VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Print exam correction: Section B, Q1 table, in the 'formula' column, last formula changed to $C_{18}H_{32}O_2$

Victorian Certificate of Education 2023

Letter

STUDENT NUMBER | | | | | | | | | |

CHEMISTRY

Written examination

Wednesday 8 November 2023

Reading time: 9.00 am to 9.15 am (15 minutes)
Writing time: 9.15 am to 11.45 am (2 hours 30 minutes)

QUESTION AND ANSWER BOOK

Structure of book

Section	*Number of questions*	*Number of questions to be answered*	*Number of marks*
A	30	30	30
B	9	9	90
			Total 120

- Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners, rulers and one scientific calculator.
- Students are NOT permitted to bring into the examination room: blank sheets of paper and/or correction fluid/tape.

Materials supplied
- Question and answer book of 35 pages
- Data book
- Answer sheet for multiple-choice questions

Instructions
- Write your **student number** in the space provided above on this page.
- Check that your **name** and **student number** as printed on your answer sheet for multiple-choice questions are correct, **and** sign your name in the space provided to verify this.
- Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.
- All written responses must be in English.

At the end of the examination
- Place the answer sheet for multiple-choice questions inside the front cover of this book.
- You may keep the data book.

Students are NOT permitted to bring mobile phones and/or any other unauthorised electronic devices into the examination room.

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SECTION A – Multiple-choice questions

Instructions for Section A

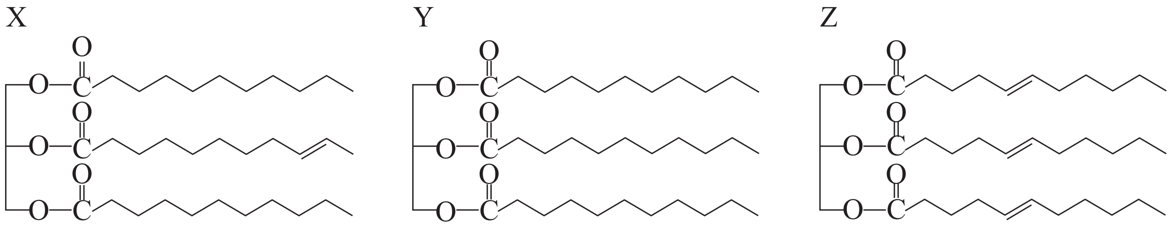
Answer **all** questions in pencil on the answer sheet provided for multiple-choice questions.
Choose the response that is **correct** or that **best answers** the question.
A correct answer scores 1; an incorrect answer scores 0.
Marks will **not** be deducted for incorrect answers.
No marks will be given if more than one answer is completed for any question.
Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

Question 1
Which one of the following correctly represents the reaction of glucose in human cells?

	Type of reaction	Endothermic or exothermic
A.	respiration	endothermic
B.	respiration	exothermic
C.	hydrolysis	endothermic
D.	hydrolysis	exothermic

Question 2
Which one of the following statements is correct?
A. Fuel cells and galvanic cells produce heat.
B. Fuel cells have inert electrodes whereas galvanic cells do not.
C. Fuel cells have porous electrodes whereas galvanic cells do not.
D. Fuel cells and galvanic cells operate when electrons flow through the electrolyte.

Question 3
Molecules X, Y and Z all have the same number of carbon atoms.



What is the order of melting points, from highest to lowest, for these three molecules?
A. Y, X, Z
B. Y, Z, X
C. Z, X, Y
D. Z, Y, X

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Question 4

A cell can be considered a secondary cell if

A. it has a continuous supply of reactants.

B. it can operate at different temperatures.

C. the polarity of the electrodes remains unchanged.

D. it can operate as both a galvanic and electrolytic cell.

Question 5

Consider the following statements about coenzymes.

I. Coenzymes assist enzymes to catalyse a reaction.

II. Coenzymes bind loosely to the active site of an enzyme.

III. Coenzymes act as carriers in the transfer of electrons and atoms.

Which of the statements above are correct?

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Question 6

Consider the following statements.

I. HPLC is a qualitative process.

II. HPLC is a quantitative process.

III. Triplets give information about molecule structure.

Which of the above statements apply to high-performance liquid chromatography (HPLC)?

A. I only

B. II only

C. I and II only

D. I, II and III

Question 7

Consider the following statements about fossil fuels and biofuels.

I. Production of biofuels does not damage the environment.

II. Combustion of both biofuels and fossil fuels generates greenhouse gases.

III. Biofuels and fossil fuels are both renewable as they are produced from plants.

Which of the statements above are correct?

A. I only

B. II only

C. I and II only

D. I and III only

Question 8

At 327 °C, the equilibrium constant for the reaction $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ is 4.10 M^{-2}.

What is the equilibrium constant at 327 °C for the reaction $2N_2(g) + 6H_2(g) \rightleftharpoons 4NH_3(g)$?

A. 8.20 M^{-2}

B. 8.20 M^{-4}

C. 16.8 M^{-2}

D. 16.8 M^{-4}

Question 9

Consider the following statements about coal seam gas and petroleum gas.

I. Coal seam gas and petroleum gas are both mixtures.

II. Coal seam gas and petroleum gas both combust to produce carbon dioxide.

III. Coal seam gas and petroleum gas are both fossil fuels.

Which of the above statements are correct?

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Question 10

At constant temperature, which one of the following always corresponds to an increase of the yield of a chemical reaction?

A. An increase in the value of the equilibrium expression.

B. An increase in the concentration of the reactants.

C. A decrease in the activation energy.

D. An increase in the pressure.

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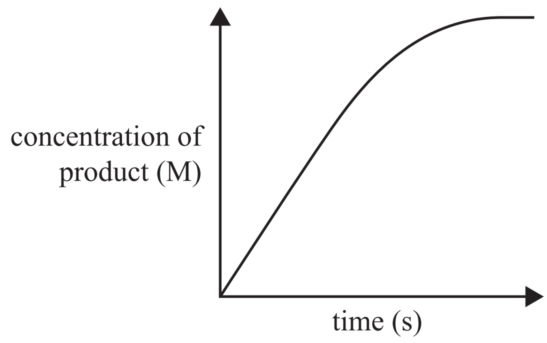
Question 11

A student conducted an experiment to determine the rate of a chemical reaction. The graph of the student's results is shown below.



Which one of the following correctly shows the units of the initial rate of reaction?

A. mol L^{-1} s^{-1}

B. mol L^{-1}

C. mol s^{-1}

D. mol

Question 12

Consider the following features of a chemical reaction.

I. activation energy

II. ΔH of the reaction

III. enthalpy of the reactants

Compared with the uncatalysed reaction pathway, the presence of a catalyst changes

A. I only.

B. II only.

C. II and III only.

D. I, II and III.

Question 13

Which molecule can exist as both a cis and a trans isomer?

A. CH_2CBrCl

B. $CH_3CHBrCl$

C. $CH_3CHCHCl$

D. $(CH_3)_2CCCl_2$

Question 14

The equation below shows the equilibrium reaction for the conversion of dinitrogen tetroxide, $N_2O_4(g)$, to nitrogen dioxide, $NO_2(g)$.

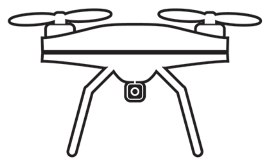
$$N_2O_4(g) \rightleftharpoons 2NO_2(g) \qquad \Delta H = +58.0 \text{ kJ mol}^{-1}$$

Which one of the following occurs when the temperature is increased from 35 °C to 80 °C?

	Rate of forward reaction	Rate of reverse reaction
A.	increases	decreases
B.	decreases	decreases
C.	increases	increases
D.	decreases	increases

Question 15

Consider two types of drone: petrol-powered and hydrogen-fuel-cell powered.



Source: elnurSS/Shutterstock.com

Which one of the following statements is correct about petrol-powered drones and hydrogen-fuel-cell powered drones?

A. They both produce greenhouse gases.

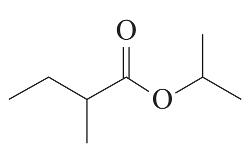
B. Only petrol-powered drones produce heat.

C. They both have the same energy transformations.

D. The overall reactions in hydrogen-fuel-cell powered drones are endothermic.

Question 16

Consider the following molecule.



How many peaks will be observed in a ^{13}C NMR spectrum of this molecule?

A. 5

B. 6

C. 7

D. 8

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Question 17

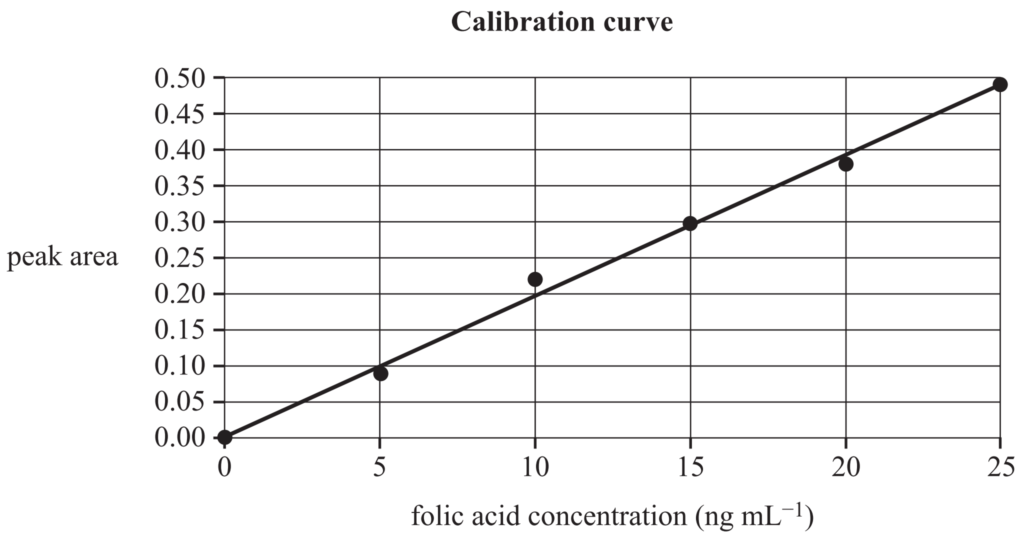
Lignite is a type of brown coal. When lignite is completely combusted in a power station, 19.0 MJ/tonne of energy is released. The efficiency of the power station is 39%.

What mass of lignite is required to produce 42.0 MJ of usable energy in the power station?

A. 0.862 tonnes
B. 1.16 tonnes
C. 2.21 tonnes
D. 5.67 tonnes

Question 18

The graph below shows the HPLC calibration curve for folic acid.



A 1.00 mL sample containing an unknown concentration of folic acid is diluted to 1.00 L. The diluted sample is analysed using the calibrated equipment at the same conditions. The folic acid peak area is found to be 0.35

What is the approximate folic acid concentration in the 1 mL sample?

A. 18 pg mL^{-1}
B. 18 ng mL^{-1}
C. 18 μg mL^{-1}
D. 18 mg mL^{-1}

Question 19

Compare omega-6 fatty acids with saturated fatty acids containing the same number of carbon atoms.

Which one of the following statements is correct?

Omega-6 fatty acids

A. have lower densities than saturated fatty acids.
B. have higher melting points than saturated fatty acids.
C. have more hydrogen atoms than saturated fatty acids.
D. undergo substitution reactions more readily than saturated fatty acids.

Question 20

Which one of the following is always correct when performing an accurate acid-base titration?

A. Water in the burette will dilute the aliquot.

B. Any acid-base indicator will give an accurate result.

C. Water in the pipette causes an underestimate of the acid concentration.

D. The pipette is not tapped against the conical flask to ensure accurate volume delivery.

Question 21

Which one of the following statements about denaturation is correct?

Denaturation

A. can only be caused by changes in temperature or the addition of acids.

B. causes the reversible change of a protein's shape.

C. hydrolyses the primary structure of a protein.

D. alters the secondary structure of a protein.

Question 22

Methane, CH_4, and methanol, CH_3OH, can both be used to power fuel cells.

Methane and methanol fuel cells produce

A. the same amount of greenhouse gases and the same number of electrons per mol of fuel reacted.

B. the same amount of greenhouse gases and a different number of electrons per mol of fuel reacted.

C. a different amount of greenhouse gases and the same number of electrons per mol of fuel reacted.

D. a different amount of greenhouse gases and a different number of electrons per mol of fuel reacted.

Question 23

Which one of the following is the semi-structural formula of 2-methylpent-1-ene?

A. $(CH_3)_2CCHCH_2CH_3$

B. $(CH_3)_2CHCH_2CHCH_2$

C. $CH_2C(CH_3)CH_2CH_2CH_3$

D. $CH_2CHCH(CH_3)CH_2CH_3$

Question 24

Which one of the following statements about acidic propan-1-ol fuel cells is correct?

A. Positive ions flow through the membrane to the cathode.

B. The voltage decreases since the reactants are used up in the half-cell reactions.

C. H_2O is formed at the negative electrode and CO_2 is formed at the positive electrode.

D. Since it is a gas, O_2 is the only reactant that must have direct contact with the electrode.

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SECTION A – continued

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Question 25

Below are the half-equations for the lead-acid accumulator cell. The lead-acid accumulator cell can operate as an electrolytic cell.

$$PbSO_4(s) + H^+(aq) + 2e^- \rightarrow Pb(s) + HSO_4^-(aq) \qquad E^0 = -0.36\ V$$
$$PbO_2(s) + HSO_4^-(aq) + 3H^+(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O(l) \qquad E^0 = 1.69\ V$$

Which one of the following correctly describes the lead-acid accumulator cell when it is operating as a galvanic cell and when it is operating as an electrolytic cell?

	Galvanic cell	Electrolytic cell
A.	H^+ ions react at the cathode.	HSO_4^- ions react at both electrodes.
B.	H^+ ions react at the anode.	HSO_4^- ions react at both electrodes.
C.	H^+ ions react at the cathode.	HSO_4^- ions are produced at both electrodes.
D.	H^+ ions react at the anode.	HSO_4^- ions are produced at both electrodes.

Use the following information to answer Questions 26 and 27.

A student investigated the viscosity of several biofuels.

The flow rate of each biofuel through a narrow glass tube was measured. The results are presented in the tables below.

Table 1: Flow rate ($mL\ min^{-1}$) of biodiesels produced using sodium hydroxide, $NaOH(aq)$, catalyst

		Alcohol used in biodiesel production with NaOH catalyst	
		Methanol	**Ethanol**
Oil used in biodiesel production	sunflower oil	4.8	4.4
	canola oil	5.1	4.7

Table 2: Flow rate ($mL\ min^{-1}$) of biodiesels produced using potassium hydroxide, $KOH(aq)$, catalyst

		Alcohol used in biodiesel production with KOH catalyst	
		Methanol	**Ethanol**
Oil used in biodiesel production	sunflower oil	4.9	4.4
	canola oil	4.8	4.6

Question 26

How many independent variables are there in this investigation?

A. 1

B. 3

C. 4

D. 6

Question 27

Select the most valid conclusion that can be drawn from the student's results presented in Table 1 and Table 2.

A. Biodiesels made from sunflower oil have a higher viscosity than biodiesels made from canola oil.

B. Biodiesels made from methanol have a lower viscosity than biodiesels made from ethanol.

C. Biodiesels are unsuitable for use in cold climates because they have a higher viscosity than petrodiesels.

D. Biodiesels made using $NaOH(aq)$ catalyst have a lower viscosity than biodiesels made using $KOH(aq)$ catalyst.

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Question 28

Consider the half-cell equations and their half-cell potentials in the table below.

Half-cell equations	Standard electrode potential (E^0) in volts at 25 °C
$Mn^{3+}(aq) + e^- \rightleftharpoons Mn^{2+}(aq)$	+1.56
$SO_3^{2-}(aq) + 3H_2O(l) + 4e^- \rightleftharpoons S_2O_3^{2-}(aq) + 6OH^-(aq)$	−0.57
$SO_4^{2-}(aq) + H_2O(l) + 2e^- \rightleftharpoons SO_3^{2-}(aq) + 2OH^-(aq)$	−0.94
$Mn^{2+}(aq) + 2e^- \rightleftharpoons Mn(s)$	−1.18

A galvanic cell contains $S_2O_3^{2-}(aq)$, $SO_3^{2-}(aq)$ and $OH^-(aq)$ with a platinum electrode in the first half-cell and $Mn^{3+}(aq)$ and $Mn^{2+}(aq)$ in the second half-cell. All solutions are 1M solutions and the cell is at SLC.

The galvanic cell will deliver

A. 2.50 V if the electrode in the second half-cell is Mn(s).

B. 2.50 V if the electrode in the second half-cell is Pt(s).

C. 1.75 V if the electrode in the second half-cell is Mn(s).

D. 1.75 V if the electrode in the second half-cell is Pt(s).

Question 29

Which one of the following statements about mass spectrometry is always correct?

A. The relative molecular mass of a molecule is determined from the base peak.

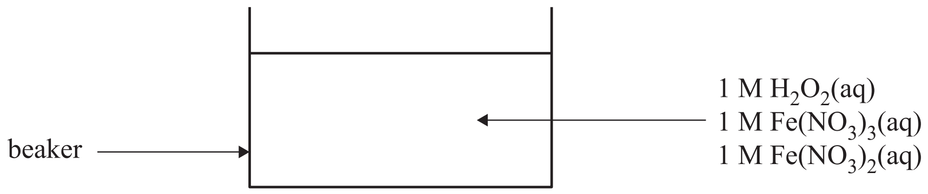
B. The peaks in a mass spectrum are caused by the presence of different isotopes.

C. The base peak is formed when an uncharged species is removed from the molecule.

D. The height of each peak in the mass spectrum is measured relative to the height of the base peak.

Question 30

At standard conditions, solutions of hydrogen peroxide, H_2O_2, iron(III) nitrate, $Fe(NO_3)_3$, and iron(II) nitrate, $Fe(NO_3)_2$, were added to a beaker. The initial concentrations of H_2O_2, $Fe(NO_3)_3$ and $Fe(NO_3)_2$ in the beaker were all 1 M.



Which one of the following statements is correct?

A. Iron, Fe, is deposited at the bottom of the beaker.

B. The two half-reactions in the beaker immediately produce 1.09 V.

C. The concentration of $H_2O_2(aq)$ decreases immediately since it is the strongest reducing agent.

D. The temperature of the contents in the beaker decreases immediately when $Fe(NO_3)_3(aq)$ reacts with $H_2O_2(aq)$.

END OF SECTION A
TURN OVER

SECTION B

Instructions for Section B

Answer **all** questions in the spaces provided.

Give simplified answers to all numerical questions, with an appropriate number of significant figures; unsimplified answers will not be given full marks.

Show all working in your answers to numerical questions; no marks will be given for an incorrect answer unless it is accompanied by details of the working.

Ensure chemical equations are balanced and that the formulas for individual substances include an indication of state, for example, H_2(g), NaCl(s).

Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

Question 1 (11 marks)

Coconut oil consists almost entirely of fats and oils. The typical fatty acid composition of coconut oil is shown in the following table.

Name	Formula	Percentage (%)
caprylic acid	$C_8H_{16}O_2$	8
capric acid	$C_{10}H_{20}O_2$	7
lauric acid	$C_{12}H_{24}O_2$	49
myristic acid	$C_{14}H_{28}O_2$	18
palmitic acid	$C_{16}H_{32}O_2$	8
stearic acid	$C_{18}H_{36}O_2$	2
oleic acid	$C_{18}H_{34}O_2$	6
linoleic acid	$C_{18}H_{32}O_2$	2

Source: adapted from L Boateng, R Ansong, W Owusu and M Steiner-Asiedu, 'Coconut oil and palm oil's role in nutrition, health and national development: A review', *Ghana Medical Journal*, 2016, National Library of Medicine, <ncbi.nlm.nih.gov/pmc/articles/PMC5044790/>

a. Determine the percentage of omega-3 fatty acids typically found in coconut oil. 1 mark

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b. State why coconut oil is resistant to oxidative rancidity. 1 mark

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SECTION B – Question 1 – continued

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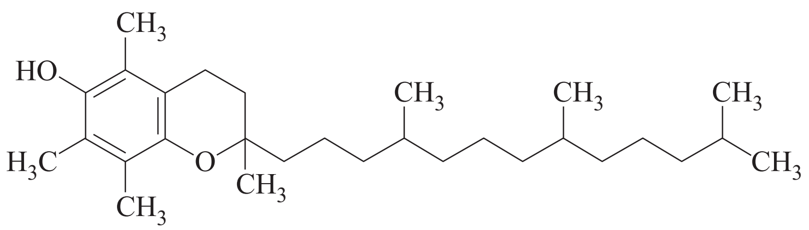
c. Coconut oil reacts in the body to produce fatty acids.

Name the other product of this reaction. 1 mark

d. Coconut oil can be metabolised by the body to produce caprylic acid.

Write the molecular formula of the molecule found in coconut oil that can be metabolised to produce three caprylic acid molecules. 1 mark

Coconut oil contains vitamin E, and negligible quantities of other vitamins and minerals.
The structure of vitamin E is given below.



e. Explain why vitamin E is soluble in coconut oil. 2 marks

Scientists are investigating the possibility of using coconut oil with an aqueous electrolyte of potassium hydroxide, KOH(aq), to power a fuel cell.

f. **i.** Write the half-equation that would occur at the cathode of a coconut oil fuel cell in an alkaline electrolyte. 1 mark

ii. State **one** design feature of the cathode that helps the fuel cell operate efficiently. 1 mark

g. State **one** reason why it may be better to obtain energy from coconut oil using a fuel cell rather than direct combustion. 1 mark

h. Give **one** reason why coconut oil may not be a **practical** fuel for a fuel cell. Do not refer to environmental issues or sustainability in your answer. 2 marks

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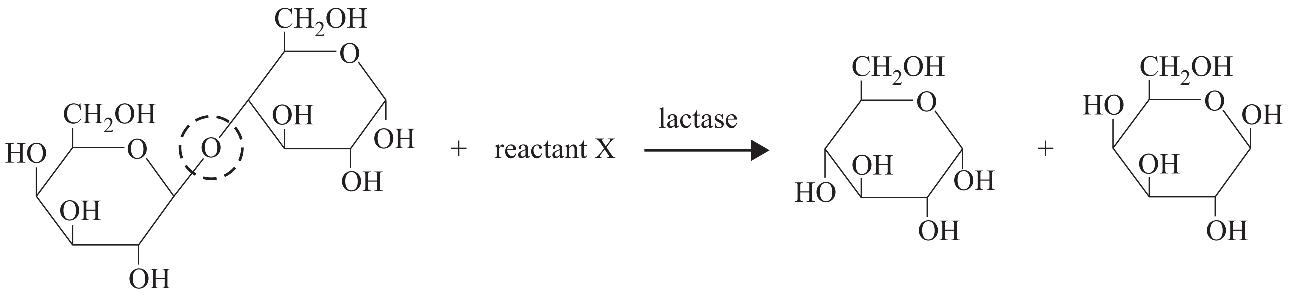
Question 2 (12 marks)

Cow's milk contains proteins, fats and carbohydrates. The main carbohydrate in cow's milk is lactose.

The reaction for the breakdown of lactose is catalysed by the enzyme lactase as shown below.



α-lactose

a. A linkage has been circled with a dashed line in the lactose molecule shown above.

Name the circled linkage. 1 mark

____

b. **i.** Explain what the GI of a food indicates. 2 marks

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ii. State why the breakdown of lactose, as shown above, contributes to the GI of lactose. 1 mark

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c. Proline is found both in cow's milk and in the enzyme lactase. Proline is not an essential amino acid. The structure of proline is shown in the data book.

i. State why proline is not an essential amino acid. 1 mark

ii. Draw the structure of proline as it would be in an acidic solution. 1 mark

iii. Proline is found in proteins throughout the human body.

Identify **two** types of enzyme-catalysed chemical reactions involving proline in the human body. 2 marks

iv. Explain why proline has two optical isomers. 2 marks

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v. Only one of proline's optical isomers is found in lactase.

Explain why lactase must contain the correct optical isomer of proline to function as an enzyme in the digestion of cow's milk. 2 marks

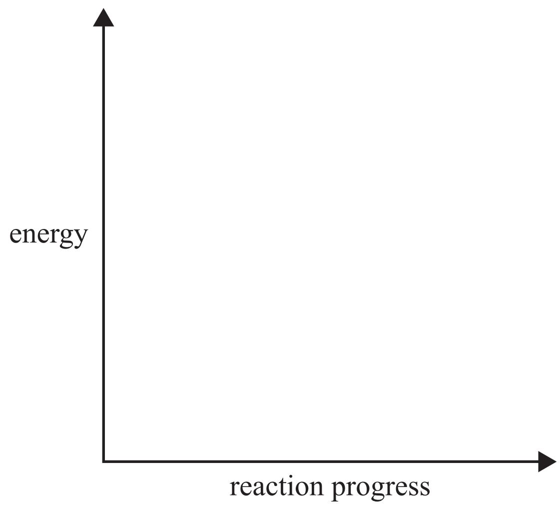
Question 3 (12 marks)

a. Propane is used as a fuel for barbeques.

i. Calculate the amount of energy released when 140.0 g of propane is completely combusted. 1 mark

ii. Write a thermochemical equation for the complete combustion of propane at SLC. 2 marks

iii. Sketch the energy profile for the complete combustion of propane on the axes provided below. 1 mark



iv. State how the energy profile for the **incomplete** combustion of propane would differ from the diagram you drew in part **a.iii**. Justify your answer. 2 marks

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b. An equation for the complete combustion of ethanol, C_2H_5OH, is shown below.

$$C_2H_5OH (l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$$

i. 96.0 g of ethanol completely combusts and the CO_2 produced is collected.

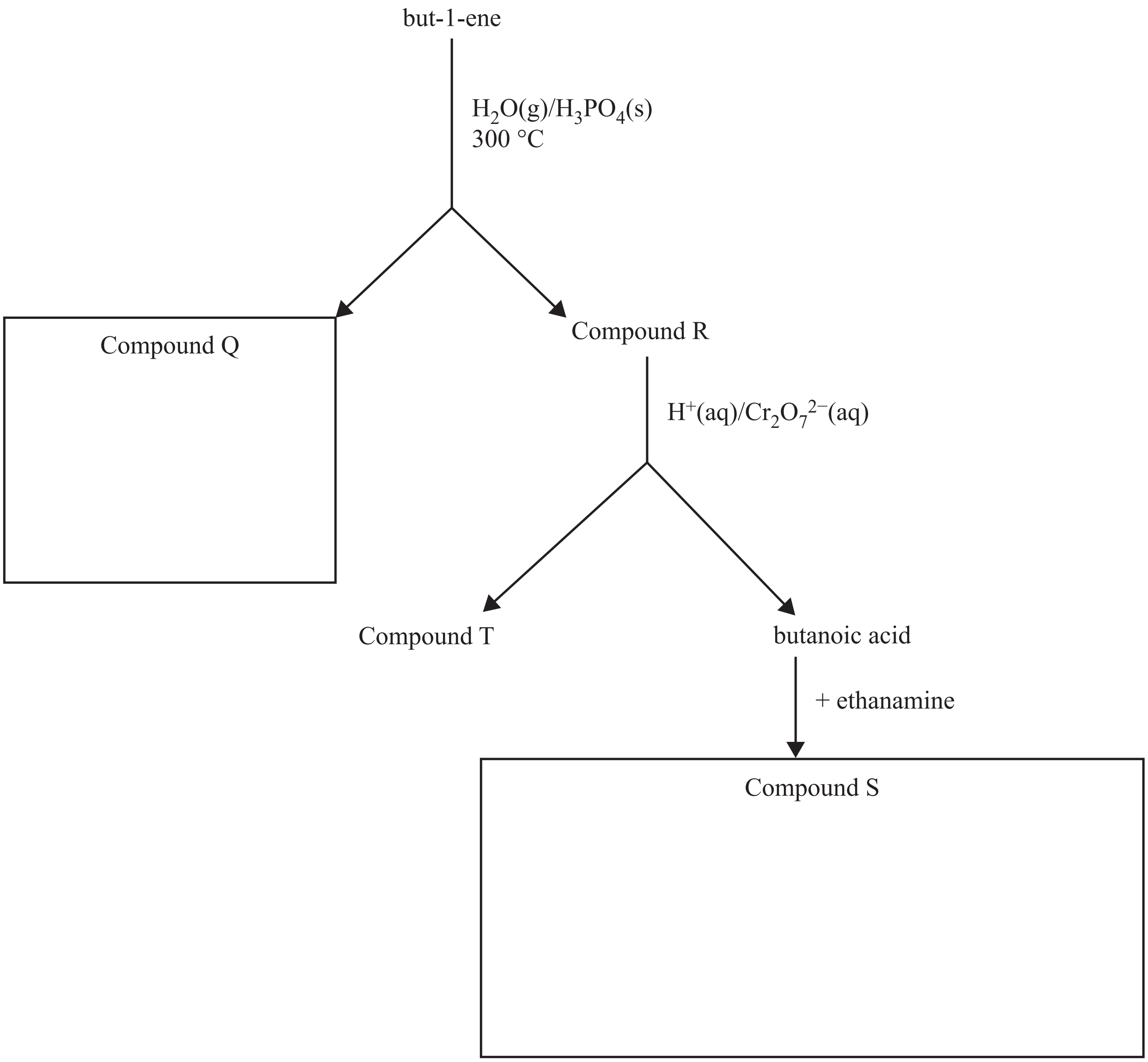
Calculate the volume of a tank required to store the captured CO_2 at 15.0 °C and 100.0 kPa. 3 marks

ii. The molar mass of ethanol is 46.0 g mol^{-1} and the molar mass of propane is 44.0 g mol^{-1}.

State whether the flashpoint of ethanol is higher or lower than the flashpoint of propane. Explain the reasons for your choice with reference to the structure of both molecules. 3 marks

Question 4 (7 marks)

The diagram below shows a reaction pathway starting with but-1-ene.



a. But-1-ene can react with water vapour at 300 °C with $H_3PO_4(s)$ as a catalyst to produce two different products, Compound Q and Compound R. Only Compound R can react to produce butanoic acid.

i. Name the type of reaction that forms Compound Q and Compound R from but-1-ene. 1 mark

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ii. Give the IUPAC name of Compound Q in the box provided on the diagram above. 1 mark

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b. As shown in the diagram, compound R can oxidise completely with acidified potassium dichromate solution, $H^+(aq)/Cr_2O_7^{2-}(aq)$, to form butanoic acid. Compound R can also undergo incomplete oxidation to form Compound T.

Draw the structural formula of Compound T in the space below. 1 mark

c. Under certain conditions, butanoic acid reacts with ethanamine to produce Compound S.

Draw the skeletal formula for Compound S in the box provided on the diagram on page 20. 2 marks

d. Butanoic acid can also react with ethanol in the presence of a suitable catalyst to produce an ester. The molar mass of the ester produced is 116.0 g mol^{-1}.

Calculate the atom economy for this reaction. 2 marks

Question 5 (7 marks)

Hydrogen gas, $H_2(g)$, can be produced by reacting methane, $CH_4(g)$, with steam, $H_2O(g)$, at 300 °C in the presence of a suitable catalyst. The equation for the reaction is shown below.

$$CH_4(g) + 2H_2O(g) \rightleftharpoons CO_2(g) + 4H_2(g) \qquad \Delta H = +165 \text{ kJ mol}^{-1}$$

a. State a source of $CH_4(g)$. 1 mark

b. A suitable catalyst plus 25.0 mol of $CH_4(g)$ and 25.0 mol of $H_2O(g)$ are placed into an empty, sealed 100.0 L container at 300 °C. After the reaction has reached equilibrium, the container contains 6.12 mol $H_2(g)$.

i. Write an expression for the equilibrium constant. 1 mark

ii. Calculate the equilibrium constant, *K*, for this reaction at 300 °C. 4 marks

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c. The temperature of the equilibrium system is decreased.

State how the decrease in temperature changes the **shape** of the Maxwell-Boltzmann distribution. You may use diagrams in your answer. 1 mark

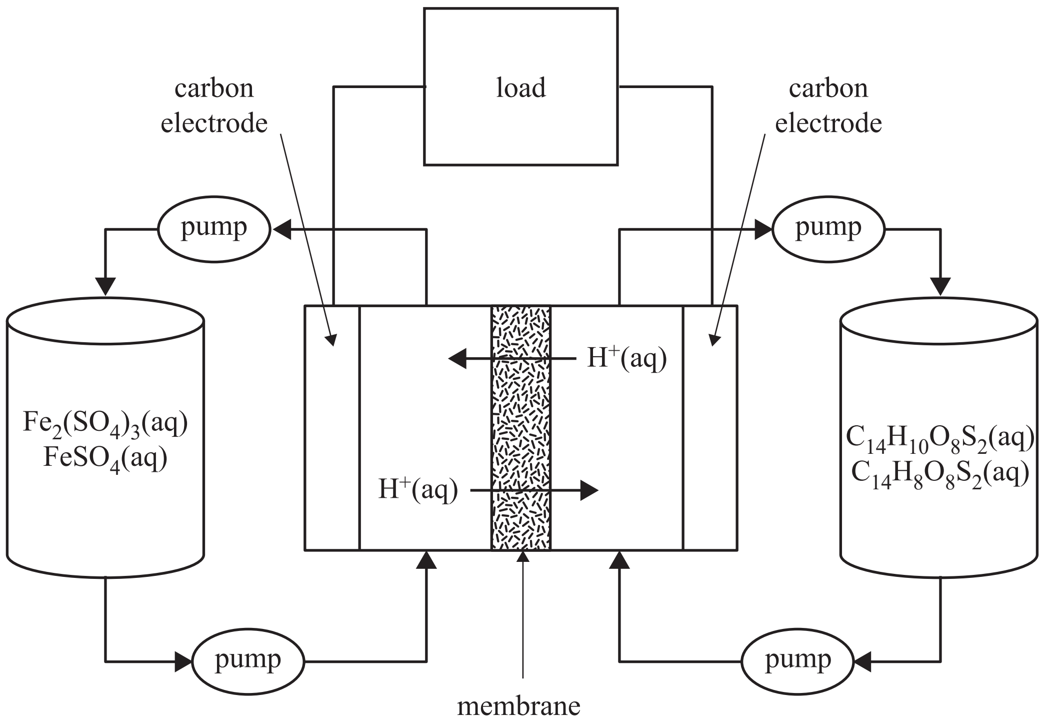
Question 6 (7 marks)

Scientists are currently researching an experimental secondary cell.

The following reaction takes place in the experimental cell during discharge.

$$Fe_2(SO_4)_3(aq) + C_{14}H_{10}O_8S_2(aq) \rightarrow 2FeSO_4(aq) + C_{14}H_8O_8S_2(aq) + HSO_4^-(aq) + H^+(aq)$$

A diagram of the experimental cell is shown below.



a. State the energy transformation that occurs in the experimental cell during discharge. 1 mark

b. Which reactant is the oxidising agent in the experimental cell during discharge? Use oxidation numbers to justify your answer. 2 marks

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c. i. Write the half-equation for the reaction that occurs in the $C_{14}H_8O_8S_2/C_{14}H_{10}O_8S_2$ half-cell during recharge. 1 mark

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ii. State the polarity of the $C_{14}H_8O_8S_2/C_{14}H_{10}O_8S_2$ half-cell electrode during recharge. 1 mark

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iii. Explain how the polarity of the electrodes is established during recharge to allow the recharge to occur. 2 marks

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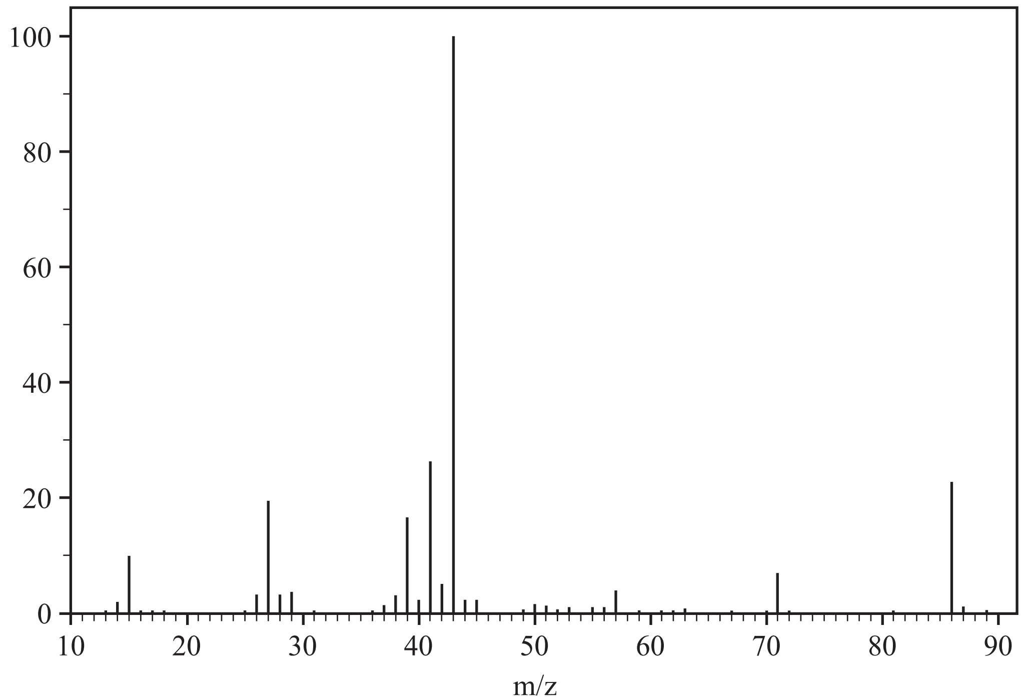
Question 7 (10 marks)

Molecule V contains only carbon atoms, hydrogen atoms and one oxygen atom.

The mass spectrum of molecule V is shown below.



Data: SDBS Web <sdbs.db.aist.go.jp>,
National Institute of Advanced Industrial Science and Technology

a. **i.** State the molecular formula of molecule V. Justify your answer by using the information in the mass spectrum. 2 marks

ii. State why there is a small peak at m/z = 87. 1 mark

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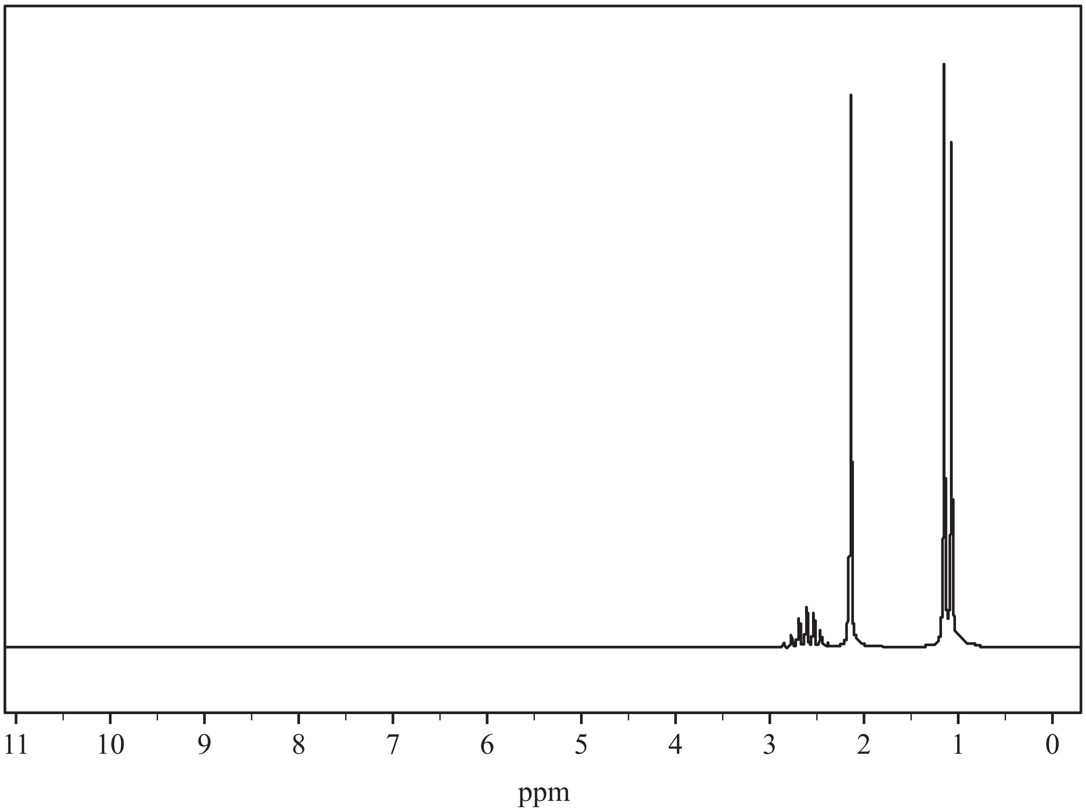
The ^{1}H NMR spectrum of molecule V is shown below.



Data: SDBS Web <sdbs.db.aist.go.jp>,
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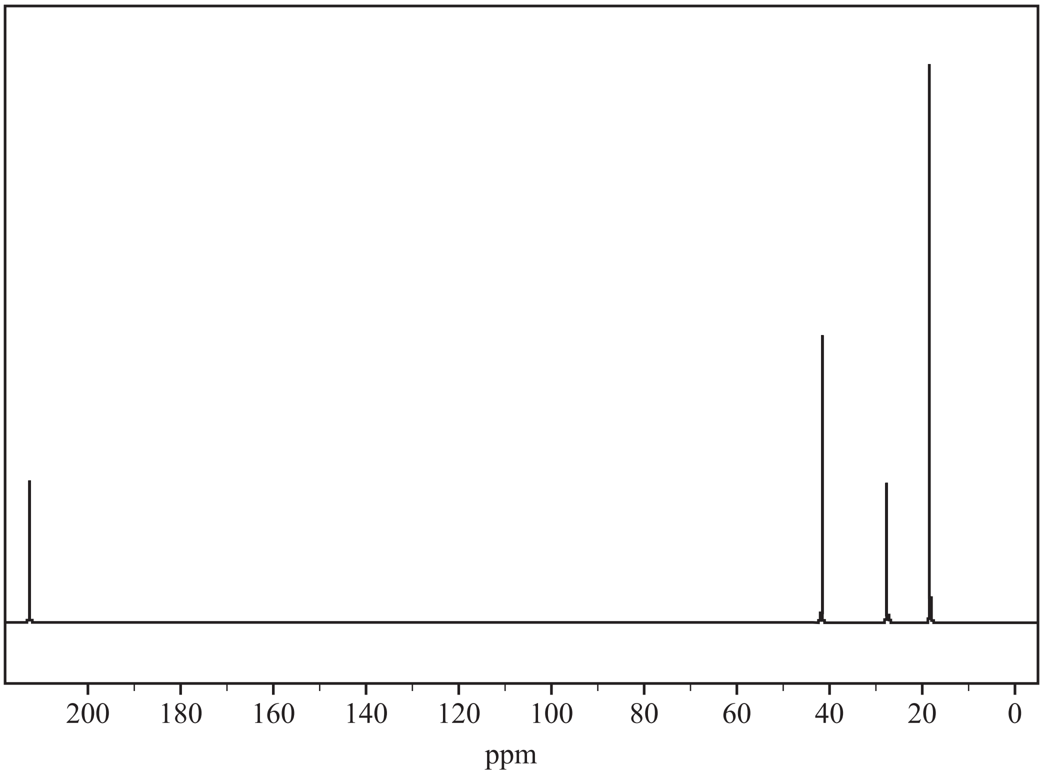
b. State what information the doublet at 1.1 ppm provides about the structure of the molecule. 1 mark

The ^{13}C NMR spectrum of molecule V is shown below.



Data: SDBS Web <sdbs.db.aist.go.jp>,
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c. In the space below, draw a structural formula of molecule V that is consistent with the information provided in **parts a.–c.** 3 marks

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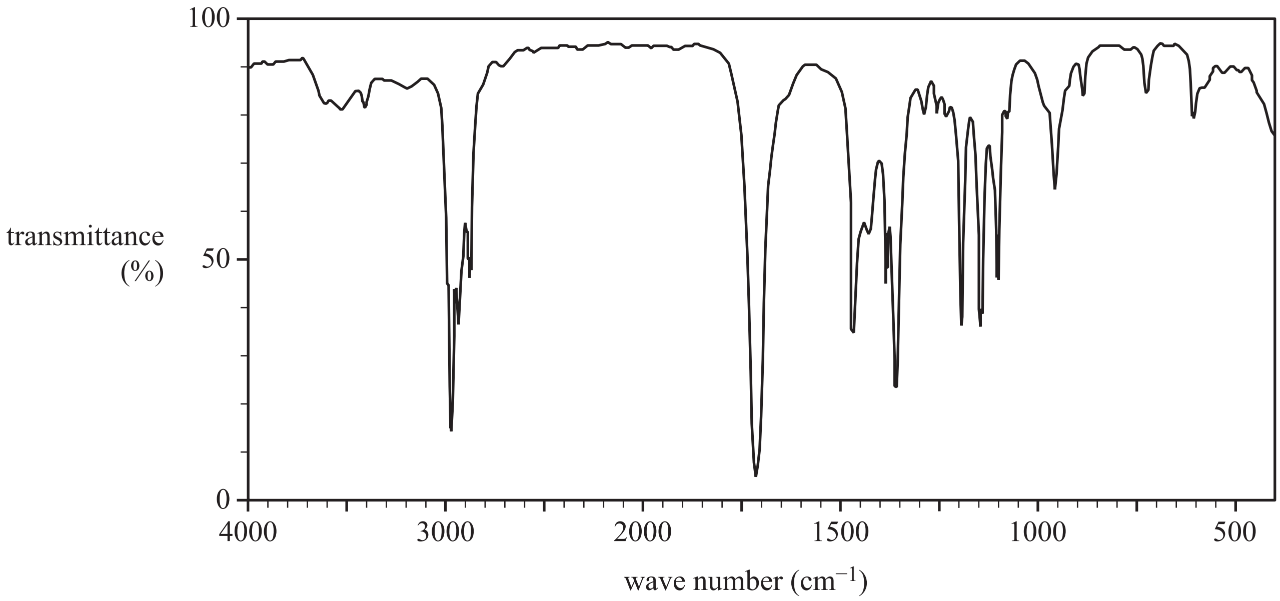
The infrared (IR) spectrum of molecule V is shown below.



Data: SDBS Web <sdbs.db.aist.go.jp>,
National Institute of Advanced Industrial Science and Technology

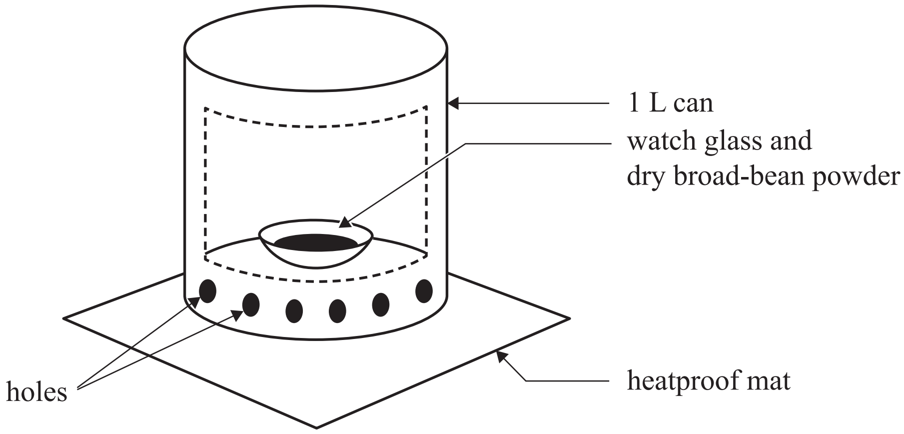
d. Explain why different frequencies of infrared radiation can be absorbed by the same molecule as shown in the spectrum above. 3 marks

Question 8 (16 marks)

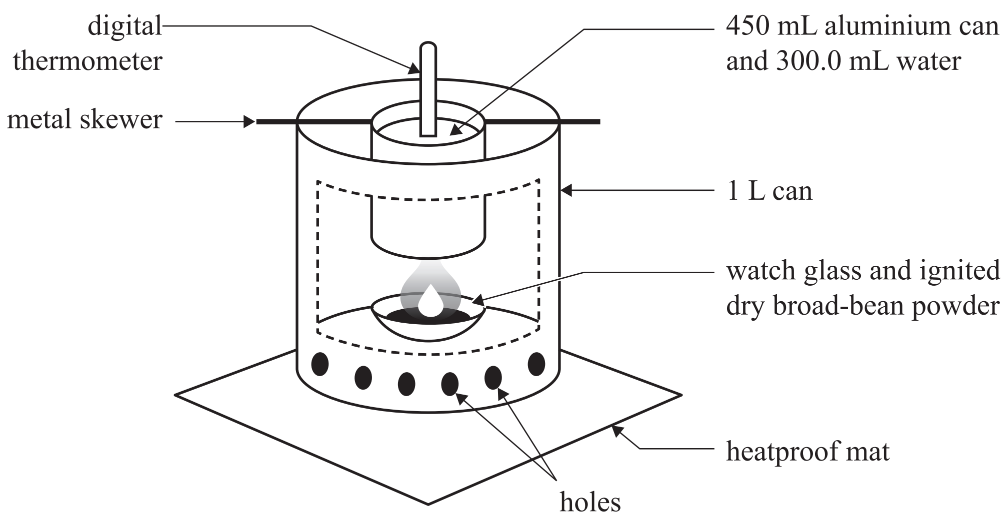
A student performed an experiment to compare the energy content of dry broad beans and dry soybeans.

The student followed the method below.

1. Fill a 2 L beaker with water and let it sit for 4 hours to come to room temperature.
2. Crush two dry broad beans to a powder.
3. Weigh and record the mass of the dry broad-bean powder, using a clean watch glass.
4. Set up the equipment on a heatproof mat as shown in the diagram below.



5. Ignite the dry broad-bean powder.
6. Suspend the 450 mL can containing 300.0 mL of water directly over the burning dry broad-bean powder.



7. Record the temperature of the water in the 450 mL can every 30 seconds until the dry broad-bean powder has stopped burning and the temperature of the water has begun to drop.
8. When the temperature of the water in the 450 mL can is below 30 °C, empty the water from the 450 mL can and wait until both cans return to room temperature.
9. Repeat steps 2 to 8 using dry soybeans instead of dry broad beans.

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a. Explain why the dry beans were crushed in step 2 of the experimental method. 2 marks

b. Identify the dependent variable in this experiment. 1 mark

c. Identify **one** step in the experimental procedure that is designed to manage safety hazards. Explain how this step reduces the risks associated with the experiment. 2 marks

d. When the experiment was undertaken with 1.11 g of dry broad-bean powder, the following results were obtained.

Mass of dry broad-bean powder	1.11 g
Initial temperature of water	25.0 °C
Final temperature of water	32.1 °C

Use the experimental results to calculate the energy content of the dry broad bean in kJ g^{-1}. 4 marks

e. The typical nutrition content of dry soybeans is provided in the table below.

	Average quantity per 100 g
protein	36 g
fat	20 g
carbohydrates	29 g

i. Use the nutrition information from the table to calculate the heat of combustion of a typical dry soybean in kJ g^{-1}. 2 marks

When the experiment was performed with a dry soybean, the heat of combustion was found to be 35 kJ g^{-1}.

ii. Suggest an experimental error that could have caused the experimental value to be different to the heat of combustion of a typical dry soybean. Explain how this error could have caused the difference between the experimental result and the expected result. 2 marks

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f. Suggest **one** improvement to the experimental method using the apparatus and method shown on page 30 that would produce more accurate results. Explain how this improvement would improve the accuracy of the results. 2 marks

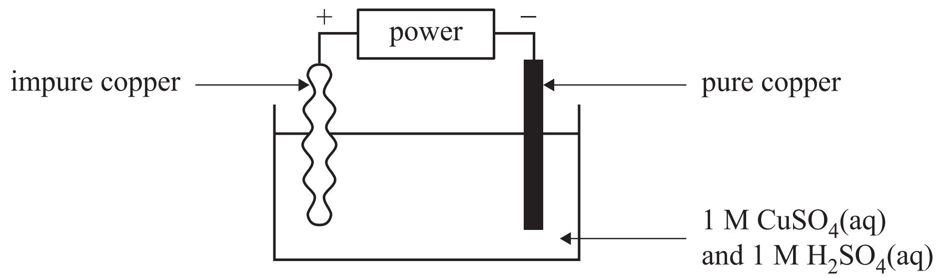
g. Write a valid conclusion for the experiment based on the experimental results. 1 mark

Question 9 (8 marks)

a. Purified copper contains at least 99.8% copper. Purified copper is used in electronic devices because it is a good electrical conductor and resists corrosion.

Purified copper is produced from impure copper by electrolysis. The electrolysis cell is shown in the diagram below. The impure copper contains 99% copper. The remainder of the impure copper consists of

- zinc, Zn
- lead, Pb
- gold, Au.



Use your understanding of electrochemistry to discuss how electrolysis is used to purify copper using the cell above. In your response

- provide a definition of electrolysis
- explain what happens to the Au, Zn and Pb with reference to the electrochemical series. 5 marks

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Faraday’s First Law of Electrolysis

It states, during electrolysis, the amount of chemical reaction which occurs at any electrode under the influence of electrical energy is proportional to the quantity of electricity passed through the electrolyte.

Source: <byjus.com/chemistry/laws-of-electrolysis/>

b. Explain how the Faraday constant, *F*, together with Faraday’s first law of electrolysis, can be used to find the amount of bromine, Br_2, produced when molten potassium bromide, KBr(l), is electrolysed. 3 marks

END OF QUESTION AND ANSWER BOOK

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Victorian Certificate of Education 2023

CHEMISTRY

Written examination

DATA BOOK

Instructions

This data book is provided for your reference.
A question and answer book is provided with this data book.

Students are NOT permitted to bring mobile phones and/or any other unauthorised electronic devices into the examination room.

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Table of contents

1. Periodic table of the elements

atomic number	79
symbol of element	Au
relative atomic mass	197.0
name of element	gold

1 **H** 1.0 hydrogen																	**2** **He** 4.0 helium
3 **Li** 6.9 lithium	**4** **Be** 9.0 beryllium											**5** **B** 10.8 boron	**6** **C** 12.0 carbon	**7** **N** 14.0 nitrogen	**8** **O** 16.0 oxygen	**9** **F** 19.0 fluorine	**10** **Ne** 20.2 neon
11 **Na** 23.0 sodium	**12** **Mg** 24.3 magnesium											**13** **Al** 27.0 aluminium	**14** **Si** 28.1 silicon	**15** **P** 31.0 phosphorus	**16** **S** 32.1 sulfur	**17** **Cl** 35.5 chlorine	**18** **Ar** 39.9 argon
19 **K** 39.1 potassium	**20** **Ca** 40.1 calcium	**21** **Sc** 45.0 scandium	**22** **Ti** 47.9 titanium	**23** **V** 50.9 vanadium	**24** **Cr** 52.0 chromium	**25** **Mn** 54.9 manganese	**26** **Fe** 55.8 iron	**27** **Co** 58.9 cobalt	**28** **Ni** 58.7 nickel	**29** **Cu** 63.5 copper	**30** **Zn** 65.4 zinc	**31** **Ga** 69.7 gallium	**32** **Ge** 72.6 germanium	**33** **As** 74.9 arsenic	**34** **Se** 79.0 selenium	**35** **Br** 79.9 bromine	**36** **Kr** 83.8 krypton
37 **Rb** 85.5 rubidium	**38** **Sr** 87.6 strontium	**39** **Y** 88.9 yttrium	**40** **Zr** 91.2 zirconium	**41** **Nb** 92.9 niobium	**42** **Mo** 96.0 molybdenum	**43** **Tc** (98) technetium	**44** **Ru** 101.1 ruthenium	**45** **Rh** 102.9 rhodium	**46** **Pd** 106.4 palladium	**47** **Ag** 107.9 silver	**48** **Cd** 112.4 cadmium	**49** **In** 114.8 indium	**50** **Sn** 118.7 tin	**51** **Sb** 121.8 antimony	**52** **Te** 127.6 tellurium	**53** **I** 126.9 iodine	**54** **Xe** 131.3 xenon
55 **Cs** 132.9 caesium	**56** **Ba** 137.3 barium	**57–71** lanthanoids	**72** **Hf** 178.5 hafnium	**73** **Ta** 180.9 tantalum	**74** **W** 183.8 tungsten	**75** **Re** 186.2 rhenium	**76** **Os** 190.2 osmium	**77** **Ir** 192.2 iridium	**78** **Pt** 195.1 platinum	**79** **Au** 197.0 gold	**80** **Hg** 200.6 mercury	**81** **Tl** 204.4 thallium	**82** **Pb** 207.2 lead	**83** **Bi** 209.0 bismuth	**84** **Po** (210) polonium	**85** **At** (210) astatine	**86** **Rn** (222) radon
87 **Fr** (223) francium	**88** **Ra** (226) radium	**89–103** actinoids	**104** **Rf** (261) rutherfordium	**105** **Db** (262) dubnium	**106** **Sg** (266) seaborgium	**107** **Bh** (264) bohrium	**108** **Hs** (267) hassium	**109** **Mt** (268) meitnerium	**110** **Ds** (271) darmstadtium	**111** **Rg** (272) roentgenium	**112** **Cn** (285) copernicium	**113** **Nh** (280) nihonium	**114** **Fl** (289) flerovium	**115** **Mc** (289) moscovium	**116** **Lv** (292) livermorium	**117** **Ts** (294) tennessine	**118** **Og** (294) oganesson

57 **La** 138.9 lanthanum	**58** **Ce** 140.1 cerium	**59** **Pr** 140.9 praseodymium	**60** **Nd** 144.2 neodymium	**61** **Pm** (145) promethium	**62** **Sm** 150.4 samarium	**63** **Eu** 152.0 europium	**64** **Gd** 157.3 gadolinium	**65** **Tb** 158.9 terbium	**66** **Dy** 162.5 dysprosium	**67** **Ho** 164.9 holmium	**68** **Er** 167.3 erbium	**69** **Tm** 168.9 thulium	**70** **Yb** 173.1 ytterbium	**71** **Lu** 175.0 lutetium

89 **Ac** (227) actinium	**90** **Th** 232.0 thorium	**91** **Pa** 231.0 protactinium	**92** **U** 238.0 uranium	**93** **Np** (237) neptunium	**94** **Pu** (244) plutonium	**95** **Am** (243) americium	**96** **Cm** (247) curium	**97** **Bk** (247) berkelium	**98** **Cf** (251) californium	**99** **Es** (252) einsteinium	**100** **Fm** (257) fermium	**101** **Md** (258) mendelevium	**102** **No** (259) nobelium	**103** **Lr** (262) lawrencium

The value in brackets indicates the mass number of the longest-lived isotope.

2. Electrochemical series

Reaction	Standard electrode potential (E^0) in volts at 25 °C
$F_2(g) + 2e^- \rightleftharpoons 2F^-(aq)$	+2.87
$H_2O_2(aq) + 2H^+(aq) + 2e^- \rightleftharpoons 2H_2O(l)$	+1.77
$Au^+(aq) + e^- \rightleftharpoons Au(s)$	+1.68
$Cl_2(g) + 2e^- \rightleftharpoons 2Cl^-(aq)$	+1.36
$O_2(g) + 4H^+(aq) + 4e^- \rightleftharpoons 2H_2O(1)$	+1.23
$Br_2(l) + 2e^- \rightleftharpoons 2Br^-(aq)$	+1.09
$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$	+0.80
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+0.77
$O_2(g) + 2H^+(aq) + 2e^- \rightleftharpoons H_2O_2(aq)$	+0.68
$I_2(s) + 2e^- \rightleftharpoons 2I^-(aq)$	+0.54
$O_2(g) + 2H_2O(l) + 4e^- \rightleftharpoons 4OH^-(aq)$	+0.40
$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$	+0.34
$Sn^{4+}(aq) + 2e^- \rightleftharpoons Sn^{2+}(aq)$	+0.15
$S(s) + 2H^+(aq) + 2e^- \rightleftharpoons H_2S(g)$	+0.14
$2H^+(aq) + 2e^- \rightleftharpoons H_2(g)$	0.00
$Pb^{2+}(aq) + 2e^- \rightleftharpoons Pb(s)$	–0.13
$Sn^{2+}(aq) + 2e^- \rightleftharpoons Sn(s)$	–0.14
$Ni^{2+}(aq) + 2e^- \rightleftharpoons Ni(s)$	–0.25
$Co^{2+}(aq) + 2e^- \rightleftharpoons Co(s)$	–0.28
$Cd^{2+}(aq) + 2e^- \rightleftharpoons Cd(s)$	–0.40
$Fe^{2+}(aq) + 2e^- \rightleftharpoons Fe(s)$	–0.44
$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$	–0.76
$2H_2O(l) + 2e^- \rightleftharpoons H_2(g) + 2OH^-(aq)$	–0.83
$Mn^{2+}(aq) + 2e^- \rightleftharpoons Mn(s)$	–1.18
$Al^{3+}(aq) + 3e^- \rightleftharpoons Al(s)$	–1.66
$Mg^{2+}(aq) + 2e^- \rightleftharpoons Mg(s)$	–2.37
$Na^+(aq) + e^- \rightleftharpoons Na(s)$	–2.71
$Ca^{2+}(aq) + 2e^- \rightleftharpoons Ca(s)$	–2.87
$K^+(aq) + e^- \rightleftharpoons K(s)$	–2.93
$Li^+(aq) + e^- \rightleftharpoons Li(s)$	–3.04

3. Chemical relationships

Name	Formula
number of moles of a substance	$n = \frac{m}{M}$; $n = cV$; $n = \frac{V}{V_m}$
universal gas equation	$pV = nRT$
calibration factor (CF) for bomb calorimetry	$\mathrm{CF} = \frac{VIt}{\Delta T}$
heat energy released in the combustion of a fuel	$q = mc\Delta T$
enthalpy of combustion	$\Delta H = \frac{q}{n}$
electric charge	$Q = It$
number of moles of electrons	$n(e^-) = \frac{Q}{F}$
% atom economy	$\frac{\text{molar mass of desired product}}{\text{molar mass of all reactants}} \times \frac{100}{1}$
% yield	$\frac{\text{actual yield}}{\text{theoretical yield}} \times \frac{100}{1}$

4. Physical constants and standard values

Name	Symbol	Value
Avogadro constant	N_A or L	6.02×10^{23} mol^{-1}
charge on one electron (elementary charge)	e	-1.60×10^{-19} C
Faraday constant	F	96 500 C mol^{-1}
molar gas constant	R	8.31 J mol^{-1} K^{-1}
molar volume of an ideal gas at SLC (25 °C and 100 kPa)	V_m	24.8 L mol^{-1}
specific heat capacity of water	c	4.18 kJ kg^{-1} K^{-1} or 4.18 J g^{-1} K^{-1}
density of water at 25 °C	d	997 kg m^{-3} or 0.997 g mL^{-1}

5. Unit conversions

Measured value	Conversion
0 °C	273 K
100 kPa	750 mm Hg or 0.987 atm
1 litre (L)	1 dm^3 or 1×10^{-3} m^3 or 1×10^3 cm^3 or 1×10^3 mL

6. Metric (including SI) prefixes

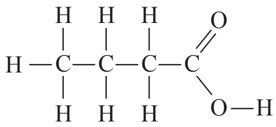
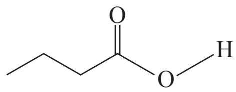
Metric (including SI) prefixes	Scientific notation	Multiplying factor
giga (G)	10^9	1 000 000 000
mega (M)	10^6	1 000 000
kilo (k)	10^3	1000
deci (d)	10^{-1}	0.1
centi (c)	10^{-2}	0.01
milli (m)	10^{-3}	0.001
micro (μ)	10^{-6}	0.000001
nano (n)	10^{-9}	0.000000001
pico (p)	10^{-12}	0.000000000001

7. Acid-base indicators

Name	pH range	Colour change from lower pH to higher pH in range
thymol blue (1st change)	1.2–2.8	red → yellow
methyl orange	3.1–4.4	red → yellow
bromophenol blue	3.0–4.6	yellow → blue
methyl red	4.4–6.2	red → yellow
bromothymol blue	6.0–7.6	yellow → blue
phenol red	6.8–8.4	yellow → red
thymol blue (2nd change)	8.0–9.6	yellow → blue
phenolphthalein	8.3–10.0	colourless → pink

8. Representations of organic molecules

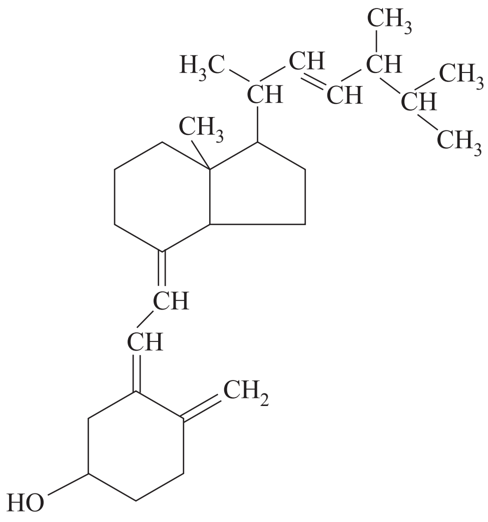
The following table shows different representations of organic molecules, using butanoic acid as an example.

Formula	Representation
molecular formula	$C_4H_8O_2$
structural formula	
semi-structural (condensed) formula	$CH_3CH_2CH_2COOH$ or $CH_3(CH_2)_2COOH$
skeletal structure	

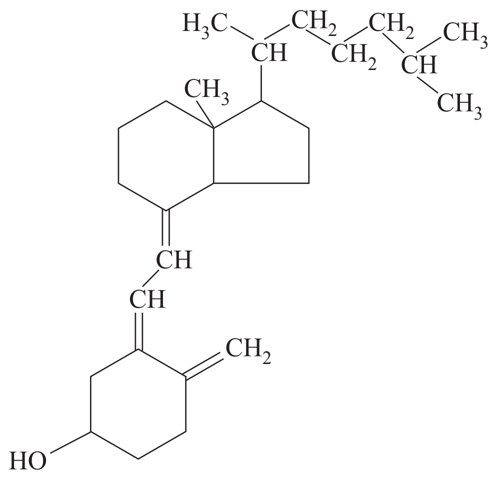
9. Formulas of some fatty acids

Name	Formula	Semi-structural formula
lauric	$C_{11}H_{23}COOH$	$CH_3(CH_2)_{10}COOH$
myristic	$C_{13}H_{27}COOH$	$CH_3(CH_2)_{12}COOH$
palmitic	$C_{15}H_{31}COOH$	$CH_3(CH_2)_{14}COOH$
palmitoleic	$C_{15}H_{29}COOH$	$CH_3(CH_2)_4CH_2CH{=}CHCH_2\,(CH_2)_5CH_2COOH$
stearic	$C_{17}H_{35}COOH$	$CH_3(CH_2)_{16}COOH$
oleic	$C_{17}H_{33}COOH$	$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$
linoleic	$C_{17}H_{31}COOH$	$CH_3(CH_2)_4(CH{=}CHCH_2)_2(CH_2)_6COOH$
linolenic	$C_{17}H_{29}COOH$	$CH_3CH_2(CH{=}CHCH_2)_3(CH_2)_6COOH$
arachidic	$C_{19}H_{39}COOH$	$CH_3(CH_2)_{17}CH_2COOH$
arachidonic	$C_{19}H_{31}COOH$	$CH_3(CH_2)_4(CH{=}CHCH_2)_3CH{=}CH(CH_2)_3COOH$

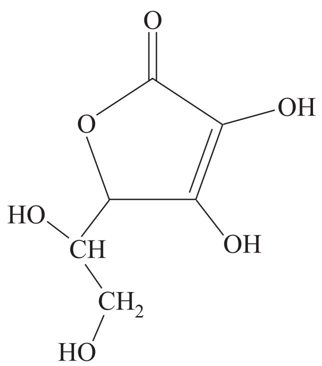
10. Formulas of some biomolecules



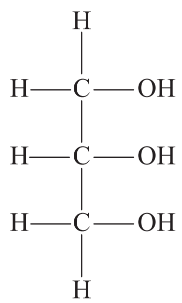
vitamin D_2 (ergocalciferol)



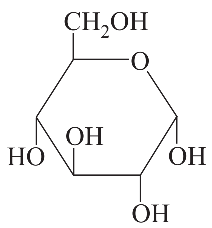
vitamin D_3 (cholecalciferol)



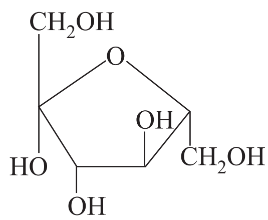
vitamin C (ascorbic acid)



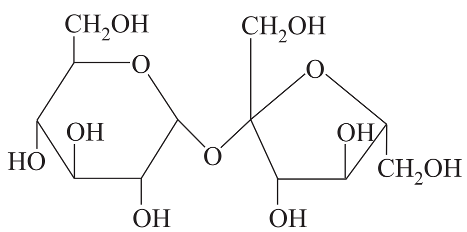
glycerol



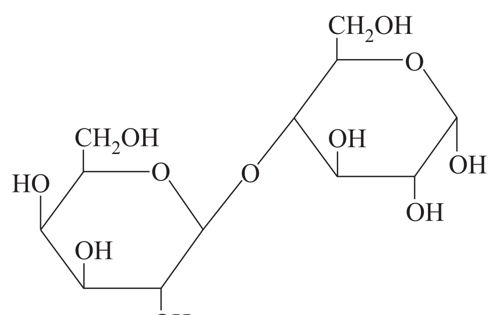
α-glucose



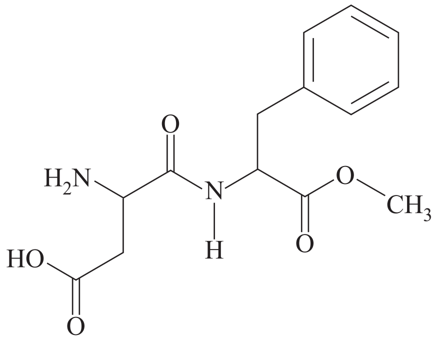
β-fructose



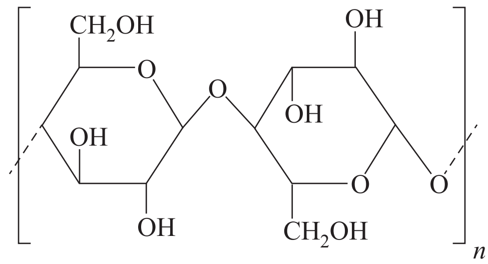
sucrose



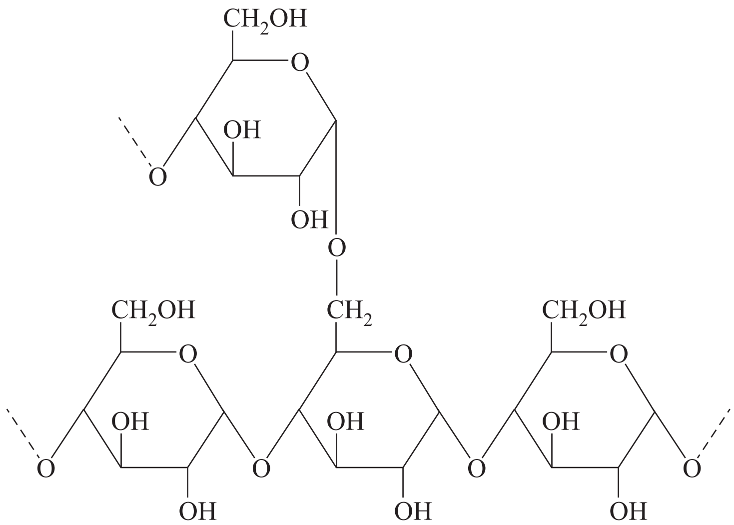
α-lactose



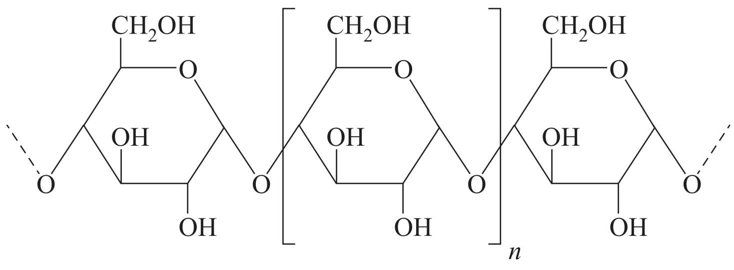
aspartame



cellulose



amylopectin (starch)



amylose (starch)

11. Heats of combustion of common fuels

The heats of combustion in the following table are calculated at SLC (25 °C and 100 kPa) with combustion products being CO_2 and H_2O. Heat of combustion may be defined as the heat energy released when a specified amount of a substance burns completely in oxygen and is, therefore, reported as a positive value, indicating a magnitude. Enthalpy of combustion, ΔH, for the substances in this table would be reported as negative values, indicating the exothermic nature of the combustion reaction.

Fuel	Formula	State	Heat of combustion (kJ g^{-1})	Molar heat of combustion (kJ mol^{-1})
hydrogen	H_2	gas	141	282
methane	CH_4	gas	55.6	890
ethane	C_2H_6	gas	51.9	1560
propane	C_3H_8	gas	50.5	2220
butane	C_4H_{10}	gas	49.7	2880
octane	C_8H_{18}	liquid	47.9	5460
ethyne (acetylene)	C_2H_2	gas	49.9	1300
methanol	CH_3OH	liquid	22.7	726
ethanol	C_2H_5OH	liquid	29.6	1360

12. Heats of combustion of common blended fuels

Blended fuels are mixtures of compounds with different mixture ratios and, hence, determination of a generic molar enthalpy of combustion is not realistic. The values provided in the following table are typical values for heats of combustion at SLC (25 °C and 100 kPa) with combustion products being CO_2 and H_2O. Values for heats of combustion will vary depending on the source and composition of the fuel.

Fuel	State	Heat of combustion (kJ g^{-1})
kerosene	liquid	46.2
diesel	liquid	45.0
natural gas	gas	54.0

13. Energy content of food groups

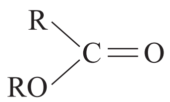
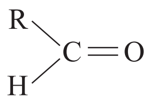
Food	Heat of combustion (kJ g^{-1})
fats and oils	37
protein	17
carbohydrate	16

14. Characteristic ranges for infra-red absorption

Bond	Wave number (cm^{-1})	Bond	Wave number (cm^{-1})
C–Cl (chloroalkanes)	600–800	C=O (ketones)	1680–1850
C–O (alcohols, esters, ethers)	1050–1410	C=O (esters)	1720–1840
C=C (alkenes)	1620–1680	C–H (alkanes, alkenes, arenes)	2850–3090
C=O (amides)	1630–1680	O–H (acids)	2500–3500
C=O (aldehydes)	1660–1745	O–H (alcohols)	3200–3600
C=O (acids)	1680–1740	N–H (amines and amides)	3300–3500

15. ^{13}C NMR data

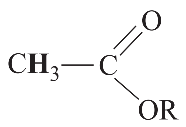
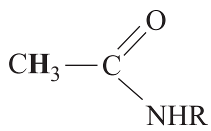
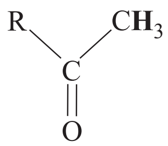
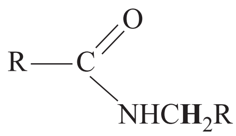
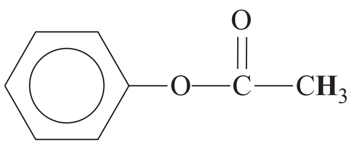
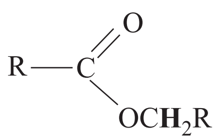
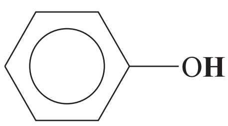
Typical ^{13}C shift values relative to TMS = 0
These can differ slightly in different solvents.

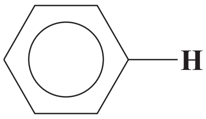
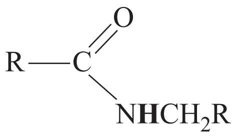
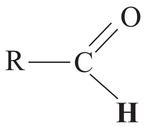
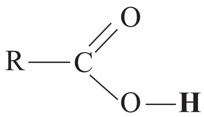
Type of carbon	Chemical shift (ppm)
$R–CH_3$	8–25
$R–CH_2–R$	20–45
$R_3–CH$	40–60
$R_4–C$	36–45
$R–CH_2–X$	15–80
$R_3C–NH_2$, $R_3C–NR$	35–70
$R–CH_2–OH$	50–90
RC≡CR	75–95
$R_2C=CR_2$	110–150
RCOOH	160–185
	165–175
	190–200
$R_2C=O$	205–220

16. [1]H NMR data

Typical proton shift values relative to TMS = 0

These can differ slightly in different solvents. The shift refers to the proton environment that is indicated in bold letters in the formula.

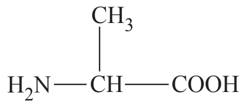
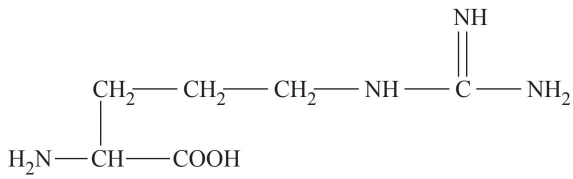
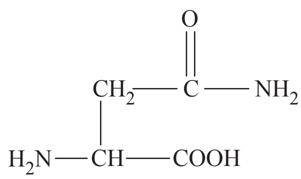
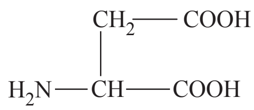
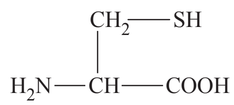
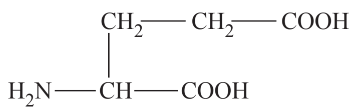
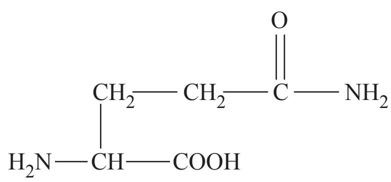
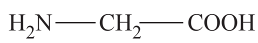
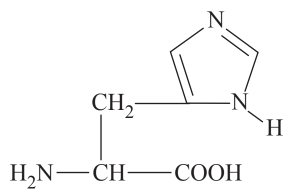
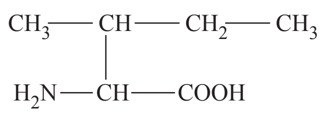
Type of proton	Chemical shift (ppm)
$\mathrm{R{-}C}\mathbf{H}_3$	0.9–1.0
$\mathrm{R{-}C}\mathbf{H}_2\mathrm{{-}R}$	1.3–1.4
$\mathrm{RCH{=}CH{-}C}\mathbf{H}_3$	1.6–1.9
$\mathrm{R_3{-}C}\mathbf{H}$	1.5
 or 	2.0
	2.1–2.7
$\mathrm{R{-}C}\mathbf{H}_2\mathrm{{-}X}$ (X = F, Cl, Br or I)	3.0–4.5
$\mathrm{R{-}C}\mathbf{H}_2\mathrm{{-}OH}$, $\mathrm{R_2{-}C}\mathbf{H}\mathrm{{-}OH}$	3.3–4.5
	3.2
$\mathrm{R{-}O{-}C}\mathbf{H}_3$ or $\mathrm{R{-}O{-}C}\mathbf{H}_2\mathrm{R}$	3.3–3.7
	2.3
	3.7–4.8
$\mathrm{R{-}O{-}}\mathbf{H}$	1–6 (varies considerably under different conditions)
$\mathrm{R{-}N}\mathbf{H}_2$	1–5
$\mathrm{RHC{=}C}\mathbf{H}\mathrm{R}$	4.5–7.0
	4.0–12.0

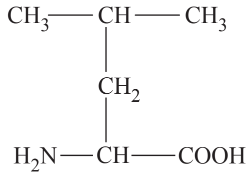
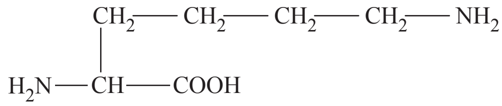
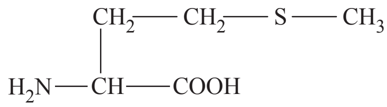
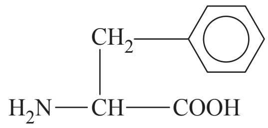
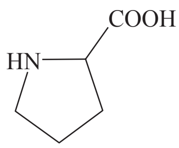
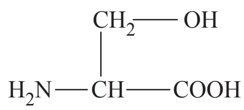
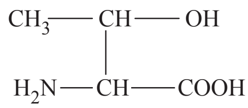
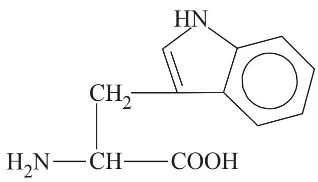
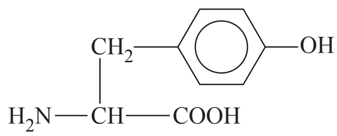
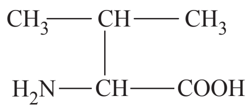
Type of proton	Chemical shift (ppm)
	6.9–9.0
	8.1
	9.4–10.0
	9.0–13.0

TURN OVER

17. 2-amino acids (*α*-amino acids)

The table below provides simplified structures to enable the drawing of zwitterions, the identification of products of protein hydrolysis and the drawing of structures involving condensation polymerisation of amino acid monomers.

Name	Symbol	Structure
alanine	Ala	
arginine	Arg	
asparagine	Asn	
aspartic acid	Asp	
cysteine	Cys	
glutamic acid	Glu	
glutamine	Gln	
glycine	Gly	
histidine	His	
isoleucine	Ile	

Name	Symbol	Structure
leucine	Leu	
lysine	Lys	
methionine	Met	
phenylalanine	Phe	
proline	Pro	
serine	Ser	
threonine	Thr	
tryptophan	Trp	
tyrosine	Tyr	
valine	Val	

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