VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education 2021

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

STUDENT NUMBER | | | | | | | | | Letter

CHEMISTRY

Written examination

Tuesday 9 November 2021

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	10	10	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 38 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.

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
Rechargeable batteries
A. use reversible reactions.
B. operate as galvanic cells during recharge.
C. require a continuous flow of reactants to operate.
D. have fewer side reactions as temperature increases.

Question 2
Biodiesel and petrodiesel
A. have different viscosities.
B. have the same environmental impact.
C. contain molecules with no polar groups.
D. will flow easily through fuel lines in very cold climate conditions.

Question 3
People who are lactose intolerant have a deficiency of the lactase enzyme.
Which one of the following statements about people who are lactose intolerant is correct?
A. Some of their consumed lactose remains undigested.
B. They metabolise lactose in a non-aqueous environment.
C. They are unable to digest the proteins found in dairy foods.
D. Their glycaemic index rises due to galactose passing into the blood.

Question 4

A titration was performed to determine the concentration of an ethanoic acid, $C_2H_4O_2$, solution using the following procedure:

1. 25.00 mL of the $C_2H_4O_2$ solution was pipetted into a conical flask.
2. A few drops of indicator were added to the flask.
3. A burette was filled with standard sodium hydroxide, NaOH, solution.
4. The $C_2H_4O_2$ solution was then titrated with the NaOH solution.
5. Steps 1–4 were repeated until three concordant titres were obtained.

A systematic error could result if the

A. burette tap leaked during one of the titrations.

B. burette readings were recorded to the nearest 0.1 mL.

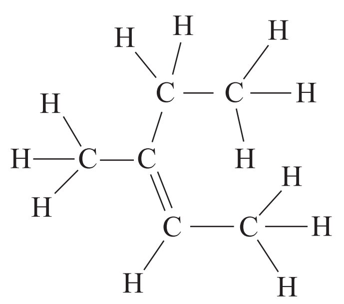
C. number of drops of indicator was not consistent for each titration.

D. actual concentration of the standard NaOH solution was lower than the stated concentration.

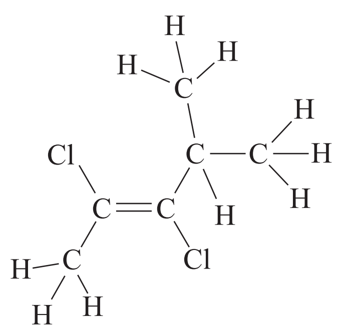
Question 5

Consider the following two molecules.

Molecule 1



Molecule 2



Which of the following options correctly describes Molecule 1 and Molecule 2?

	Molecule 1	Molecule 2
A.	cis	cis
B.	cis	trans
C.	trans	trans
D.	trans	cis

Question 6

Which of the following correctly identifies the bonds that break in a protein when it undergoes denaturation and when it undergoes hydrolysis?

	Denaturation	Hydrolysis
A.	covalent	hydrogen
B.	covalent	covalent
C.	hydrogen and ionic	hydrogen
D.	hydrogen and ionic	covalent

Question 7

Consider the following characteristics of electrolytic cells and galvanic cells.

Characteristic number	Electrolytic cells	Galvanic cells
1	cathode is negative	cathode is positive
2	have non-spontaneous reactions	have spontaneous reactions
3	reduction occurs at the anode	reduction occurs at the cathode
4	produce electricity	consume electricity

Which of the following combinations of characteristics of electrolytic cells and galvanic cells are correct?

A. only 1 and 2

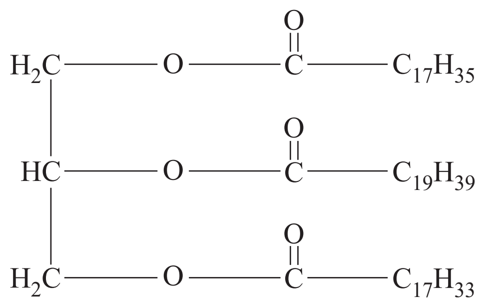
B. only 2 and 3

C. only 3 and 4

D. only 1, 2 and 4

Question 8

A triglyceride is shown below.



Which one of the following statements about the triglyceride is correct?

A. The fatty acids from the triglyceride will not undergo oxidative rancidity.

B. The triglyceride will hydrolyse to carbon dioxide and water.

C. The triglyceride has three carbon–carbon double bonds.

D. The triglyceride is insoluble in water.

Question 9

An electrolysis cell consumed a charge of 4.00 C in 5.00 minutes.

This represents a consumption of

A. 4.15×10^{-5} mol of electrons.

B. 2.07×10^{-4} mol of electrons.

C. 1.93×10^{4} mol of electrons.

D. 2.41×10^{4} mol of electrons.

Question 10

A student hypothesised that polishing the zinc, Zn, electrode in an Fe–Zn galvanic cell would increase the current produced by the cell.

What would be the **most** valid method of testing this hypothesis?

A. researching the scientific literature to determine how polishing changes the structure of Zn

B. measuring the conductivity of a Zn electrode after polishing it

C. measuring the change in mass per unit time of the Fe electrode in the same Fe–Zn galvanic cell before and after the Zn electrode was polished

D. measuring the current produced by two different Fe–Zn galvanic cells, one using a polished Zn electrode and the other using an unpolished Zn electrode

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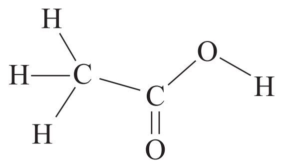
Question 11

The spectroscopy information for an organic molecule is given below.

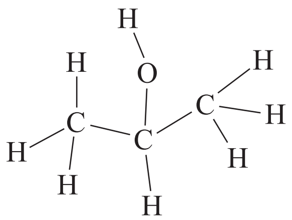
number of peaks in ^{13}C NMR	2
number of sets of peaks in ^{1}H NMR	3
m/z of the last peak in the mass spectrum	60
infra-red (IR) spectrum	an absorption peak appears at 3350 cm^{-1}

The organic molecule is

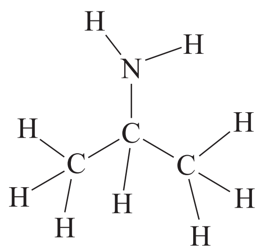
A.



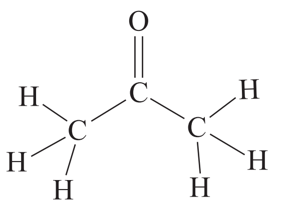
B.



C.



D.



Question 12

Butane, C_4H_{10}, undergoes complete combustion according to the following equation.

$$2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(g)$$

67.0 g of C_4H_{10} released 3330 kJ of energy during complete combustion at standard laboratory conditions (SLC). The mass of carbon dioxide, CO_2, produced was

A. 0.105 g

B. 3.18 g

C. 50.9 g

D. 204 g

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Use the following information to answer Questions 13 and 14.

The overall discharge reaction for a lead-acid battery is

$$Pb(s) + PbO_2(s) + 2H_2SO_4(aq) \rightarrow 2PbSO_4(s) + 2H_2O(l)$$

Question 13

During recharge, the reaction at the cathode is

A. $Pb(s) + SO_4^{2-}(aq) \rightarrow PbSO_4(s) + 2e^-$

B. $PbSO_4(s) + 2e^- \rightarrow Pb(s) + SO_4^{2-}(aq)$

C. $PbO_2(s) + SO_4^{2-}(aq) + 4H^+ + 2e^- \rightarrow PbSO_4(s) + 2H_2O(l)$

D. $PbSO_4(s) + 2H_2O(l) \rightarrow PbO_2(s) + SO_4^{2-}(aq) + 4H^+(aq) + 2e^-$

Question 14

When the lead-acid battery is discharging, the oxidising agent is

A. Pb

B. PbO_2

C. $PbSO_4$

D. H_2SO_4

Question 15

Which one of the following statements is correct?

A. Pentane has a higher flashpoint than octane.

B. The flashpoint of all the structural isomers of $C_4H_{10}O$ are equal.

C. The higher the flashpoint of a compound, the higher its fire risk.

D. The flashpoint of all the optical isomers of 3-methyl hexane are equal.

Question 16

Which one of the following statements about IR spectroscopy is correct?

A. IR radiation changes the spin state of electrons.

B. Bond wave number is influenced only by bond strength.

C. An IR spectrum can be used to determine the purity of a sample.

D. In an IR spectrum, high transmittance corresponds to high absorption.

Question 17

The electrolysis of water is used to produce oxygen, O_2, gas.

The O_2 gas produced is piped into a 200.0 L fixed-volume gas storage container at 22.0 °C.

When more O_2 is added, the pressure in the container increases.

What mass of O_2 needs to be added to increase the pressure by 250.0 kPa?

A. 1.53×10^{-3} g

B. 6.37×10^{-1} g

C. 6.53×10^{2} g

D. 8.75×10^{3} g

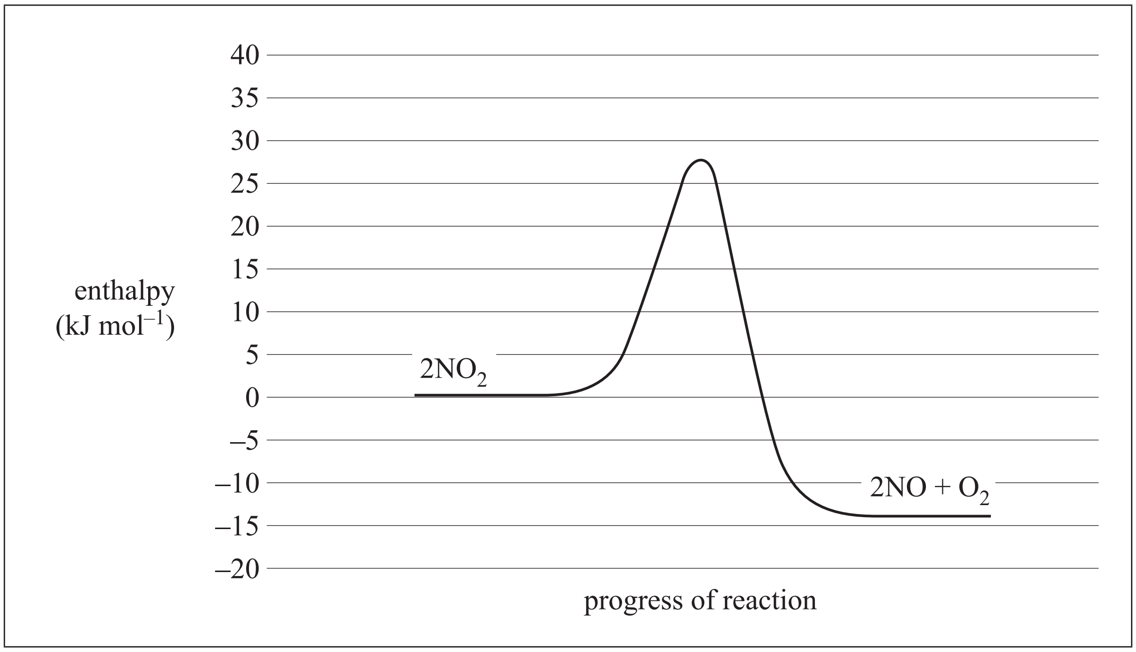
Question 18

Consider the following chemical equations.

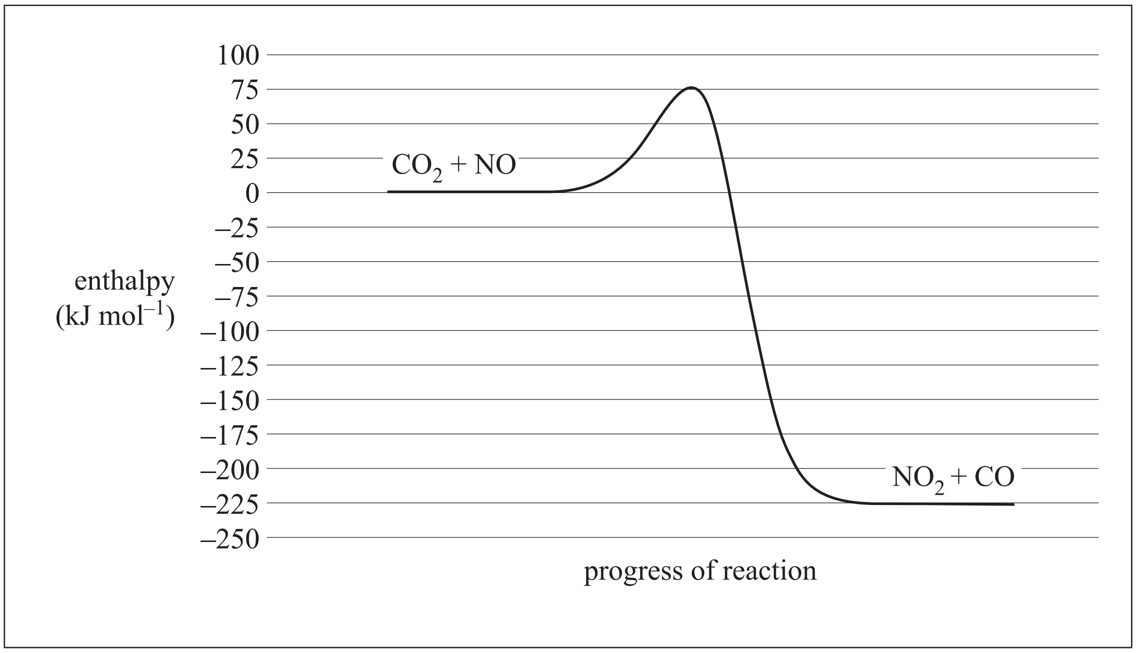
$$2NO_2(g) \rightarrow 2NO(g) + O_2(g) \qquad \Delta H = +14 \text{ kJ mol}^{-1}$$
$$NO_2(g) + CO(g) \rightarrow CO_2(g) + NO(g) \qquad \Delta H = -226 \text{ kJ mol}^{-1}$$
$$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad \Delta H = -57 \text{ kJ mol}^{-1}$$
$$N_2(g) + O_2(g) \rightleftharpoons 2NO(g) \qquad \Delta H = +181 \text{ kJ mol}^{-1}$$

Which one of the following graphs is consistent with the chemical equations above?

A.



B.



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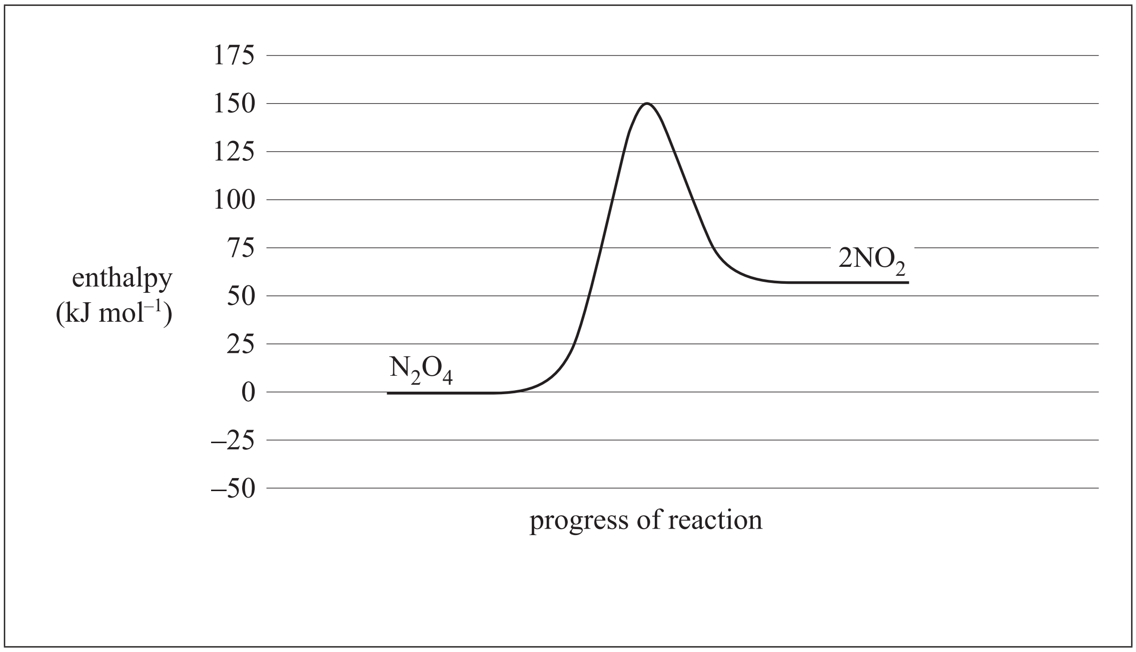
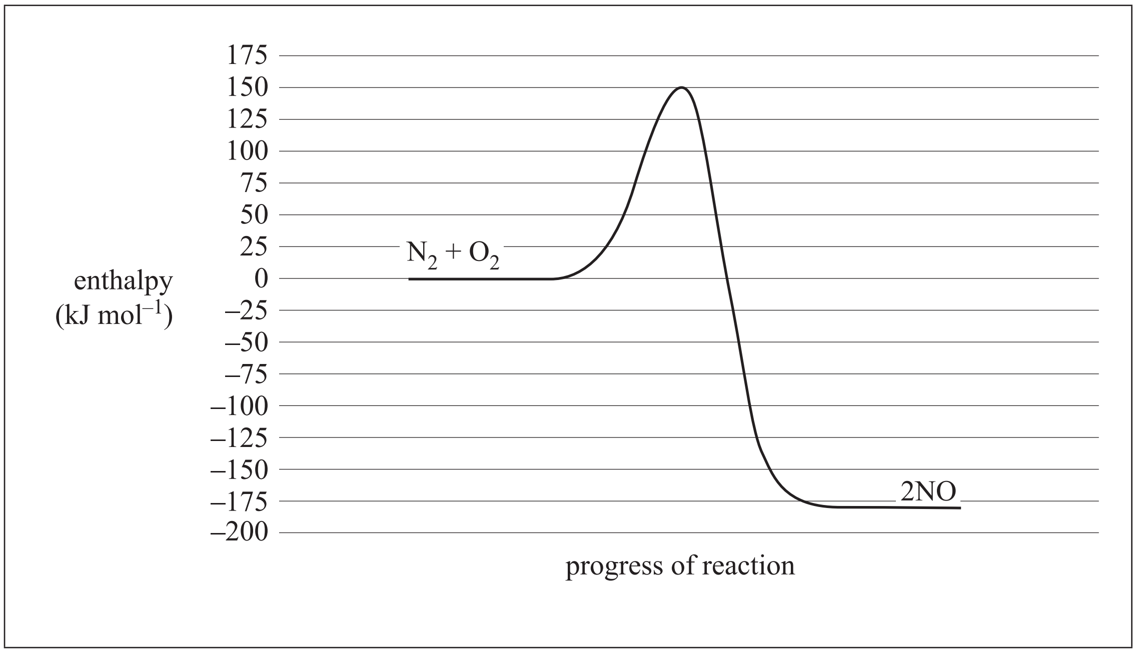
C.



D.



Question 19

A food chemist conducted an experiment in a bomb calorimeter to determine the energy content, in joules per gram, of a muesli bar. A 3.95 g sample of the muesli bar was combusted in the calorimeter and the temperature of the water rose by 16.7 °C. The calibration factor of the calorimeter was previously determined to be 4780 J $°C^{-1}$.

The energy content of the muesli bar is

A. 3.51×10^5 J g^{-1}

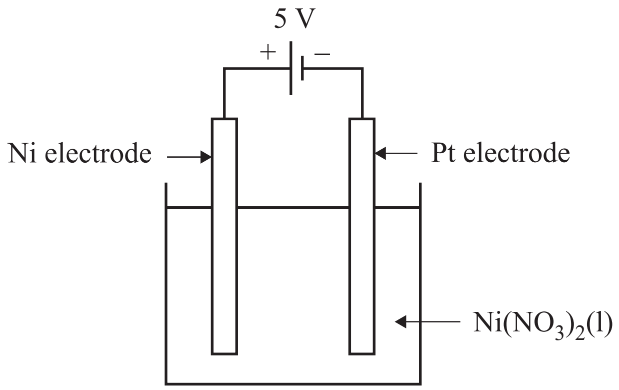
B. 2.02×10^4 J g^{-1}

C. 1.13×10^3 J g^{-1}

D. 7.25×10 J g^{-1}

Use the following information to answer Questions 20 and 21.

An electrolysis cell with a 5 V power supply is shown below.



Question 20

1 F is equivalent to the charge on 1 mol of electrons.

The mass of nickel, Ni, that can be electroplated onto the platinum, Pt, electrode with 320 F of charge is

A. 9.73×10^{-2} g

B. 1.95×10^{-1} g

C. 9.39×10^3 g

D. 1.88×10^4 g

Question 21

Using the electrochemical series, which one of the following changes to the electrolysis cell may reduce the amount of Ni electroplated onto the Pt electrode?

A. replacing the Ni electrode with a Cu electrode

B. replacing $Ni(NO_3)_2(l)$ with 1 M $Ni(NO_3)_2(aq)$

C. replacing the Pt electrode with Pb(s)

D. replacing $Ni(NO_3)_2(l)$ with $NiCl_2(l)$

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Question 22

1 L of octane has a mass of 703 g at SLC. The efficiency of the reaction when octane undergoes combustion in the petrol engine of a car is 25.0%.

What volume of octane stored in a petrol tank at SLC is required to produce 528 MJ of usable energy in a combustion engine?

A. 3.92 L

B. 11.8 L

C. 15.7 L

D. 62.7 L

Question 23

A student titrated 25 mL aliquots of three different concentrations of an organic acid against a standardised potassium hydroxide, KOH, solution. The student's results are shown in the table below.

	KOH titre for Sample 1 (mL)	**KOH titre for Sample 2 (mL)**	**KOH titre for Sample 3 (mL)**
Titration 1	20.35	19.85	21.55
Titration 2	20.45	19.65	21.45
Titration 3	20.30	20.45	21.65
Average titre	20.37	19.98	21.55

Which one of the following statements is consistent with the results shown in the table?

A. Sample 2 is the most concentrated acid.

B. Sample 3 is the most concentrated acid.

C. There is not enough information to draw a valid conclusion.

D. The averages in the table are correct as the results are concordant.

Question 24

Which one of the following statements describes the effect that adding a catalyst will have on the energy profile diagram for an exothermic reaction?

A. The energy of the products will remain the same.

B. The shape of the energy profile diagram will remain the same.

C. The peak of the energy profile will move to the left as the reaction rate increases.

D. The activation energy will be lowered by the same proportion in the forward and reverse reactions.

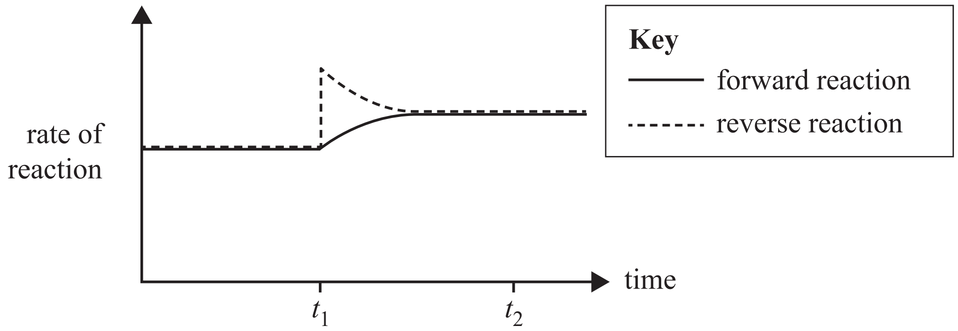
Question 25

An equilibrium mixture of four gases is represented by the following equation.

$$A(g) + 2B(g) \rightleftharpoons C(g) + D(g) \qquad \Delta H > 0$$

The graph below shows the rate of the forward and reverse reactions versus time.

A single change is made to the equilibrium mixture at time t_1 and equilibrium is re-established at time t_2.



Which one of the following is consistent with the information given above?

A. Argon is added to the equilibrium mixture at time t_1.

B. At time t_1 reactants are removed from the equilibrium mixture.

C. The amount of products is higher at time t_2 compared to just before time t_1.

D. The change made at time t_1 results in an increase in the equilibrium constant at time t_2.

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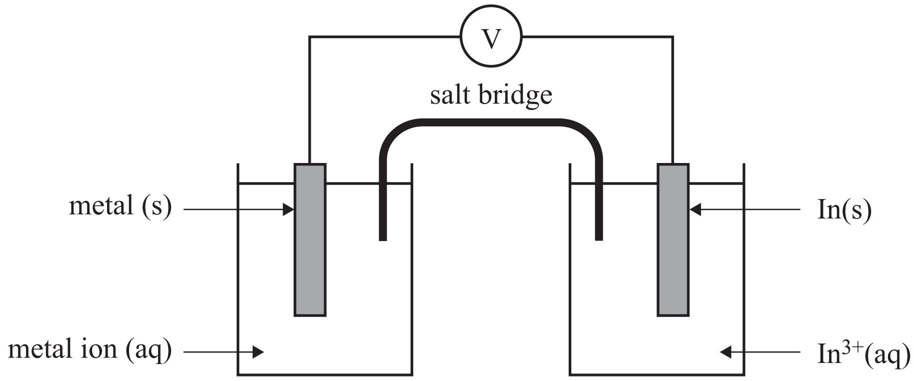
Question 26

Different metal ion (aq)/metal (s) half-cells are combined with an In^{3+}(aq)/In(s) half-cell to create a galvanic cell at SLC, as shown in the diagram below. The equation for the In^{3+}(aq)/In(s) half-cell is

$$In^{3+}(aq) + 3e^{-} \rightleftharpoons In(s) \qquad E^{0} = -0.34 \text{ V}$$



Which of the following shows the half-cells in decreasing order of voltage produced when combined with the In^{3+}(aq)/In(s) half-cell and In(s) is the negative electrode?

A. Mn^{2+}(aq)/Mn(s), Al^{3+}(aq)/Al(s), Mg^{2+}(aq)/Mg(s)

B. Mg^{2+}(aq)/Mg(s), Al^{3+}(aq)/Al(s), Mn^{2+}(aq)/Mn(s)

C. Cu^{2+}(aq)/Cu(s), Pb^{2+}(aq)/Pb(s), Ni^{2+}(aq)/Ni(s)

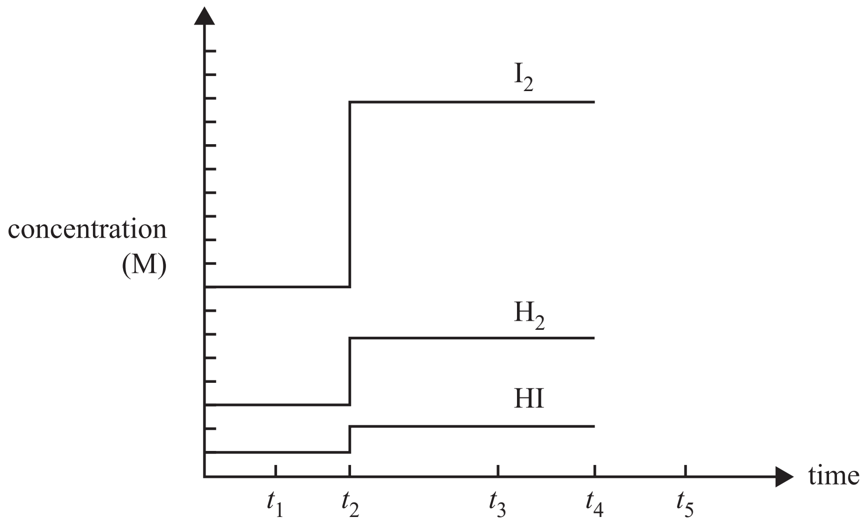
D. Ni^{2+}(aq)/Ni(s), Pb^{2+}(aq)/Pb(s), Cu^{2+}(aq)/Cu(s)

Use the following information to answer Questions 27 and 28.

Hydrogen, H_2, and iodine, I_2, react to form hydrogen iodide, HI.

$$\frac{1}{2}H_2(g) + \frac{1}{2}I_2(g) \rightleftharpoons HI(g) \qquad \Delta H = +25.9 \text{ kJ mol}^{-1}$$

The graph below shows the concentrations of H_2, I_2 and HI in a sealed container. One change was made to the equilibrium system at time t_2.



Question 27

Which one of the following statements is correct?

A. A catalyst was added at time t_2.

B. The amount of HI is greater at time t_3 compared with time t_1.

C. The rate of reaction producing HI is the same at time t_1 and time t_3.

D. The rate of production of HI at time t_3 is double the rate of production of H_2 at time t_3.

Question 28

One change was made to the equilibrium system at time t_4,which altered the equilibrium constant. Equilibrium was re-established at time t_5. The rate of the reverse reaction at time t_5 was higher than at time t_3.

Which of the following options correctly shows the change in the equilibrium system from time t_3 to time t_5?

	Change from time t_3 to time t_5	
	Equilibrium constant	**Total chemical energy**
A.	increase	increase
B.	increase	decrease
C.	decrease	increase
D.	decrease	decrease

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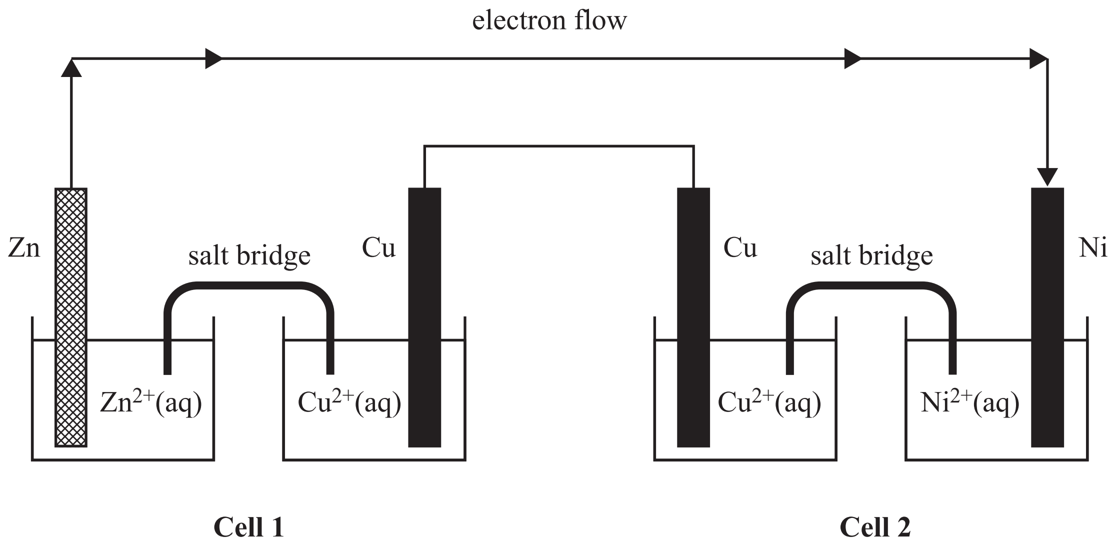
Question 29

The following diagram shows two connected electrochemical cells.



Which of the following gives the energy transformations that occur in Cell 1 and in Cell 2?

	Cell 1	Cell 2
A.	chemical → electrical	chemical → electrical
B.	electrical → chemical	chemical → electrical
C.	chemical → electrical	electrical → chemical
D.	electrical → chemical	electrical → chemical

Question 30

The ^{1}H NMR spectrum of an organic compound has three unique sets of peaks: a single peak, seven peaks (septet) and two peaks (doublet).

The compound is

A. 3-methyl butanoic acid.

B. 2-methyl propanoic acid.

C. 2-chloro-2-methylpropane.

D. 1,2-dichloro-2-methylpropane.

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 (9 marks)

Digesters use bacteria to convert organic waste into biogas, which contains mainly methane, CH_4. Biogas can be used as a source of energy.

a. Both biogas and coal seam gas contain CH_4 as their main component.

Why is biogas considered a renewable energy source but coal seam gas is not? 1 mark

b. A digester processed 1 kg of organic waste to produce 496.0 L of biogas at standard laboratory conditions (SLC). The biogas contained 60.0% CH_4.

i. Write the thermochemical equation for the complete combustion of CH_4 at SLC. 2 marks

ii. Calculate the amount of energy that could be produced by CH_4 from 1 kg of organic waste. 3 marks

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SECTION B – Question 1 – continued

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c. Biogas was combusted to release 1.63×10^3 kJ of energy. This energy was used to heat 100 kg of water in a tank. The initial temperature of the water was 25.0 °C.

i. What is the maximum temperature that the water in the tank could reach? 2 marks

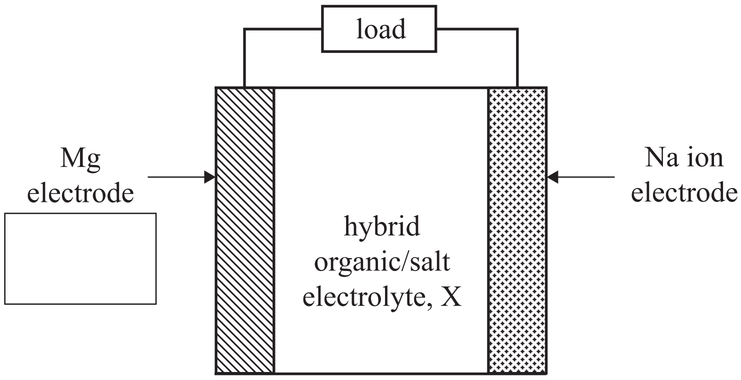
ii. State why this temperature may not be reached. 1 mark

Question 2 (7 marks)

Research scientists are developing a rechargeable magnesium–sodium, Mg–Na, hybrid cell for use in portable devices.

The Mg–Na hybrid cell uses magnesium metal and sodium ion electrodes and a hybrid organic/salt electrolyte, X.

A simplified diagram of the rechargeable Mg–Na hybrid cell is shown below.



a. The equation for the overall reaction during **recharge** is

$$2NaX + Mg^{2+} \rightarrow Mg + 2Na^{+} + 2X$$

i. Identify the polarity of the Mg electrode when the cell is discharging by placing a positive (+) or a negative (−) sign in the box provided in the diagram above. 1 mark

ii. Write the half-cell equation of the reaction that occurs at the Mg electrode when the cell is **discharging**. 1 mark

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b. A pacemaker is a small electronic device that is implanted in the body to regulate a person's heart rate.

If the Mg–Na hybrid cell were to be used to power pacemakers, what would be **two** potential safety hazards of having this cell in the body? 2 marks

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c. One source of Mg is magnesium chloride, $MgCl_2$, which can be obtained from seawater.

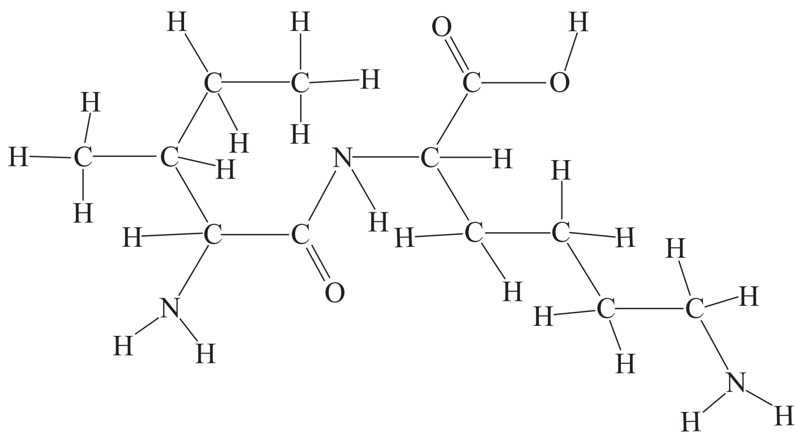
Explain how Mg can be produced from $MgCl_2$ in an electrolytic cell. 3 marks

Question 3 (12 marks)

a. All nine essential amino acids are found in quinoa.

State what is meant by an essential amino acid. 1 mark

b. Consider the dipeptide below.



i. Circle the peptide bond in the dipeptide above. 1 mark

ii. Name the amino acid with the non-polar Z group, which is involved in the formation of the dipeptide. 1 mark

c. When papaya fruit is eaten with protein in a meal, it can aid the digestion of that protein.

Explain why papaya can aid protein digestion. 2 marks

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d. Quinoa fat contains oleic acid and linoleic acid.

i. What type of omega fatty acid is linoleic acid? 1 mark

ii. Which of the two fatty acids – oleic acid or linoleic acid – would be expected to have a lower melting point? Justify your answer. 3 marks

e. Amylose and cellulose are two polysaccharides.

Identify two similarities and one difference between the structures of amylose and cellulose. 3 marks

Similarity 1

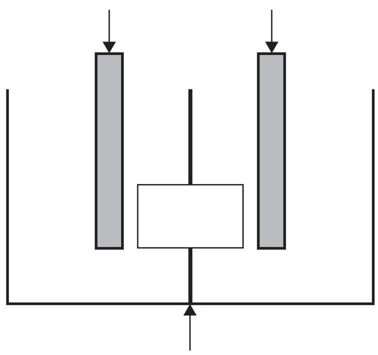
Similarity 2

Difference

Question 4 (9 marks)

a. What is a fuel cell? 2 marks

The diagram below shows part of an ethanol fuel cell, which produces carbon dioxide and uses an acidic electrolyte.



b. **i.** Name the species that crosses the membrane to enable fuel cell operation. 1 mark

ii. In the box provided on the diagram above, indicate the direction of flow of the species named in **part b.i.** 1 mark

c. Write the equation for the reaction that occurs at the anode of an ethanol fuel cell, which produces carbon dioxide and uses an acidic electrolyte. 1 mark

d. If an ethanol fuel cell was operating at 25 °C and at 100% efficiency, how much electrical energy could be produced from 1.0 g of ethanol? 1 mark

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e. Identify **two** aspects of electrode design that can improve the efficiency of a fuel cell. 2 marks

f. State how the environmental impact of using an ethanol fuel cell operating at 100% efficiency can be minimised. 1 mark

Question 5 (8 marks)

The nutritional information for one medium serving (124 g) of sweet potato is provided in the table below.

Nutrient	Per 124 g
protein	2.0 g
fat	3.0 g
carbohydrates	18.7 g
vitamin C	3.0 mg
vitamin D	less than 0.2 mg

a. Calculate the energy contained in one medium serving of sweet potato. 1 mark

b. Explain, with reference to the chemistry, how boiling sweet potato in water may affect its level of vitamin D. 3 marks

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c. The loss of vitamin C, $C_6H_8O_6$, in sweet potato after heating can be determined in a titration by reacting vitamin C with iodine, I_2, solution. The balanced titration equation is shown below.

$$C_6H_8O_6(aq) + I_2(aq) \rightarrow 2HI(aq) + C_6H_6O_6(aq)$$

A sample of sweet potato was blended with water and filtered. The filtrate was titrated against 0.0500 M of I_2(aq). The average of three concordant titres was 21.81 mL.

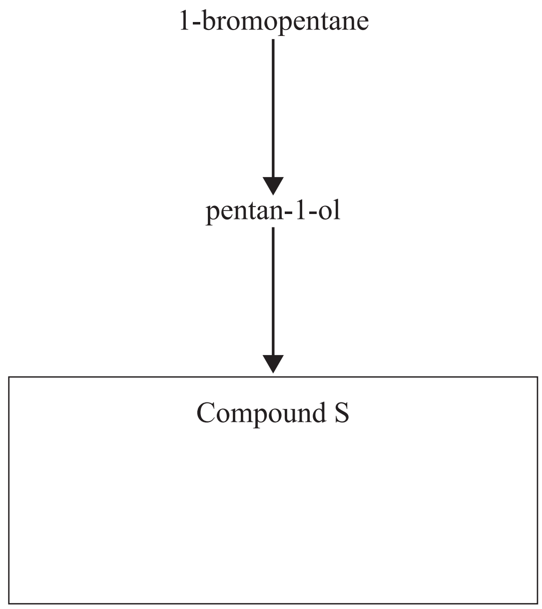
Calculate the mass of vitamin C in the sweet potato sample. 2 marks

d. Some coenzymes are derived from vitamins.

Explain the role of coenzymes in metabolic reactions. 2 marks

Question 6 (9 marks)

A reaction pathway beginning with 1-bromopentane is shown below.



a. Draw the structural formula for an isomer of 1-bromopentane that contains a chiral carbon and circle this chiral carbon. 2 marks

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b. **i.** Write a balanced equation for the reaction that will produce pentan-1-ol from 1-bromopentane and a sodium salt. 2 marks

ii. Calculate the atom economy in the production of pentan-1-ol from 1-bromopentane and a sodium salt. 3 marks

c. Pentan-1-ol is fully oxidised to Compound S.

Write the IUPAC name of Compound S in the box provided on page 26. 1 mark

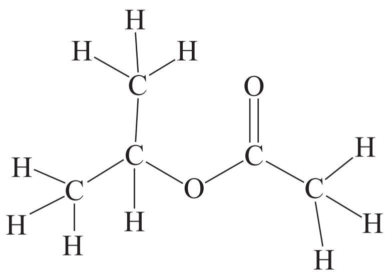
d. In an alternative reaction pathway, pentanamide can be formed from 1-bromopentane.

Draw the skeletal formula for pentanamide. 1 mark

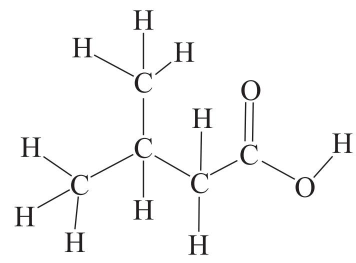
Question 7 (8 marks)

Two students are given a homework assignment that involves analysing a set of spectra and identifying an unknown compound. The unknown compound is one of the molecules shown below.

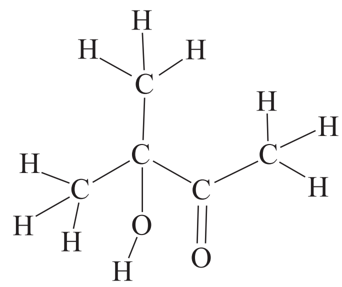
P



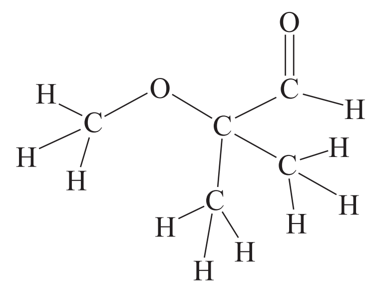
Q



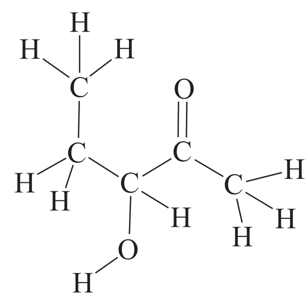
R



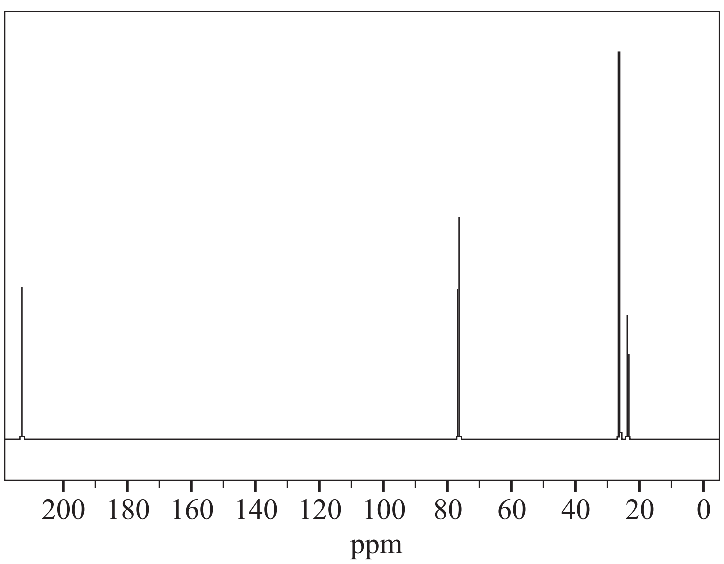
S



T



The ^{13}C NMR spectrum of the unknown compound is shown below.



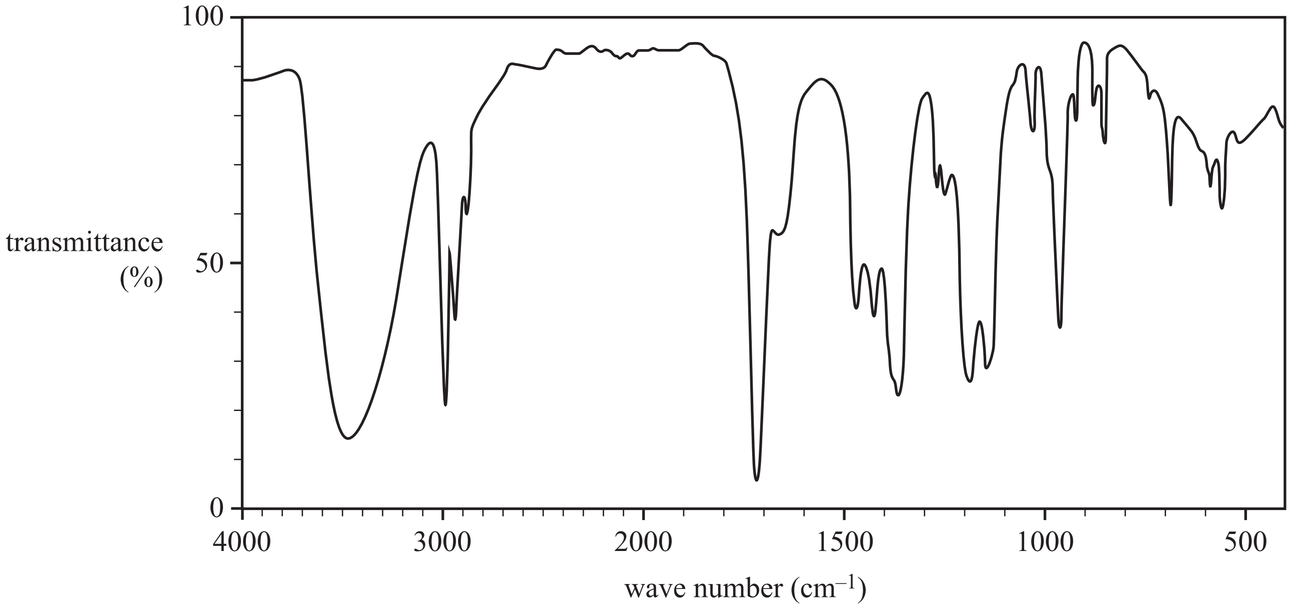
Data: SDBS Web, <https://sdbs.db.aist.go.jp>,
National Institute of Advanced Industrial Science and Technology

DO NOT WRITE IN THIS AREA

a. Based on the number of peaks in the ^{13}C NMR spectrum on page 28, which compound – P, Q, R, S or T – could be eliminated as the unknown compound? 1 mark

____

b. The infra-red (IR) spectrum of the unknown compound is shown below.



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

Identify which of the five compounds can be eliminated on the basis of the IR spectrum. Justify your answer using data from the IR spectrum. 3 marks

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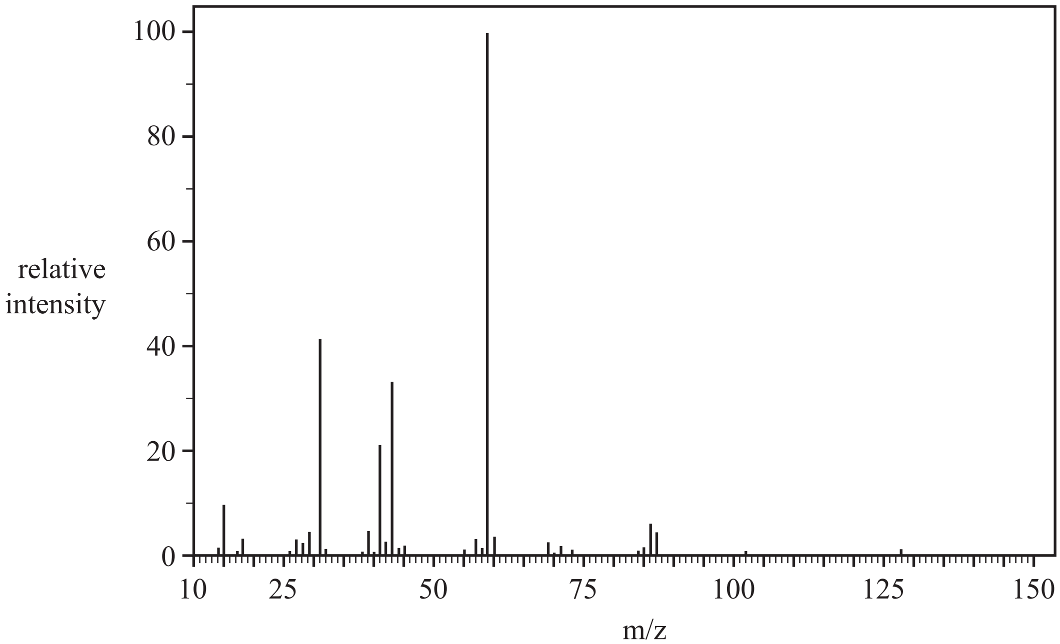
c. The mass spectrum of the unknown compound is shown below.



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

i. Write the chemical formula of the species that produces a peak at m/z = 43. 1 mark

ii. Define m/z as used in mass spectroscopy. 1 mark

iii. Explain why one molecule can produce multiple peaks on a mass spectrum. 2 marks

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Question 8 (9 marks)

The reaction for the oxidation of sulfur dioxide, SO_2, is shown below.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -197 \text{ kJ mol}^{-1}$$

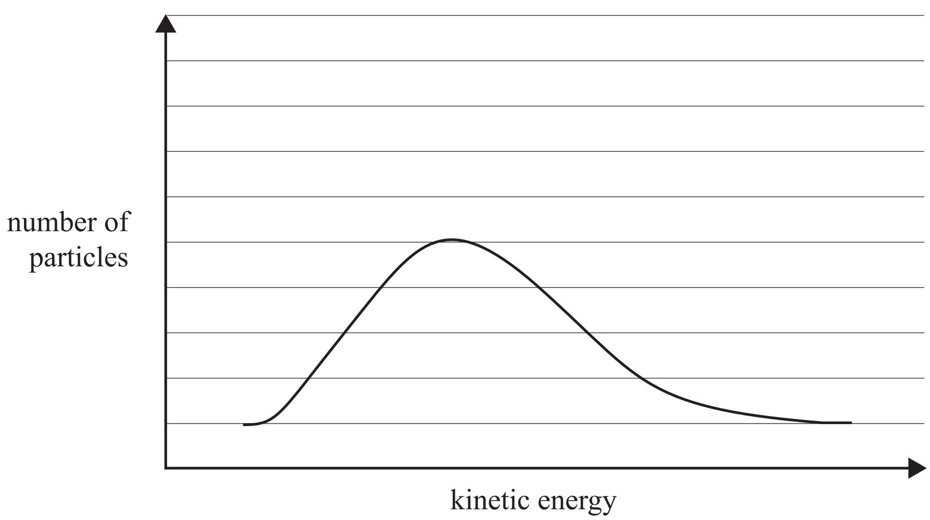
a. 1.00 mol of SO_2 and 1.00 mol of oxygen, O_2, are placed into an evacuated, sealed 3.00 L container at 100 °C. After the reaction reaches equilibrium, the container contains 20.0 g of sulfur trioxide, SO_3.

Calculate the equilibrium constant, K_c, for this reaction at 100 °C. 4 marks

b. The graph below shows the Maxwell-Boltzmann distribution curve for the SO_3 molecules in the container at a particular temperature.

On the graph, draw the Maxwell-Boltzmann distribution curve of SO_3 at a significantly lower temperature. 2 marks

Maxwell-Boltzmann distribution curve



c. The volume of the closed container is doubled.

Describe the effect that this has on the concentration of SO_2 from the time just before the volume was changed until after the system re-established its equilibrium. 3 marks

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Question 9 (11 marks)

Aspartame is an ingredient in some soft drinks. Aspartame is unstable in some conditions and reacts to form four main products. One of the products of aspartame breakdown is 5-benzyl-3,6-dioxo-2-piperazineacetic acid (DKP). It is thought that DKP may be harmful to humans.

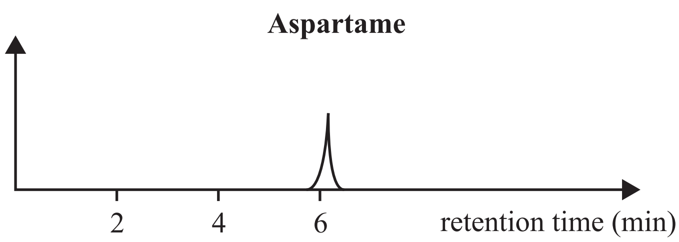
A student, Kim, investigates the effect of storage temperature on the rate of production of DKP from aspartame in lemonade. Experimental data is obtained using high-performance liquid chromatography (HPLC) to analyse the aspartame and DKP content in lemonade samples.

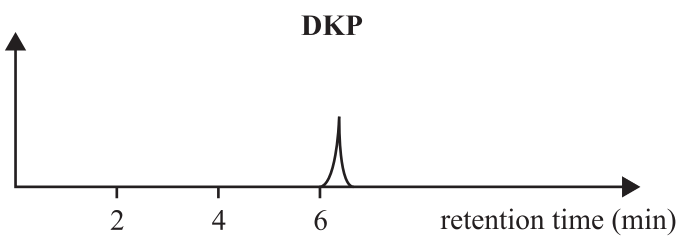
HPLC calibration

Kim first calibrated the HPLC using the following method:

1. Prepare and refrigerate a standard solution of pure aspartame with a concentration of 1000 mg L^{-1}.
2. Transfer a 10.00 mL aliquot of the pure aspartame solution into a 1.000 L volumetric flask.
3. Fill the volumetric flask up to the 1.000 L mark with deionised water and shake the flask.
4. Inject a sample of the diluted aspartame solution into the HPLC to obtain a chromatogram.
5. Repeat steps 1–4 with DKP.

The following two calibration chromatograms were obtained.



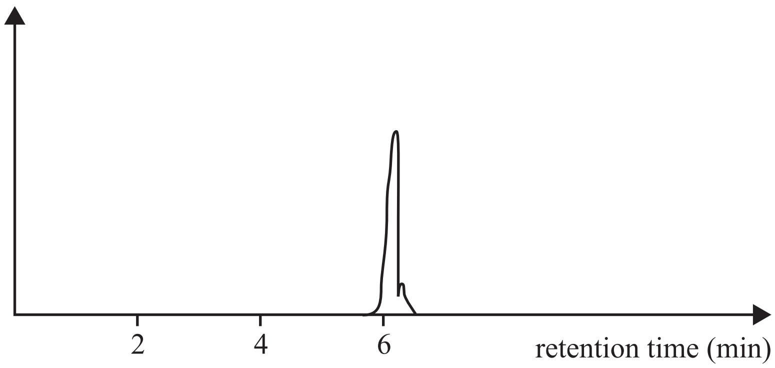


Analysis of lemonade samples

Kim then followed the method given in steps 6–14 to investigate the rate of production of DKP from aspartame in lemonade at different storage temperatures.

6. Open a can of lemonade.
7. Transfer a 10.00 mL aliquot of lemonade from the can into a 1.000 L volumetric flask.
8. Fill the volumetric flask up to the 1.000 L mark with deionised water and shake the flask.
9. Inject a sample of the diluted lemonade into the HPLC using the same operating conditions used during calibration.
10. Set up three water baths at temperatures of 15 °C, 25 °C and 35 °C.
11. Put three unopened cans of lemonade into each of the three water baths.
12. After one day, take one can from each water bath and follow steps 6–9.
13. After two days, take one can from each water bath and follow steps 6–9.
14. After three days, take one can from each water bath and follow steps 6–9.

One of the chromatograms from the diluted lemonade is given below.



a. Using your knowledge of food chemistry, explain why aspartame is sometimes added to lemonade. 2 marks

b. **i.** What is the dependent variable? 1 mark

ii. What steps, in addition to steps 1–14, need to be taken to use the HPLC data to measure the dependent variable? 3 marks

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c. **i.** State a change to the operating conditions of the HPLC that could be made to reduce the errors in measuring the concentrations of aspartame and DKP. 1 mark

ii. State how this change would reduce the measurement errors. 1 mark

Kim found that the can of lemonade tested at the beginning of the experiment contained:

- 0.00178 M aspartame
- 0.00045 M DKP.

Kim quantified the remaining data from the HPLC and prepared the following table.

Storage temperature	**Concentration after one day (M)**		**Concentration after two days (M)**		**Concentration after three days (M)**	
	Aspartame	**DKP**	**Aspartame**	**DKP**	**Aspartame**	**DKP**
15 °C	0.00179	0.00043	0.00175	0.00042	0.00176	0.00041
25 °C	0.00175	0.00044	0.00172	0.00046	0.00171	0.00063
35 °C	0.00160	0.00051	0.00155	0.00049	0.00154	0.00058

d. Write a conclusion based on the results given in the table above. 1 mark

e. **i.** Identify a variable that has not been controlled. 1 mark

ii. Explain how the variable identified in **part e.i.** affects the validity of the experiment. 1 mark

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Question 10 (8 marks)

While all experts agreed that protein needs for performance are likely greater than believed in past generations, particularly for strength training athletes, and that dietary fat could sustain an active person through lower-intensity training bouts, current research still points to carbohydrate as an indispensable energy source for high-intensity performance.

Source: M Kanter, 'High-quality carbohydrates and physical performance', *Nutrition Today*, 53(1), January 2018

a. Starch contains approximately 70% amylopectin and 30% amylose.

Use your understanding of food chemistry to discuss why eating a meal containing starch several hours prior to going on a run could benefit a runner. In your answer, refer to:

- the glycaemic indexes of amylopectin and amylose
- cellular respiration. 3 marks

Traffic is a major source of air pollution and primarily consists of gaseous emissions including nitrogen oxides (NOx) and carbon monoxide. Concentrations of traffic-related air pollution (TRAP) vary in rural and urban areas. Some busy urban traffic areas have up to three times as much TRAP as rural areas.

A Norwegian study found a statistically significant association between the level of TRAP and the incidence of respiratory symptoms in humans exposed to TRAP.

Reference: MN Hegseth, BM Oftedal, AC Höper, AL Aminoff, MR Thomassen, MV Svendsen and AK Møller Fell, 'Self-reported traffic-related air pollution and respiratory symptoms among adults in an area with modest levels of traffic', *PLoS ONE*, 14(12): e0226221, 2019

b. Tien notices that she breathes easily when running in a park away from traffic. However, when running in a particularly high-traffic area, Tien experiences shortness of breath. In this high-traffic area, the concentration of carbon monoxide, CO, is between 50 and 100 ppm, but the levels of other air pollutants are negligible. After moving away from the high-traffic area, Tien's breathing becomes easier.

Use Le Chatelier's principle to discuss the changes in Tien's breathing in the park and in the particularly high-traffic area. In your answer, refer to competing equilibria involving CO. You may use equations in your answer. 5 marks

END OF QUESTION AND ANSWER BOOK

VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education
2021

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.

Table of contents

1. Periodic table of the elements

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

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

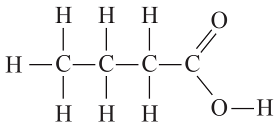
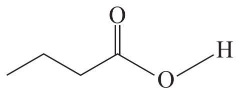
Metric (including SI) prefixes	Scientific notation	Multiplying factor
giga (G)	10^9	1 000 000 000
mega (M)	10^6	1 000 000
kilo (k)	10^3	1000
deci (d)	10^{-1}	0.1
centi (c)	10^{-2}	0.01
milli (m)	10^{-3}	0.001
micro (μ)	10^{-6}	0.000001
nano (n)	10^{-9}	0.000000001
pico (p)	10^{-12}	0.000000000001

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

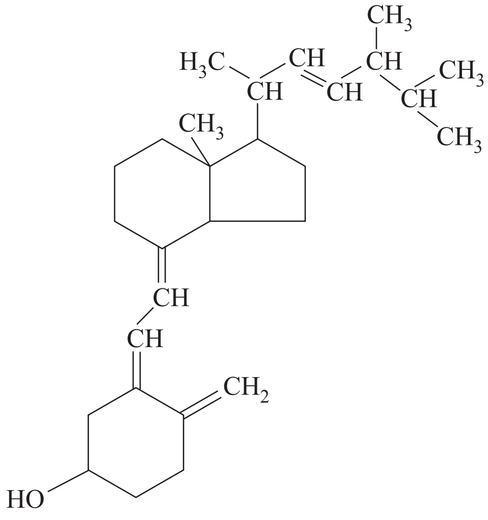
The following table shows different representations of organic molecules, using butanoic acid as an example.

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	

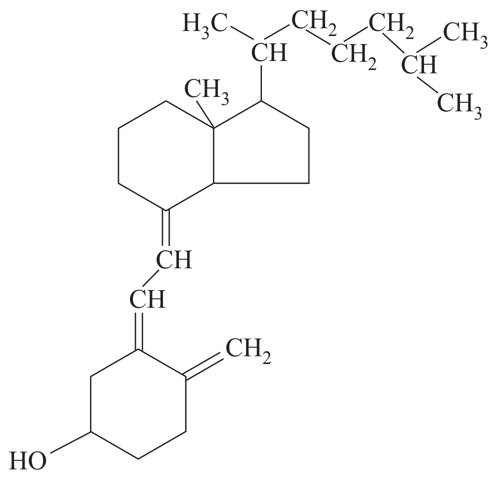
9. Formulas of some fatty acids

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	$C_{19}H_{31}COOH$	$CH_3(CH_2)_4(CH{=}CHCH_2)_3CH{=}CH(CH_2)_3COOH$

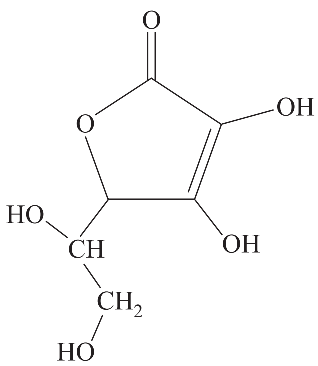
10. Formulas of some biomolecules



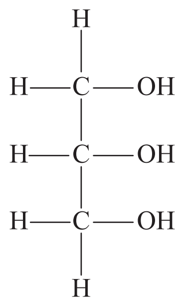
vitamin D_2 (ergocalciferol)



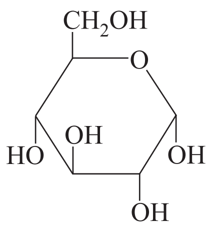
vitamin D_3 (cholecalciferol)



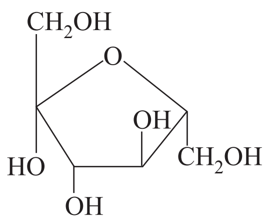
vitamin C (ascorbic acid)



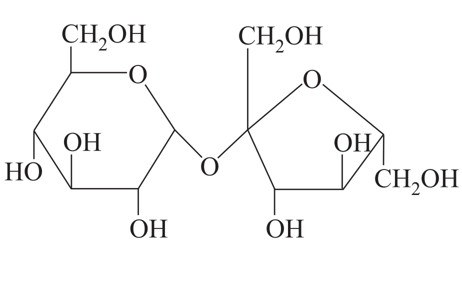
glycerol



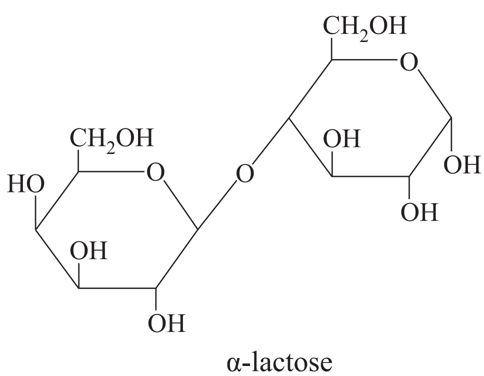
α-glucose



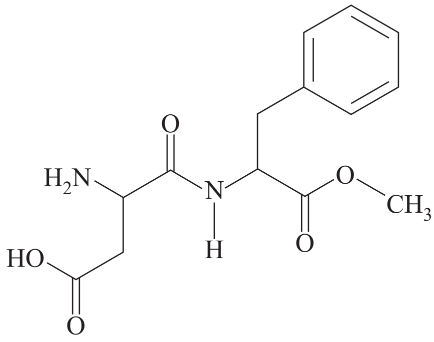
β-fructose



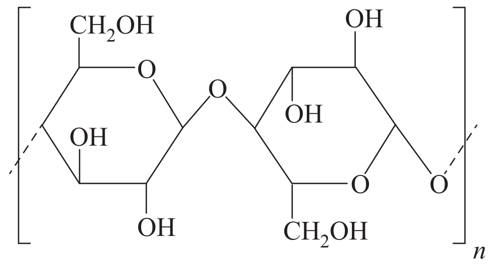
sucrose



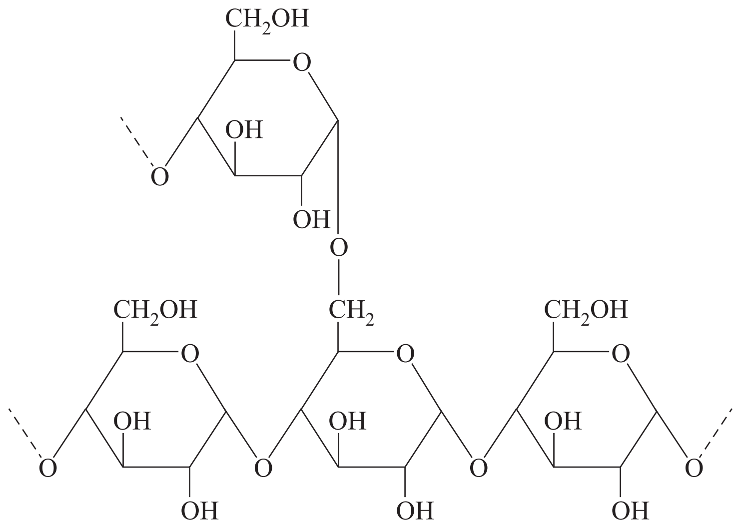
α-lactose



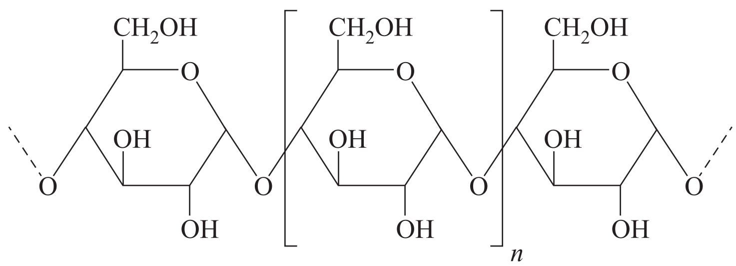
aspartame



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

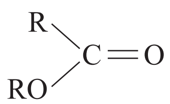
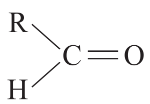
Food	Heat of combustion (kJ g^{-1})
fats and oils	37
protein	17
carbohydrate	16

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

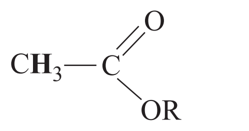
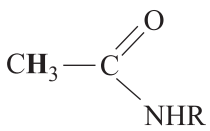
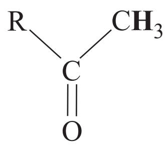
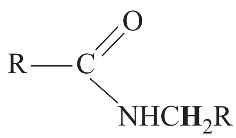
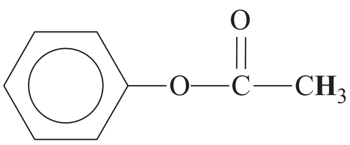
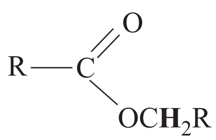
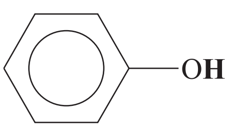
Typical ^{13}C shift values relative to TMS = 0
These can differ slightly in different solvents.

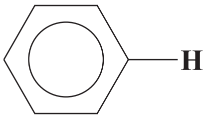
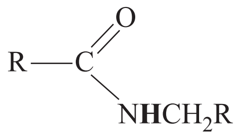
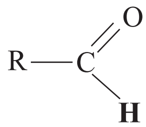
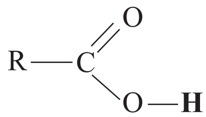
Type of carbon	Chemical shift (ppm)
$R–CH_3$	8–25
$R–CH_2–R$	20–45
$R_3–CH$	40–60
$R_4–C$	36–45
$R–CH_2–X$	15–80
$R_3C–NH_2$, $R_3C–NR$	35–70
$R–CH_2–OH$	50–90
RC≡CR	75–95
$R_2C=CR_2$	110–150
RCOOH	160–185
	165–175
	190–200
$R_2C=O$	205–220

16. ^{1}H NMR data

Typical proton shift values relative to TMS = 0

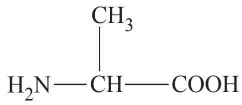
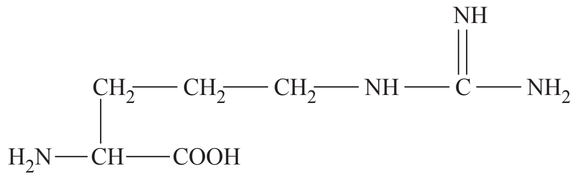
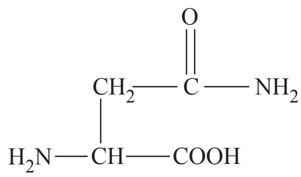
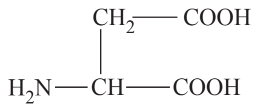
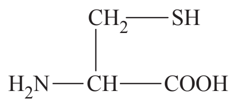
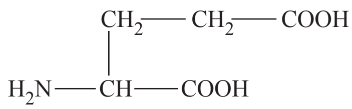
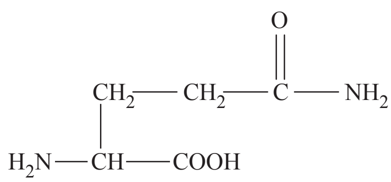
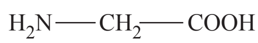
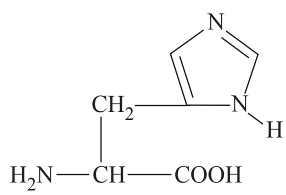
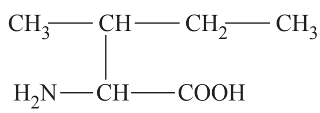
These can differ slightly in different solvents. The shift refers to the proton environment that is indicated in bold letters in the formula.

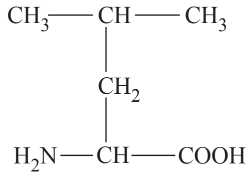
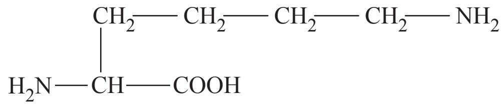
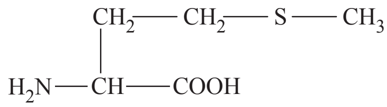
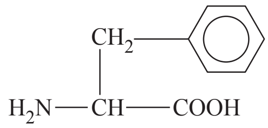
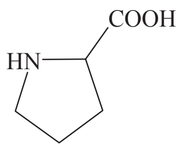
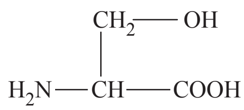
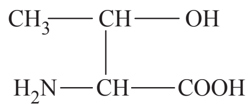
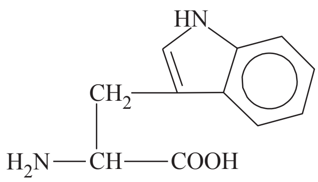
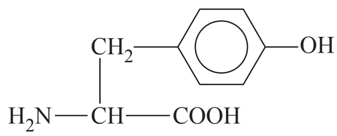
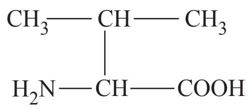
Type of proton	Chemical shift (ppm)
R–C**H**$_3$	0.9–1.0
R–C**H**$_2$–R	1.3–1.4
RCH=CH–C**H**$_3$	1.6–1.9
R$_3$–C**H**	1.5
 or 	2.0
	2.1–2.7
R–C**H**$_2$–X (X = F, Cl, Br or I)	3.0–4.5
R–C**H**$_2$–OH, R$_2$–C**H**–OH	3.3–4.5
	3.2
R—O—C**H**$_3$ or R—O—C**H**$_2$R	3.3–3.7
	2.3
	3.7–4.8
R–O–**H**	1–6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

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	

END OF DATA BOOK