 / 0.50 \times 0.50$* *$[HI]^2 = 50 \times 0.25$* *$[HI] = \sqrt{50 \times 0.25}$* *= 3.5 M*

organic reactions and pathways, including equations, reactants, products, reaction conditions and catalysts (specific enzymes not required): -hydrolytic reactions of proteins, carbohydrates and fats and oils to break down large biomolecules in food to produce smaller molecules

Question 30

Consider the structure of the dipeptide shown below.



Source: https://commons.wikimedia.org/wiki/File:Glycylglycine.png

Which statement is correct regarding the hydrolysis of the dipeptide during digestion?

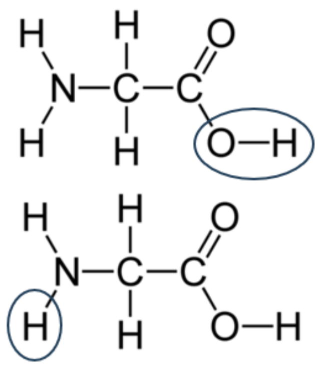
A. two different amino acids are produced and water is lost during the reaction

B. two of the same amino acids are produced and water is required for the reaction

C. two different amino acids are produced and water is required for the reaction

D. two of the same amino acids are produced and water is lost during the reaction

B *Two glycine molecules are produced when the molecule is hydrolysed at the CONH peptide link. Water is required for the reaction to re-form the COOH and NH_2 functional groups on the glycine amino acids (shown in circles below).*

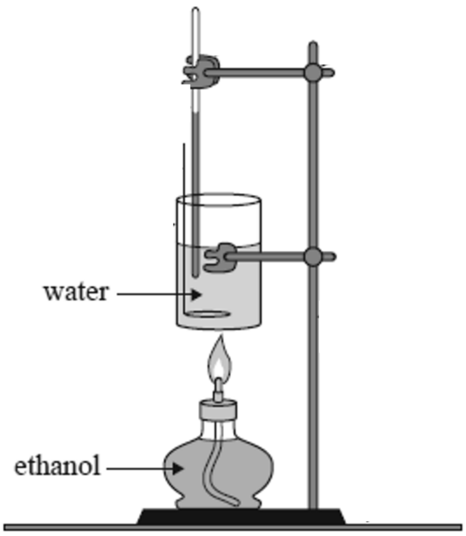


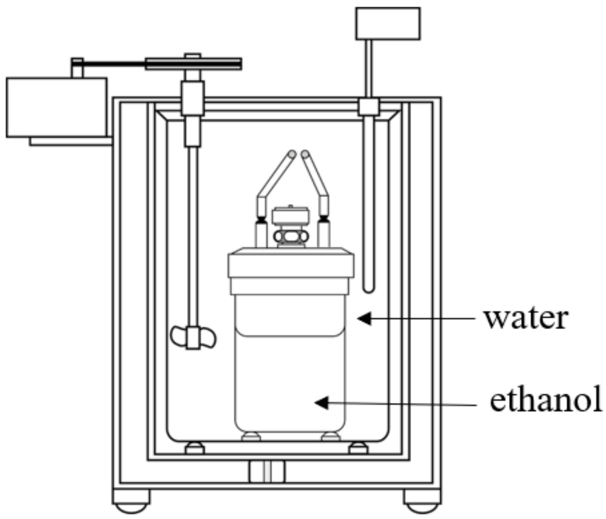
Source: https://commons.wikimedia.org/wiki/File:Glycine-2D-flat.png

Section B

VCAA Key Knowledge	Question	Answer Guide

The amount of energy absorbed or released during a reaction can be estimated using calorimetric processes in a laboratory. The table below shows two different methods for recording the change in temperature of water as a known mass of ethanol combusts.

<table>
<tr><th>Method 1: spirit burner and metal can</th><th>Method 2: bomb calorimeter</th></tr>
<tr><td>

Source: http://www.dynamicscience.com.au/tester/solutions1/chemistry/pastexamquestion/2014enthalpy.html</td><td>

Source: https://commons.wikimedia.org/wiki/File:Bomb_calorimeter_scheme.png</td></tr>
</table>

A student designs an investigation to compare the two processes. The results, taken at SLC, are shown in the tables below.

Method 1: spirit burner results

Mass of ethanol combusted (g)	Mass of water in can (g)	ΔT water (°C)	Energy transferred to water (kJ)	ΔH_c ethanol (kJ g^{-1})
1.48	100	9.5		

Method 2: bomb calorimeter results

Mass of ethanol combusted (g)	Calorimeter calibration factor (kJ °C^{-1})	ΔT water (°C)	Energy transferred to water (kJ)	ΔH_c ethanol (kJ g^{-1})
10.6	5.60	58.5	328	30.9

characteristics of the selected scientific methodology and method, and appropriateness of the use of independent, dependent and controlled variables in the selected scientific investigation	**Question 1a** (1 mark) State the independent variable in this investigation.	**Answer:** • *The method of calorimetry.* **Marking Protocol:** One mark for the above point.

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 1b** (2 marks) Calculate the amount of energy, in kJ, that was transferred to the water using the spirit burner method. Record your answer in the results table.	**Answer:** • *Energy = m x c x ΔT* *= 100 x 4.18 x 9.5* *= 3971 J* • *= 4.0 kJ (answer in kJ, correct to two significant figures)* **Marking Protocol:** One mark for each of the above points. Significant figures must be correct for the mark.

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 1c** (1 mark) Calculate the ΔH_c of ethanol, in kJ g^{-1}, using results from the spirit burner method. Record your answer in the results table.	**Answer:** • *ΔH_c = Energy released / mass of fuel* *= 4.0 / 1.48* *= 2.7 kJ g^{-1}* **Marking Protocol:** One mark for the above point. Note: Award consequential marks if the answer to Question 1b is incorrect but the calculation here is correct.

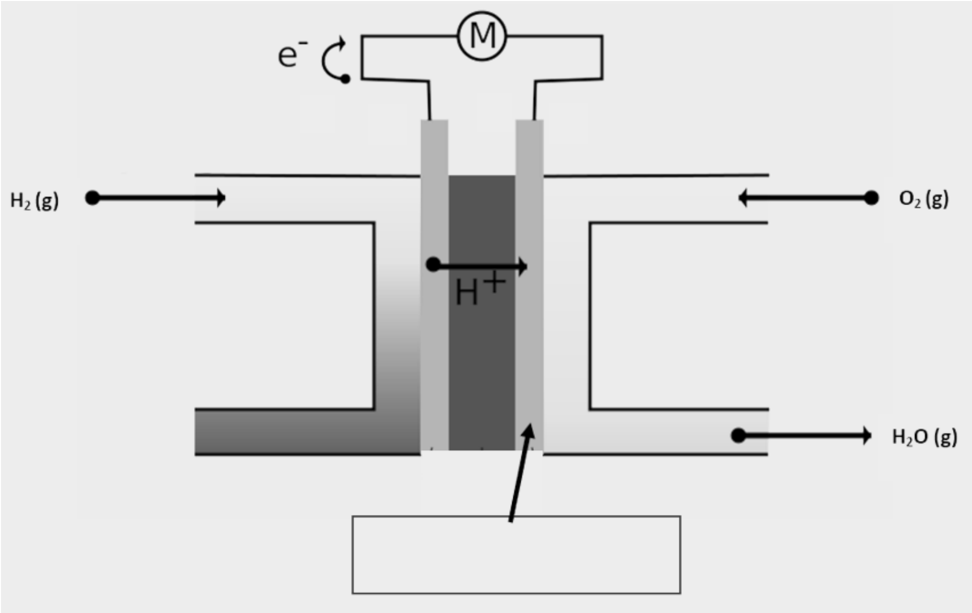
the accuracy, precision, repeatability, reproducibility, resolution and validity of measurements	**Question 1d** (3 marks) Calculate the theoretical heat of combustion for ethanol in kJ g^{-1}. Compare the results of the two methods with the calculated, theoretical value.	**Answer:** • *From the Data Book, ethanol's molar enthalpy is -1370 kJ mol^{-1}* *M(ethanol) = (12.0 x 2) + (1.0 x 6) + 16.0 = 46.0 g mol^{-1}* *Heat of combustion (ethanol) = 1370/46.0* *= 29.8 kJ g^{-1}* • *Spirit burner results are significantly lower than theoretical 29.8 kJ g^{-1}* • *Calorimeter results are higher than theoretical 29.8 kJ g^{-1}* **Marking Protocol:** One mark for each of the above points. Note: Check for consequential marks based on student calculations.

assumptions and limitations of investigation methodology and/or data generation and/or analysis methods	**Question 1e** (2 marks) A bomb calorimeter is similar to a solution calorimeter as they both insulate against heat loss. Both types of calorimeter measure the temperature change of a known mass of water in order to determine energy changes. Assuming that the calorimeter was calibrated correctly, describe one source of error for each method that could have affected the accuracy of results obtained by the student.	**Answer:** • *Spirit burner – Possible Errors* *- Heat loss to the environment due to no lid on the metal can / metal can absorbs some of the heat / a flame not being centred under the can.* *OR* *- Incomplete combustion of the fuel, producing CO and less energy than expected.* *OR* *- Experimental error leading to a lower change in temperature: more than 100g water in the can / lower mass of ethanol burnt than recorded.* Note: Must be an error that leads to a value lower than 29.8 kJ g^{-1} (however, award consequential marks for incorrect calculations leading to a higher heat of combustion). • *Bomb Calorimeter – Possible Errors* *- A lower volume of water in calorimeter than for calibration / a higher mass of ethanol combusted than recorded, resulting in a higher change in temperature.* *OR* *- Not stirring the water as it heats, leading to uneven heating of water and recording of a higher final temperature.* Note: Must be an error that leads to a value higher than 29.8 kJ g^{-1} (however, award consequential marks for incorrect calculations leading to a lower heat of combustion). **Marking Protocol:** One mark for an error associated with the spirit burner and one mark for an error associated with the calorimeter.

the accuracy, precision, repeatability, reproducibility, resolution and validity of measurements	**Question 1f** (1 mark) The thermometer used for the spirit burner method was labelled as having a resolution of 0.5°C. Explain how this could affect the student's ability to check for the precision of data.	**Answer:** • *The low resolution does not allow for a fine distinction between measurements. While repeat trials may look precise, the range of values may be large, and the student may not be able to determine if the results are precise (close together).* **Marking Protocol:** One mark for the above point. Note: The response must focus on precision, not accuracy (i.e. the measurements being close to the true value).

the principles of solution calorimetry, including determination of calibration factor and consideration of the effects of heat loss; analysis of temperature-time graphs obtained from solution calorimetry	**Question 1g** (3 marks) Solution and bomb calorimeters are both calibrated before use. The bomb calorimeter was initially calibrated using a known quantity of thermal energy supplied by an electric heater. A current of 4.50 A was passed through the heater for 5 minutes with a potential difference of 8.00 V. If the temperature of the water was 22.0°C before calibration, calculate the highest temperature the water reached during calibration. Assume the calorimeter is well insulated.	**Answer:** • *Calculation of energy supplied (including time conversion)* *Energy Supplied = VIt* *= 8.00 x 4.50 x (5 x 60)* *= 10,800 J* • *Calculation of temperature change (including conversion of CF to J)* *ΔT = VIt/CF* *= 10,800/5600* *= 1.92 °C* • *Highest temperature = 22.0 + 1.92* *= 23.9°C* **Marking Protocol:** One mark for each of the above points.

The diagram below shows the set-up of a hydrogen fuel cell.



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

the common design features and general operating principles of fuel cells	**Question 2a** (1 mark) The diagram shows a box with an arrow, pointing to one of the electrodes. Identify this electrode as either the anode or the cathode and write your answer in the box.	**Answer:** • *Cathode* **Marking Protocol:** One mark for the above point.

the writing of balanced half-equations (including states) for oxidation and reduction reactions	**Question 2b** (1 mark) Write the equation for the half-cell reaction occurring at the negative electrode in the fuel cell.	**Answer:** • $H_2 \rightarrow 2H^+ + 2e^-$ **Marking Protocol:** One mark for the above point. Note: States are not required.

deducing overall equations from redox half-equations and for determining maximum cell voltage under standard conditions	**Question 2c** (1 mark) The reactions occurring in the acidic fuel cell were replicated in a lab at SLC. Predict the potential difference of the replicated cell, in volts.	**Answer:** • *Acidic conditions: 1.23 – 0.00 = 1.23 V* **Marking Protocol:** One mark for the above point.

the common design features and general operating principles of fuel cells	**Question 2d** (2 marks) Hydrogen fuel cells can also be constructed with an alkaline electrolyte, such as potassium hydroxide, KOH. State two differences between acidic and alkaline hydrogen fuel cells with reference to the reactions occurring at the anode and cathode.	**Answer:** • *OH^- ions are required at the anode for reaction with H_2 in an alkaline cell but not in an acidic cell.* • *Water is a reactant at the cathode in an alkaline cell. It is a product at the cathode in an acidic cell.* • *Hydrogen ions travel from anode to cathode through the electrolyte in an acidic cell. Hydroxide ions travel from cathode to anode in an alkaline cell.* **Marking Protocol:** One mark for any of the above points, to a maximum of two.

the application of Faraday's Laws and stoichiometry to determine the quantity of galvanic or fuel cell 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 2e** (3 marks) To increase the electrical energy output of fuel cells, individual cells can be linked together, forming a stack. A particular stack of acidic hydrogen fuel cells can generate a current of 250 A. Calculate the mass of hydrogen gas that would be consumed by the fuel cell stack over a 5-hour period.	**Answer:** • *Q = It* *= 250 x (5 x 60 x 60)* *= 4500000 C* *n(e-) = 4500000/96500* *n(e-) = 46.6 mol* • *$n(H_2)$ = 46.6/2* *= 23.3 mol H_2* • *mass H_2 = 23.3 x 2.0* *= 46.6 g* **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 2f** (2 marks) Fuel cell electrodes are both porous and conductive. Explain how these electrode properties improve the overall function of the cell.	**Answer:** • *Electrodes are porous to increase available surface area for reactions, improving the efficiency of the cell / they are porous to allow for catalyst particles to be embedded in them, increasing the efficiency of reaction / they allow gaseous reactants to enter the cell to make contact with the electrolyte.* • *Electrodes are conductive to allow for the flow of charge through the cell / to allow for the movement of electrons from anode to cathode.* **Marking Protocol:** One mark for each of the above points. Note: The response must explain both properties for two marks.

Sulfuric acid is a very useful chemical. It can be used as an electrolyte in batteries, as a cleaning agent, or as a precursor in the production of other chemicals. One of the key stages in the commercial production of sulfuric acid is the reaction of sulfur dioxide with oxygen in the air. The reaction is reversible and exothermic in the forward direction.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

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 3a** (1 mark) With the use of oxidation numbers, show that sulfur, in sulfur dioxide, undergoes oxidation during this process.	**Answer:** • *S = +4 to +6. An increase in oxidation number indicates that oxidation has taken place.* **Marking Protocol:** One mark for the above point.

the application of Le Chatelier's principle to identify factors that favour the yield of a chemical reaction	**Question 3b** (1 mark) It is common for oxygen to be mixed with sulfur dioxide in a 1:1 ratio during industrial manufacturing processes. However, the molar coefficients suggest that only one mole of oxygen is required for every two moles of sulfur dioxide. Suggest a likely reason for the 1:1 mixing ratio.	**Answer:** • *Excess oxygen as a reactant causes the reaction to favour the forward direction, maximising yield.* **Marking Protocol:** One mark for the above point.

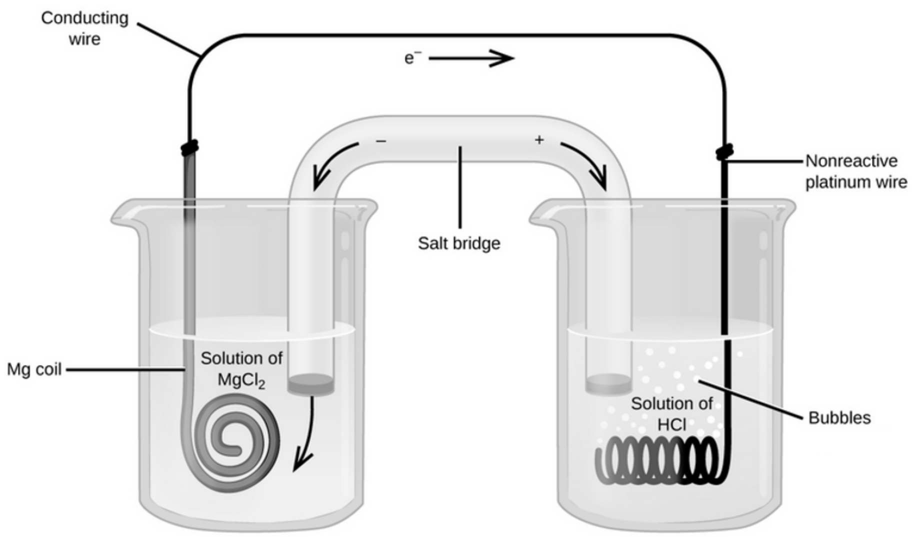
responses to the conflict between optimal rate and temperature considerations in producing equilibrium reaction products, *the distinction between reversible and irreversible reactions, and between rate and extent of a reaction*	**Question 3c** (2 marks) The optimum temperature for the production of sulfur trioxide is 450°C. With reference to yield and rate of reaction, explain the factors involved in this choice of temperature.	**Answer:** • *The reaction is exothermic. Temperatures that are too high would favour the reverse reaction, decreasing yield.* • *The rate of reaction would drop at temperatures that are too low due to decreased average kinetic energy of particles/fewer collisions.* **Marking Protocol:** One mark for each of the above points.

the role of catalysts in increasing the rate of specific reactions, with reference to alternative reaction pathways of lower activation energies	**Question 3d** (1 mark) A vanadium catalyst is used for this reaction. Explain how a catalyst increases the rate of reaction.	**Answer:** • *A catalyst provides an alternative pathway with reduced activation energy.* **Marking Protocol:** One mark for the above point.

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 3e** (2 marks) Explain how the use of catalysts supports the green chemistry principle of designing processes for greater energy efficiency.	**Answer:** • *Improving energy efficiency requires processes to be designed to have the same outcome, whilst using less energy, or eliminating energy waste.* • *Catalysts increase the rate of reaction without increasing energy demands so the same outcome can be achieved without increasing temperature.* **Marking Protocol:** One mark for each of the above points.

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 3f** (3 marks) Analysis of the composition of reacting gases shows that, at a particular point in time, the following molar concentrations are present at 450°C: 1.20 M $SO_2(g)$ 2.40 M O_2 (g) 2.95 M $SO_3(g)$ The equilibrium constant, K, for the reaction at the same temperature, is 24.8 M^{-1}. Explain how the reaction will proceed from this point in time, with reference to the reaction quotient (Q) and the rate of both forward and reverse pathways.	**Answer:** • *Calculate Q* $Q = [SO_3]^2 / [SO_2]^2 [O_2]$ $= 2.95^2 / 1.20^2 \times 2.40$ $= 2.52\ M^{-1}$ • *K is greater than Q at the particular point in time.* • *Therefore, the rate of the forward reaction will be higher than the rate of the reverse reaction until equilibrium is established.* **Marking Protocol:** One mark for each of the above points.

The diagram below shows the laboratory set-up of a simple galvanic cell.



Source: https://commons.wikimedia.org/wiki/File:CNX_Chem_17_02_Oxidareduc.png

the common design features and general operating principles of non-rechargeable (primary) galvanic cells converting chemical energy into electrical energy, including electrode polarities and the role of the electrodes (inert and reactive) and electrolyte solutions	**Question 4ai** (1 mark) Write the half equation for the reaction occurring at the anode.	**Answer:** • $Mg(s) \rightarrow Mg^{2+}(aq) + 2e^-$ **Marking Protocol:** One mark for the above point. Note: Correct states are required.

the common design features and general operating principles of non-rechargeable (primary) galvanic cells converting chemical energy into electrical energy, including electrode polarities and the role of the electrodes (inert and reactive) and electrolyte solutions	**Question 4aii** (1 mark) State the identity of the gas bubbles forming in the half cell containing the platinum wire.	**Answer:** • *Hydrogen gas.* **Marking Protocol:** One mark for the above point.

the health, safety and ethical guidelines relevant to the selected scientific investigation	**Question 4b** (1 mark) State one safety hazard that would need to be controlled during the operation of this cell.	**Answer:** • *Production of H_2 – H_2 is flammable.* • *Magnesium is reactive in water, producing heat, causing burns.* • *The acidic electrolyte at the cathode is corrosive.* • *Electricity is generated and could cause injury. $MgCl_2$ is a skin and eye irritant.* **Marking Protocol:** One mark for any of the above points. Note: The response must clearly state the hazard. For example, 'Production of H_2' is not enough for a mark.

the use and limitations of the electrochemical series in designing galvanic cells and as a tool for predicting the products of redox reactions,	**Question 4c** (3 marks) Explain the likely outcome of replacing the magnesium coil with an inert carbon electrode.	**Answer:** • *The cell would stop functioning.* • *There is no species present strong enough to cause the reduction of H^+ ions at the cathode (no species present would react).* • *Water is the strongest reductant present, therefore no reaction would occur.* **Marking Protocol:** One mark for each of the above points. Note: Water must be identified for full marks.

The chemical equation below represents the process of photosynthesis in plant cells, where atmospheric carbon dioxide is converted into biomass.

$$6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(aq) + 6O_2(g) \qquad \Delta H = +2803 \text{ kJ}$$

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 5a** (3 marks) Calculate the amount of energy, in kJ, required to convert 10.0 g of atmospheric carbon dioxide into glucose.	**Answer:** • *$n(CO_2) = m/M$* *= 10.0/44.0* *= 0.227 mol* • *Energy required per mole of CO_2 = 2803/6* *= 467 kJ* • *Energy = n x ΔH* *= 0.227 x 467* *= 106 kJ* **Marking Protocol:** One mark for each of the above points.

condensation reactions to synthesise large biologically important molecules for storage as proteins, starch, glycogen and lipids (fats and oils)	**Question 5b** (1 mark) The glucose produced during photosynthesis can be stored as starch in plant cells. State the type of reaction that occurs to form starch from glucose.	**Answer:** • *Condensation reaction (or condensation polymerisation).* **Marking Protocol:** One mark for the above point.

condensation reactions to synthesise large biologically important molecules for storage as proteins, starch, glycogen and lipids (fats and oils)	**Question 5c** (1 mark) Calculate the molar mass of a starch polymer consisting of 50 glucose monomers. The molar mass of glucose is 180.0 g mol^{-1}.	**Answer:** • *Each bond formed involves the removal of water (18.0 g mol^{-1}). 49 bonds form between 50 glucose molecules, so the molar mass will be 50 x 180 – (49 x 18.0)* *= 8.12×10^3 g mol^{-1}* **Marking Protocol:** One mark for the above point.

Plants that contain a high percentage of starch and cellulose are used as biomass for the production of bioethanol. The equation for this reaction is shown below.

$$C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(l) + 2CO_2(g)$$

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 5di** (1 mark) Calculate the atom economy of the reaction to form bioethanol from glucose.	**Answer:** • *M(desired product) / M(all reactants) x100* *= 92/180 x 100* *51 %* **Marking Protocol:** One mark for the above point.

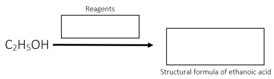
calculations of percentage yield and atom economy of single-step or overall reaction pathways, and the advantages for society and for industry of developing chemical processes with a high atom economy	**Question 5dii** (1 mark) Explain whether the value calculated in Question 5di supports the green chemistry principle for atom economy.	**Answer:** • *The atom economy for the production of ethanol is low, with almost 50% of the reactant atoms ending up as waste gas. It does not support the green chemistry principle for atom economy.* **Marking Protocol:** One mark for the above point. Note: Award consequential marks if the answer to Question 5di is high and the explanation is consistent with a high atom economy.

advantages for society and for industry of developing chemical processes with a high atom economy	**Question 5e** (1 mark) State one reason why it is more sustainable for industrial processes to have a high atom economy.	**Answer:** • *High atom economy reactions minimise waste.* • *High atom economy reactions require fewer resources for the production of a particular chemical.* **Marking Protocol:** One mark for either of the above points.

pathways for the synthesis of primary amines and carboxylic acids

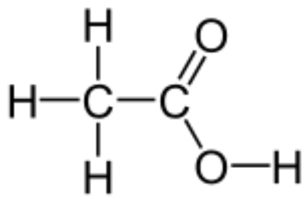
Question 5f (2 marks)

Ethanol can also be used as a reactant in the commercial production of ethanoic acid. Complete the equation below, identifying the reagents required for the reaction and the structural formula of ethanoic acid. Write your responses into the boxes.



Answer:

- *Reagents: $H^+(aq)/Cr_2O_7^{2-}(aq)$ or $H^+(aq)/MnO_4^-(aq)$*
- *Structural formula of ethanoic acid showing all bonds:*



Source: *https://commons.wikimedia.org/wiki/File:Essigs%C3%A4ure_-_Acetic_acid.svg*

Marking Protocol:

One mark for each of the above points.

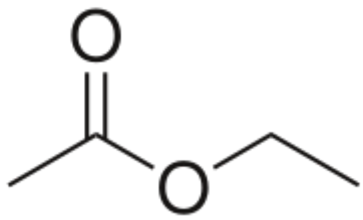
the esterification between an alcohol and a carboxylic acid

Question 5g (1 mark)

The process of esterification between an alcohol and a carboxylic acid produces molecules that can be used as artificial flavours and scents. Draw the skeletal formula of the ester formed from the reaction between ethanol and ethanoic acid.

Answer:

- *Ethyl ethanoate skeletal formula:*



Source: *https://commons.wikimedia.org/wiki/File:Ethyl-acetate-2D-skeletal.svg*

Marking Protocol:

One mark for the above point.

artificial photosynthesis using a water oxidation and proton reduction catalyst system

Question 5h (2 marks)

Scientists are developing methods of fuel production through artificial photosynthesis. Compare the processes of natural photosynthesis and artificial photosynthesis.

Answer:

Similarities:

- *Both processes harness sunlight for chemical energy production.*

Differences:

- *Artificial photosynthesis is more efficient than natural photosynthesis.*
- *Natural photosynthesis produces food for plants/glucose, whereas artificial photosynthesis produces fuels like methane or hydrogen gas.*

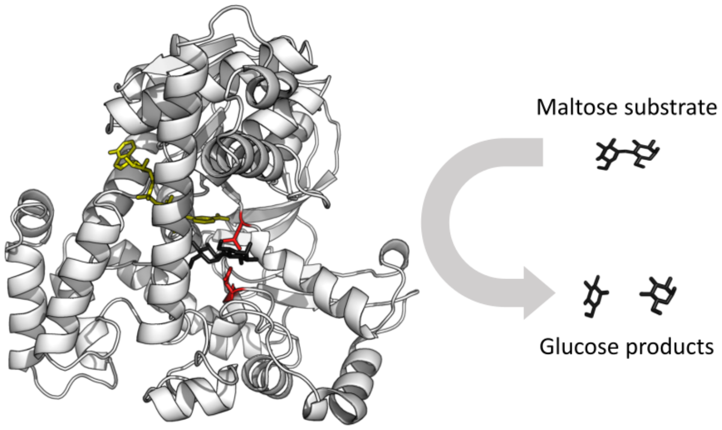
Marking Protocol:

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

Note: One similarity and one difference, as well as a comparison between both processes, is required for full marks.

Enzymes are biological catalysts that speed up the rate of many important biological reactions.

The diagram below shows the folded structure of maltase, an enzyme that catalyses the breakdown of maltose into glucose during the hydrolysis of carbohydrates.



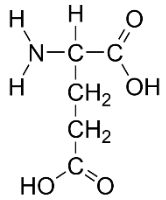
Source: File:Galactosidase enzyme 2.svg

enzymes as protein-based catalysts in living systems: primary, secondary, tertiary and quaternary	**Question 6a** (1 mark) The coiled structures in the folded enzyme represent alpha helices. Describe the bonding that occurs in the enzyme to produce these coiled sections.	**Answer:** • *Hydrogen bonds between peptide linkages.* **Marking Protocol:** One mark for the above point. Note: The response must mention both hydrogen bonds AND peptide links (or amide groups) for the mark.

enzymes as protein-based catalysts in living systems *oxidation of glucose as the primary carbohydrate energy source*	**Question 6b** (2 marks) Explain why people who suffer from maltase deficiency are likely to experience a feeling of tiredness, lack of energy and motivation.	**Answer:** • *A maltase deficiency results in an inability to break bonds/hydrolyse bonds between glucose molecules and would lead to a decrease in available glucose for respiration.* • *A decreased availability of glucose for respiration would result in less energy being available to the body to carry out daily functions.* **Marking Protocol:** One mark for each of the above points.

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) preventing binding of the actual substrate

Question 6c (4 marks)
Maltase has an optimum pH range of 6.5-7.5. The structural formula of glutamic acid, one of the amino acids found in maltase, is shown below.



Source: File:Glutamic Acid.svg

Explain how the presence of glutamic acid in the peptide chain could affect the tertiary structure and function of the enzyme if the pH drops below the optimum range.

Answer:

- *In acidic conditions, the COOH group in the R side chain does not ionise.*
- *This will prevent or break ionic bonds in the tertiary structure.*
- *Incorrect folding leads to the loss of the required 3D shape of the molecule.*
- *The active site shape will be altered and not fit the substrate, slowing catalysis.*

Marking Protocol:
One mark for each of the above points.

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medicines that function as competitive enzyme inhibitors: organic molecules that bind through lock-and-key mechanism to an active site preventing binding of the actual substrate

Question 6d (2 marks)
Tangzhiqing (TZQ) is a Chinese herbal medicine that is sometimes used to treat high blood glucose levels associated with Type II diabetes. It works to inhibit the action of enzymes, like maltase, that break down carbohydrates.
Explain the likely function of TZQ to inhibit the enzyme.

Answer:

- *TZQ binds to the active site of the enzyme as it has a similar shape.*
- *This inhibits substrate binding and subsequent hydrolysis of carbohydrates/disaccharides.*

Marking Protocol:
One mark for each of the above points.

Terminalia ferdinandiana, or gubinge, is a native plum found in the Kimberley region of Western Australia. The fruit is known to be very high in Vitamin C (ascorbic acid). Laboratory analysis of the native fruit was conducted to compare its ascorbic acid content with that of an orange. Oranges have been found to contain approximately 53 mg of ascorbic acid per 100 g.

A redox titration was performed and a summary of the procedure is given below.

- A 20.0 g sample of gubinge was crushed and juiced, then filtered to remove solids.
- The juice was diluted to 250 mL in a volumetric flask.
- A 25.0 mL aliquot of the diluted juice was added to a conical flask with a few drops of HCl and 10 drops of starch indicator.
- The aliquot was titrated with a standardised solution of 0.050 M I_2 and the average titre was found to be 6.63 mL.

The chemical equation for the reaction is:

$$C_6H_8O_6(aq) + I_2(aq) \rightarrow C_6H_6O_6(aq) + 2I^-(aq) + 2H^+(aq)$$

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 7a** (1 mark) The half equation for the reduction of iodine during the analysis is $I_2(aq) + 2e^- \rightarrow + 2I^-(aq)$. Write the half equation for the oxidation of ascorbic acid to show that the use of a redox titration is justified.	**Answer:** • $C_6H_8O_6(aq) \rightarrow C_6H_6O_6(aq) + 2H^+(aq) + 2e^-$ **Marking Protocol:** One mark for the above point. Note: States are not required for the mark.

volumetric analysis, including calculations of excess and limiting reactants using redox titrations (excluding back titrations)	**Question 7b** (1 mark) Calculate the amount of I_2, in mol, required to reach the end point of the reaction.	**Answer:** • *$n(I_2) = cV$* *$= 0.05 \times (6.63/1000)$* *$= 3.32 \times 10^{-4}$ mol* **Marking Protocol:** One mark for the above point.

volumetric analysis, including calculations of excess and limiting reactants using redox titrations (excluding back titrations)	**Question 7c** (3 marks) Assuming all the ascorbic acid in the fruit was present in the diluted juice, use the balanced equation to calculate the mass of ascorbic acid, in mg, present in the 20.0 g sample of gubinge.	**Answer:** • *n*($C_6H_8O_6$) = *n*(I_2) *= 3.32 x 10^{-4} mol in 25.0 mL aliquot* • *n*($C_6H_8O_6$) *in 250 mL volumetric flask* *= 3.32 x 10^{-4} x 10DF = 3.32 x 10^{-3} mol* • *m*($C_6H_8O_6$) *in 250 mL volumetric flask/20g sample = n x M* *= 3.32 x 10^{-3} mol x 176.0 g mol^{-1}* *= 0.583 x 1000* *= 583 mg in the 20.0 g sample.* **Marking Protocol:** One mark for each of the above points.

the key findings and implications of the selected scientific investigation	**Question 7d** (2 marks) Referring to the results of the analysis, compare the ascorbic acid content of oranges and gubinge.	**Answer:** • *Given that there is 583 mg of ascorbic acid in the 20.0 g sample of gubinge, there would be 2915 mg in 100 g.* • *This compares to only 53 mg in 100 g for oranges. There is a difference of 2862 mg, or 55 times more ascorbic acid, in gubinge than in oranges.* **Marking Protocol:** One mark for each of the above points. Note: Students must compare both fruits in the answer.

the accuracy, precision, repeatability, reproducibility, resolution and validity of measurements	**Question 7e** (2 marks) The investigation was reproduced by scientists in a different laboratory. The scientists followed the method correctly, under the same conditions, however their results were much lower than those achieved in the original analysis. State two possible reasons for this difference.	**Answer:** • *The experiment is not reproducible as different fruit samples may contain different amounts of ascorbic acid.* • *The ripeness of the fruit may have differed between the two groups.* • *The discarded pulp may contains different amounts of ascorbic acid.* **Marking Protocol:** One mark for any of the above points, to a maximum of two.

An unknown organic compound found in a sample of cat food is tested to determine its identity. A range of laboratory and instrumental analysis techniques are used to determine whether the organic compound could be harmful to cats if it is consumed.

Test 1: Laboratory analysis

Test	Result
Boiling point	102°C
Bromine test	Brown colour observed
Test for ester formation	No smell or odour was detected when the sample was heated with ethanoic acid and sulfuric acid
Test for acids	No reaction with Na_2CO_3

qualitative tests for the presence of carbon-carbon double bonds, hydroxyl and carboxyl functional groups

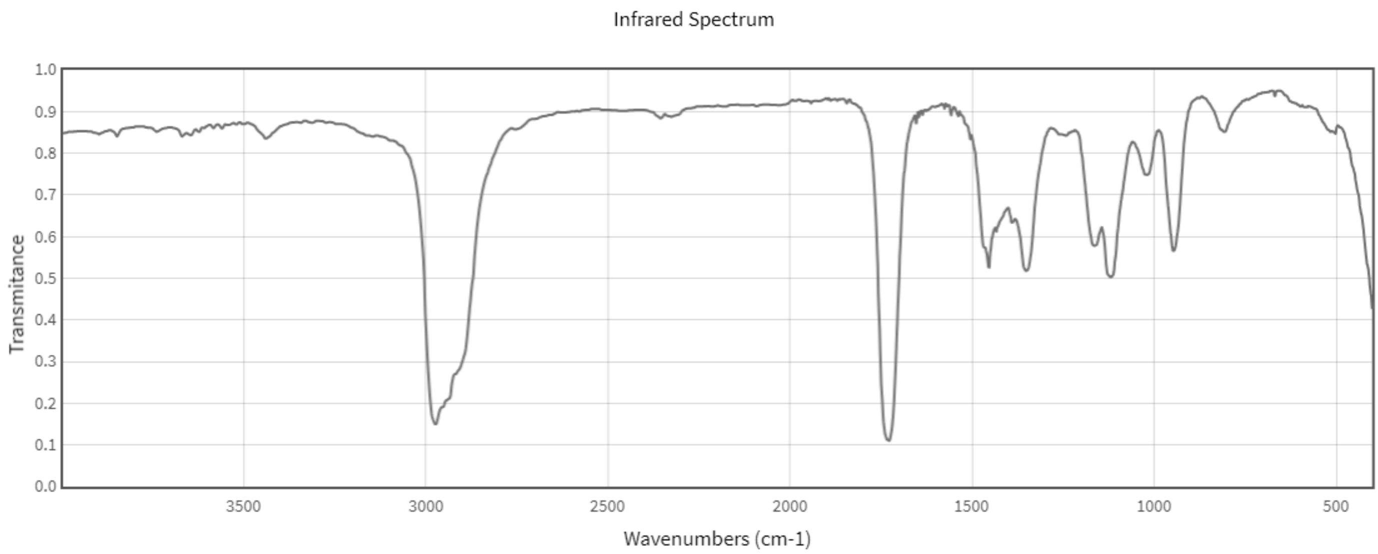
Question 8a (3 marks)
The laboratory tests provide initial information about the structure and properties of the unknown compound. Looking at the results of the laboratory experiments, state three inferences that can be made about the compound.

Answer:

- *A relatively high BP, suggesting a molecule that can form many dispersion forces.*
- *A relatively high BP, suggesting a polar functional group could be present.*
- *A BP of 102 ℃ means the compound is liquid at room temperature, with stronger intermolecular forces than water molecules.*
- *No reaction with bromine, so no C-C double bonds.*
- *Does not react with carboxylic acid to form an ester, so unlikely to be an alcohol.*
- *No reaction with a base, so unlikely to be a carboxylic acid.*

Marking Protocol:
One mark for any of the above points, to a maximum of three.

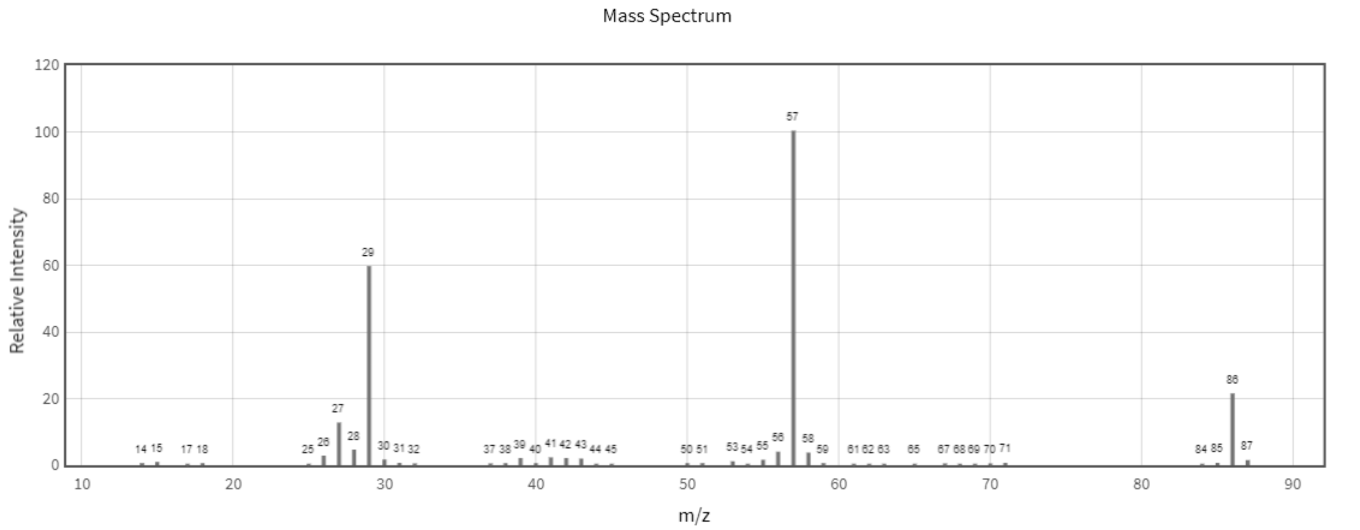
Test 2: IR Spectroscopy



Source: 3-Pentanone (nist.gov)

identification of bond types by qualitative infrared spectroscopy (IR) data analysis using characteristic absorption bands	**Question 8b** (2 marks) Identify the bonds responsible for the two strongest transmittance bands shown on the IR spectrum that are also consistent with the laboratory analysis results.	**Answer:** • *C-H bond at ~2850-3090 cm^{-1}* • *C=O bond at ~1700 cm^{-1}* **Marking Protocol:** One mark for each of the above points.

Test 3: Mass Spectrometry

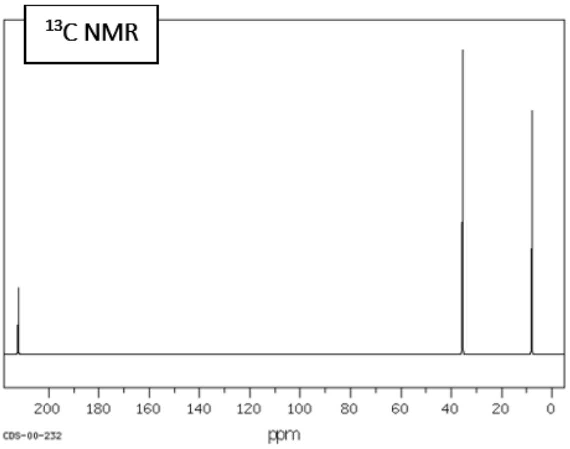


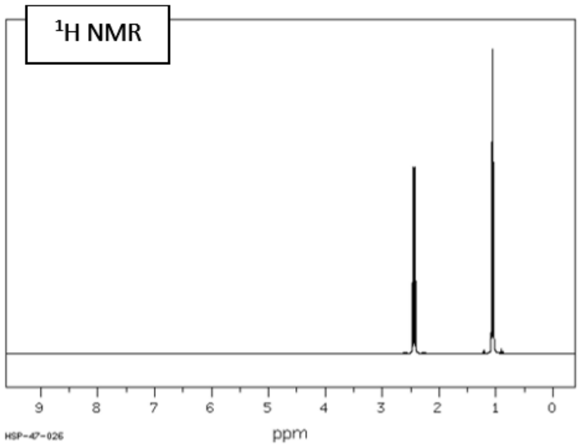
Source: 3-Pentanone (nist.gov)

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 8c** (1 mark) The mass spectrum shows a base peak at m/z 57. Identify a possible fragment that could have produced this peak.	**Answer:** • *$[C_3H_5O]+$ or $[C_4H_9]+$* **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 8d** (2 marks) State the two classes of compounds that match the laboratory test results, the IR spectrum and mass spectrum of the unknown compound.	**Answer:** • *Ketone.* • *Aldehyde.* **Marking Protocol:** One mark for each of the above points.

Test 4: ^{13}C NMR and low resolution ^{1}H NMR Spectroscopy





Source: 3-Pentanone(96-22-0) 1H NMR spectrum (chemicalbook.com)

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

structural determination of organic compounds by low and high resolution proton nuclear magnetic resonance (^{1}H-NMR) spectral analysis

Question 8e (2 marks)

Complete the tables below to summarise the information provided in the two NMR spectra.

Number of unique hydrogen environments	
Number of unique carbon environments	

Chemical shift (ppm) and likely identity of one carbon in the unknown structure	

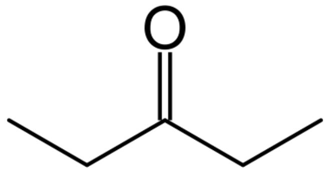
Answer:

- *Hydrogen environments = 2 and Carbon environments = 1*
- *Carbon present in the molecule – one of:*
  - *ppm 9 = R-CH_3*
  - *ppm 36 = R-CH_2-R*
  - *ppm 215 = R_2C=O*

Marking Protocol:

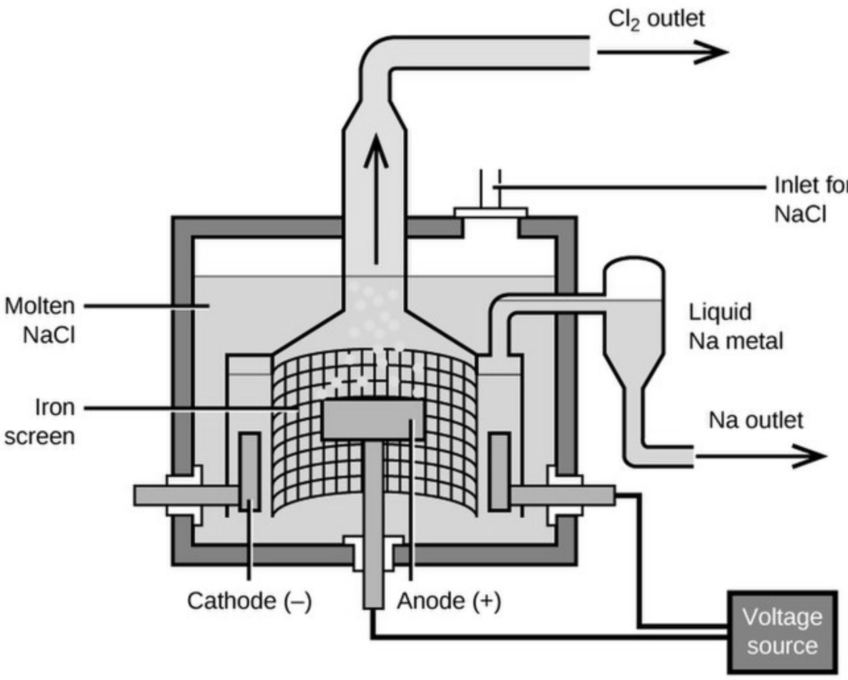
One mark for each of the above points.

Note: Responses must have both references for the first mark.

deduction of the structures of simple organic compounds using a combination of mass spectrometry (MS), infrared spectroscopy (IR), proton nuclear magnetic resonance (^{1}H-NMR) and carbon-13 nuclear magnetic resonance (^{13}C-NMR) (limited to data analysis) *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 8f** (2 marks) Considering the evidence provided by the laboratory and instrumental analysis of the molecules in the unknown organic compound, draw the skeletal structure of one molecule in the space below.	**Answer:**  Source: *https://commons.wikimedia.org/wiki/File:3-Pentanone.png* **Marking Protocol:** Two marks awarded for the correct skeletal formula of pentan-3-one, as shown above. Only award one mark if pentan-3-one is represented as a structural formula or semi-structural formula.

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 8g** (1 mark) State the IUPAC, systematic name for the molecule drawn in Question 8f.	**Answer:** • *Pentan-3-one.* **Marking Protocol:** One mark for the above point. Note: If a valid attempt at identifying the molecule has been made, apply consequential marks for the correct naming of the incorrect molecule.

The diagram below shows the operation of the Downs cell to produce sodium metal and chlorine gas.



Source: File:Downs cell diagram.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) and any chemical additives that result in a desired electrolysis product (no specific cell is required)

Question 9a (3 marks)

Describe three of the operating features, shown in the diagram of the cell, that are required for the production of sodium metal and chlorine gas in the Downs cell.

Answer:

- *Molten NaCl to prevent the reduction of water at the cathode.*
- *Voltage must be supplied from an external source as this is a non-spontaneous reaction/electrolytic cell.*
- *Mesh screen to prevent mixing of products that would spontaneously react.*
- *Molten NaCl to prevent oxidation of water at the anode.*
- *Products of the reactions are removed as they form to prevent reverse reactions.*
- *Inert electrodes that would not need to be replaced.*
- *No water is present as sodium metal reacts violently with water.*

Marking Protocol:

One mark for any of the above points, to a maximum of three.

the sustainability of the production of chemicals, with reference to the green chemistry principles of use of renewable feedstocks, catalysis and designing safer chemicals	**Question 9b** (4 marks) Chemists are challenged to modify the operating conditions and energy requirements of commercial cells to help reduce environmental damage and improve safety. The two green chemistry principles that outline these requirements are: • Use of renewable feedstocks • Designing safer chemicals Explain how modifications could be made to the Downs cell to help the commercial production of sodium align with these green chemistry principles.	**Answer:** *Renewable feedstocks responses:* • *Sources of energy for use in the Downs cell should be derived from natural sources that can be replenished or recycled (renewable), reducing the environmental impact of mining and minimising depletion.* • *Biofuels should be chosen over fossil fuels so that CO_2 emissions are partially offset by plant photosynthesis, improving sustainability.* • *The heat generated by resistance in the cell should be used to keep the electrolyte molten, rather than relying on fossil fuels.* • *A hydrogen fuel cell for electrical energy should be used – hydrogen can be generated sustainably through the use of solar-powered fuel cells. The main feedstock is water, which is (reasonably) abundant and renewable.* • *Electrode materials that are more efficient at conducting electricity should be selected, so that reliance on fossil fuels for energy is reduced.* *Safer chemicals responses:* • *Design the cell to run with safer additives to the molten electrolyte/$CaCl_2$ is known to be toxic.* • *Develop advanced methods for the capture and use of toxic Cl_2 gas to ensure safety.* • *Develop safer handling protocols for sodium metal as it is highly reactive.* • *Improve the design of the cell to minimise spills and leaks given high operating temperatures.* • *Design appropriate safety mechanisms into the cell, such as insulation, to help avoid burns associated with high temperatures.* **Marking Protocol:** One mark for any of the above points, to a maximum of four. Note: Both green principles must be referred to in the response.

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