VICTORIAN CURRICULUM
AND ASSESSMENT AUTHORITY

Victorian Certificate of Education
2022

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

Letter

STUDENT NUMBER ☐☐ ☐☐☐ ☐☐☐ ☐

CHEMISTRY

Written examination

Tuesday 31 May 2022

Reading time: 10.00 am to 10.15 am (15 minutes)
Writing time: 10.15 am to 12.45 pm (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

Which of the following correctly identifies the product of respiration and the small molecular product of metabolism?

	Product of respiration	**Small molecular product of metabolism**
A.	oxygen	glucose
B.	carbon dioxide	glucose
C.	oxygen	glycogen
D.	carbon dioxide	glycogen

Question 2

Pieces of polished magnesium, Mg(s), are added to 100 mL of 1.0 M hydrochloric acid, HCl(aq), and react according to the equation below.

$$Mg(s) + 2HCl(aq) \rightarrow H_2(g) + MgCl_2(aq)$$

Which one of the following is most likely to decrease the rate of the reaction?

A. Use 100 mL of 2.0 M HCl.

B. Use Mg powder instead of Mg pieces.

C. Warm the 100 mL of 1.0 M HCl before using it.

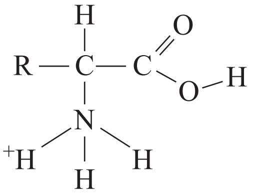
D. Use unpolished Mg pieces instead of polished Mg pieces.

Question 3

The general semi-structural formula for an amino acid is $H_2NCHRCOOH$.

When a neutral solution of an amino acid is acidified, which one of the following species will show an increase in concentration?

A.



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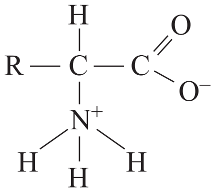

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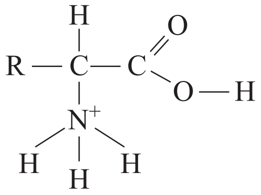

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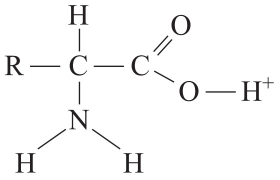


Question 4

Which one of the following statements is correct?

A. Crude oil is formed from organic matter.

B. Biodiesel has the same chemical formula as petrodiesel.

C. Ethanol can only be produced from renewable material.

D. When combusted, coal releases more energy per gram than coal seam gas.

Question 5

Commercial vegetable oils commonly contain additives to improve their chemical stability.

Which of the following combinations of additive and storage temperature will result in the least amount of rancidity in vegetable oil?

	Additive	Storage temperature (°C)
A.	oxidising agent	15
B.	reducing agent	15
C.	oxidising agent	25
D.	reducing agent	25

Question 6

The induced fit model describes

A. the denaturation process of enzymes.

B. enzyme control of specific chemical reactions.

C. enzyme processes when the active site is not modified.

D. the transfer of electrons that occurs when a reaction is catalysed.

Question 7

Hydrogen iodide, HI, can decompose to form hydrogen, H_2, and iodine, I_2. The equation for this reaction is given below.

$$2HI(g) \rightleftharpoons H_2(g) + I_2(g)$$

Which one of the following statements about collision theory is correct for this reaction?

A. The frequency of collisions is independent of the temperature.

B. The frequency of collisions depends on the orientation of the molecules.

C. The chance of a collision resulting in a reaction depends on the orientation of the molecules.

D. The chance of a collision resulting in a reaction depends only on the kinetic energy of the molecules.

Question 8

Consider the following statements about proteins:

I Hydrophilic and hydrophobic interactions are present only in the tertiary structure.

II Multiple polypeptide chains are present only in the quaternary structure.

III Polar interactions are present only in the secondary structure.

IV Peptide linkages are present only in the primary structure.

Which of the statements above are correct?

A. I and III only

B. II and IV only

C. II and III only

D. I and IV only

Question 9

A bomb calorimeter was calibrated using a constant current of 1.70 A for 10.0 minutes. The voltage was 3.85 V. The temperature increased from 19.5 °C to 20.8 °C.

The calibration factor of the bomb calorimeter was

A. 5.10×10^3 J °C^{-1}

B. 3.02×10^3 J °C^{-1}

C. 2.04×10^2 J °C^{-1}

D. 5.03×10^1 J °C^{-1}

Question 10

Two methods can be used to power a vehicle with chemical energy from bioethanol:

- Method 1 – direct combustion in a combustion engine
- Method 2 – using a fuel cell

Which one of the following is an advantage of using a bioethanol fuel cell instead of a bioethanol combustion engine?

A. Greenhouse gases are not produced in bioethanol fuel cells.

B. Bioethanol fuel cells do not require bioethanol storage facilities.

C. The thermal energy of the products is lower for a bioethanol fuel cell.

D. The amount of energy released per litre of bioethanol reacted is greater in a bioethanol fuel cell.

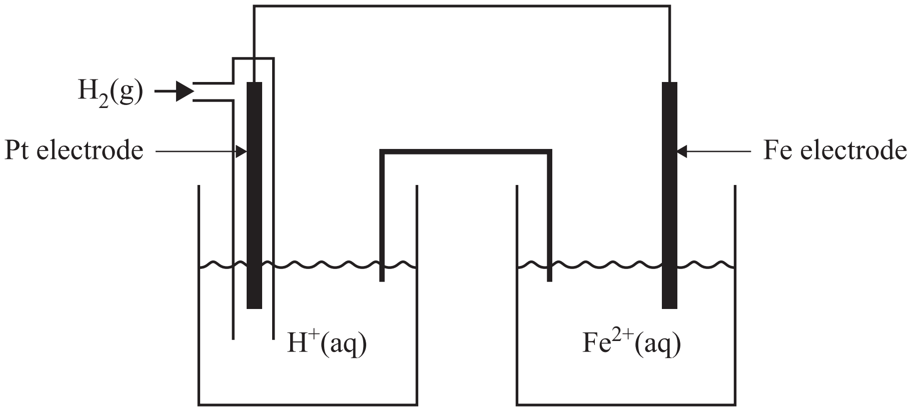
Question 11

The results of an experiment are more precise if

A. all the control variables are kept constant.
B. the experiment is repeated by another scientist.
C. the random errors in the experiment are reduced.
D. the systematic errors in the experiment are reduced.

Question 12

A diagram of a galvanic cell is shown below.

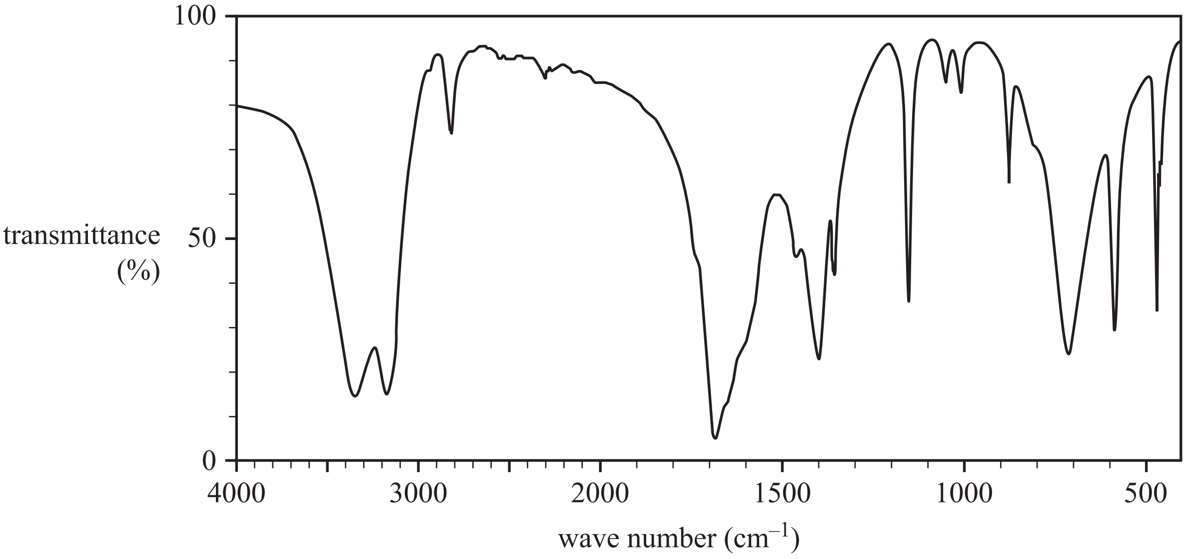


For the reaction in this galvanic cell

A. $H^+(aq)$ is the oxidising agent.
B. $H^+(aq)$ is the reducing agent.
C. $H_2(g)$ is the oxidising agent.
D. $H_2(g)$ is the reducing agent.

Question 13

The infra-red spectrum of a pure organic compound is shown below.



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

The organic compound is

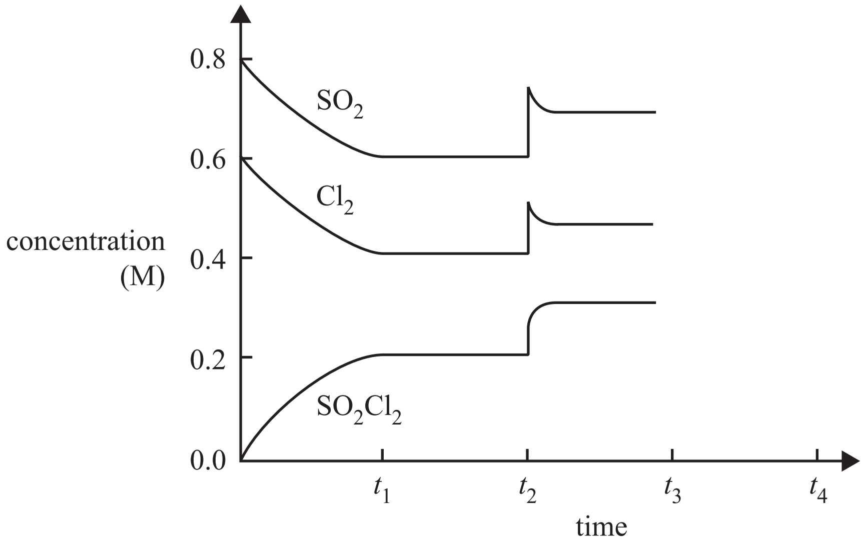
A. CH_3CONH_2
B. CH_3COOCH_3
C. $(CH_3)_2CHNH_2$
D. $HOCH_2CH_2OH$

Use the following information to answer Questions 14 and 15.

The following equation represents the reaction between sulfur dioxide gas, SO_2, and chlorine gas, Cl_2.

$$SO_2(g) + Cl_2(g) \rightleftharpoons SO_2Cl_2(g) \qquad \Delta H = -67 \text{ kJ mol}^{-1}$$

The concentration versus time graph for the reaction system is shown below.



Question 14

Which one of the following fully describes the change that took place at time t_2?

A. $SO_2(g)$ and $Cl_2(g)$ were added to the system.

B. A catalyst was added to the system.

C. Argon gas was added to the system.

D. The volume of the system was decreased.

Question 15

At time t_3 the system was in equilibrium. After time t_3 the temperature in the container was decreased and at time t_4 a new equilibrium was established.

Which of the following resulted at time t_4?

	At time t_4 the rate of the	**At time t_4 the concentration of $SO_2Cl_2(g)$ was**
A.	reverse reaction decreased compared to time t_3.	greater than at time t_3.
B.	forward reaction decreased compared to time t_3.	less than at time t_3.
C.	reverse reaction remained the same as at time t_3.	greater than at time t_3.
D.	forward reaction remained the same as at time t_3.	less than at time t_3.

Question 16

Which one of the following statements about electrolytic cells and galvanic cells is correct?

A. An electrolytic cell cannot operate if its half-cells are separated like the half-cells in a galvanic cell.

B. Oxidation occurs at the anode in a galvanic cell and at the cathode in an electrolytic cell.

C. Unlike in a galvanic cell, the weakest oxidising agent is always reduced in an electrolytic cell.

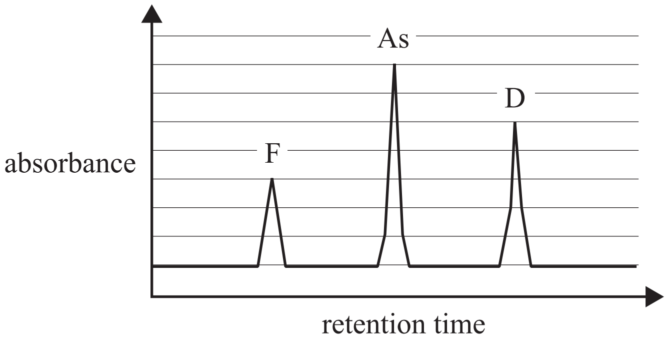
D. A rise in temperature indicates inefficiency in the transformation of energy for both galvanic cells and electrolytic cells.

Question 17

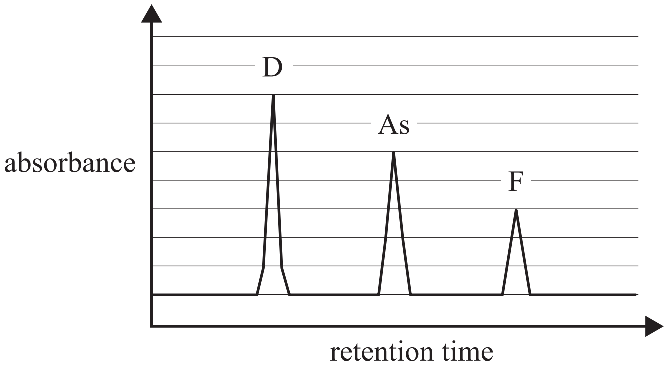
A high-performance liquid chromatography (HPLC) instrument is set up with a non-polar stationary phase and a polar mobile phase. It is used to analyse a liquid mixture containing three compounds: aspartame, fructose and vitamin D. In the diagrams below, the aspartame peak is labelled 'As', the fructose peak is labelled 'F' and the vitamin D peak is labelled 'D'.

Which one of the following best represents the chromatogram that would be produced?

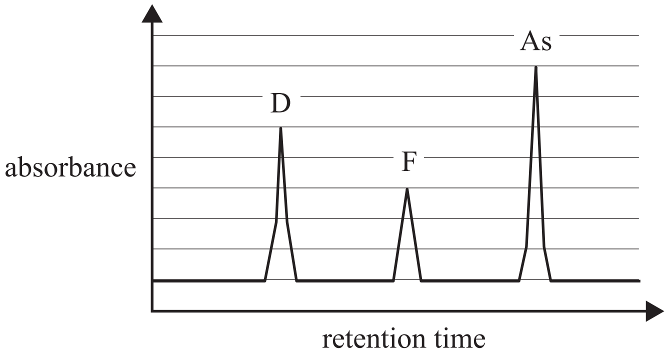
A.



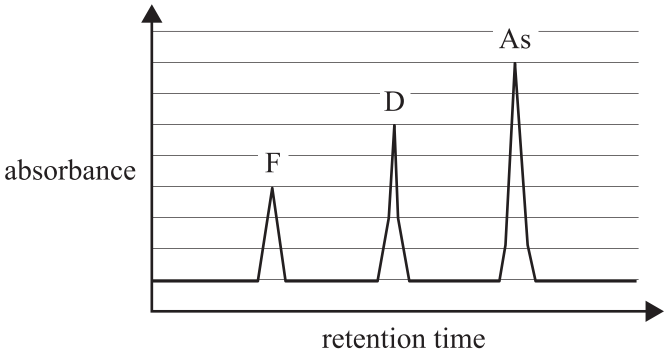
B.



C.



D.



Question 18

Which pair of reactants is sufficient to perform a redox titration?

A. $CH_3CH_2OH(l)$ and $HCl(aq)$

B. $CH_3CH_2CH_2COOH(l)$ and $NaOH(aq)$

C. $(CH_3)_3COH(l)$ and acidified $KMnO_4(aq)$

D. $CH_3CHOHCH_3(l)$ and acidified $K_2Cr_2O_7(aq)$

Question 19

Consider the following molecules:

- Q 2-chloro-2-methylpropane
- R 1-chloropentane
- S 1-chlorobutane

Which one of the following shows the molecules in order from lowest boiling point to highest boiling point?

A. R, Q, S

B. Q, S, R

C. S, Q, R

D. S, R, Q

Question 20

Consider the following statements about reactions involving enzymes:

I Coenzymes can be metallic ions.

II Coenzymes can accept electrons during a reaction.

III Coenzymes can donate groups of atoms during a reaction.

IV Coenzymes can increase the rate of reaction.

Which of the statements above are correct?

A. I and IV only

B. II and III only

C. I, III and IV only

D. II, III and IV only

Question 21

Consider an alkaline hydrogen fuel cell.

Which one of the following will reduce the amount of usable energy produced per kilogram of fuel entering the fuel cell?

A. supplying oxygen in excess

B. increasing the porosity of the cathode

C. reducing the operating temperature from 40 °C to 20 °C

D. reducing the rate at which oxide ions move through the electrolyte

Question 22

When aspartame undergoes complete hydrolysis, three molecules are produced.

All three molecules

A. can form esters.

B. have chiral centres.

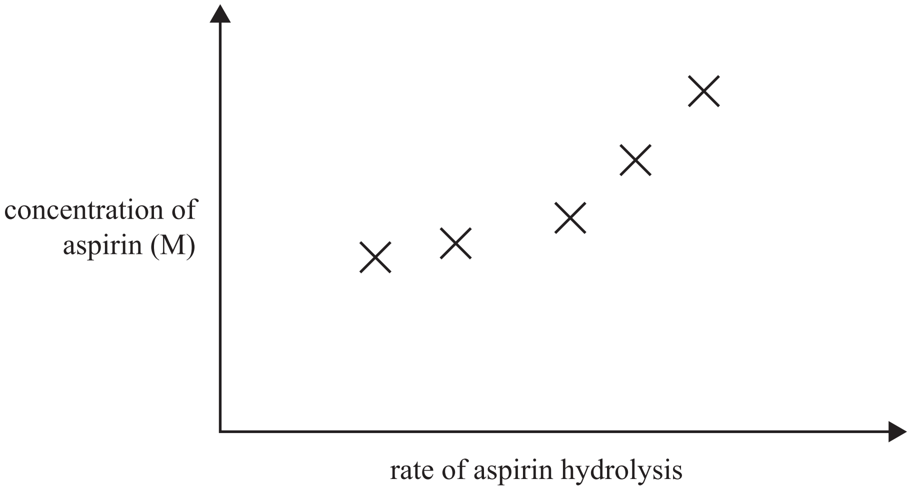
C. are insoluble in water.

D. can form positive ions in water.

Question 23

A student investigated factors affecting the reaction rate of the hydrolysis of aspirin. Aspirin was dissolved in water and the solution was placed in a water bath at 60 °C. The concentration of aspirin was monitored at regular time intervals.

The graph below was included in the results section of the student's experimental report.



Which one of the following is a valid conclusion based on the experimental results?

A. The rate of the reaction decreased over time.

B. The rate of the reaction is the independent variable.

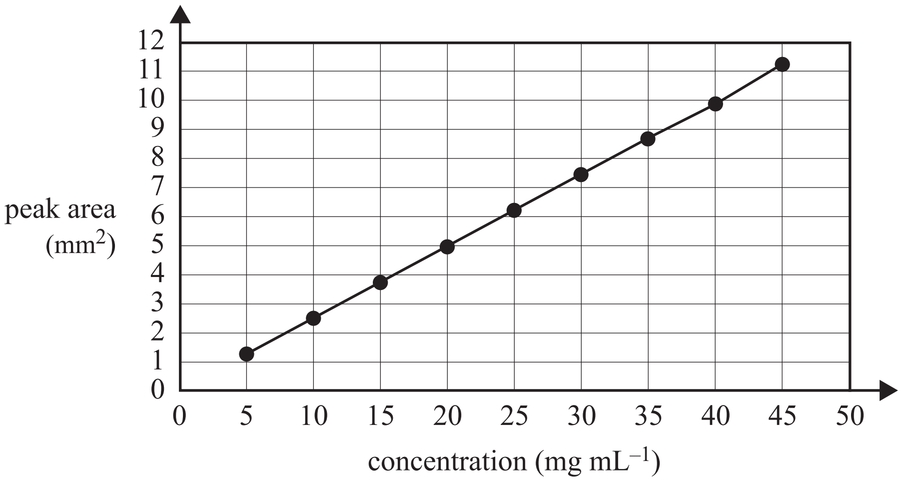
C. The rate of the reaction increased as the temperature increased.

D. The data is less accurate for the data points corresponding to lower concentrations of aspirin.

Question 24

A HPLC instrument was calibrated for sucrose. The calibration curve is shown below.

HPLC calibration curve for sucrose



20 mL of a drink containing sucrose is placed in a 100 mL volumetric flask. The volumetric flask is filled to the 100 mL mark with distilled water. A sample of the diluted solution is analysed using the calibrated HPLC.

The peak area corresponding to sucrose is found to be 6.9 mm^2. The molar mass of sucrose is 342 g mol^{-1}.

The concentration of sucrose in the drink is closest to

A. 1.375 M

B. 0.402 M

C. 0.275 M

D. 0.0804 M

Question 25

How many isomers of $C_4H_{10}O$, which belong to the alcohol family, have a chiral carbon?

A. 1

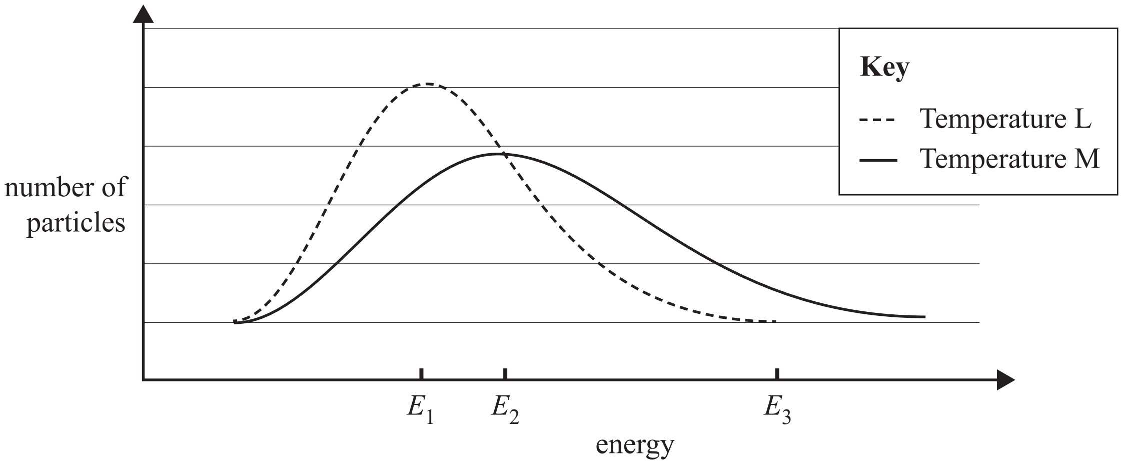
B. 2

C. 3

D. 4

Question 26

The Maxwell-Boltzmann distribution curves shown below represent the same closed reaction system at two different temperatures, Temperature L and Temperature M.



Which one of the following is information provided by the curves?

A. 50% of the particles have an energy less than E_1 at Temperature L.

B. If the activation energy is E_3, the system at Temperature L will almost fully react.

C. The higher the temperature, the greater the range of particle speeds within the system.

D. The number of particles that have an energy less than E_2 is the same at Temperature L and Temperature M.

Question 27

Consider the following statements about an unknown chemical species, X:

- A 1 M solution of X^{4+} reacts with $H_2(g)$ and X(s).
- Bubbles of gas are observed when a 1 M solution of $H^+(aq)$ is added to X(s).

What is the order of the standard half-cell potentials of each oxidising and reducing pair, from lowest to highest?

A. $X^{4+}|X^{2+} < H^+|H_2 < X^{2+}|X$

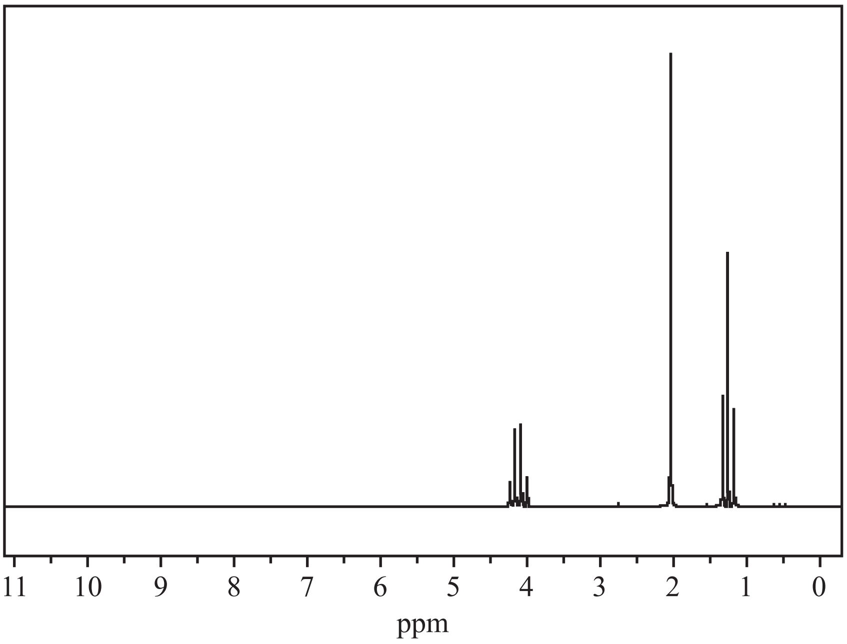
B. $H^+|H_2 < X^{4+}|X^{2+} < X^{2+}|X$

C. $H^+|H_2 < X^{2+}|X < X^{4+}|X^{2+}$

D. $X^{2+}|X < H^+|H_2 < X^{4+}|X^{2+}$

Question 28

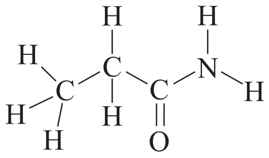
The ^{1}H NMR spectrum of an organic molecule is shown below.



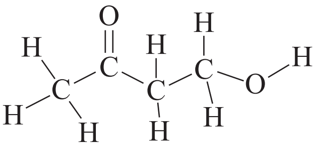
Data: SDBS Web, <https://sdbs.db.aist.go.jp>,
National Institute of Advanced Industrial Science and Technology

Which one of the following is the organic molecule?

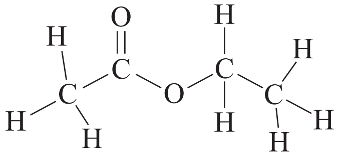
A.



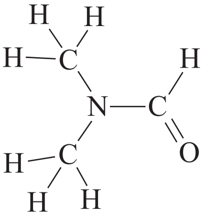
B.



C.



D.



Question 29

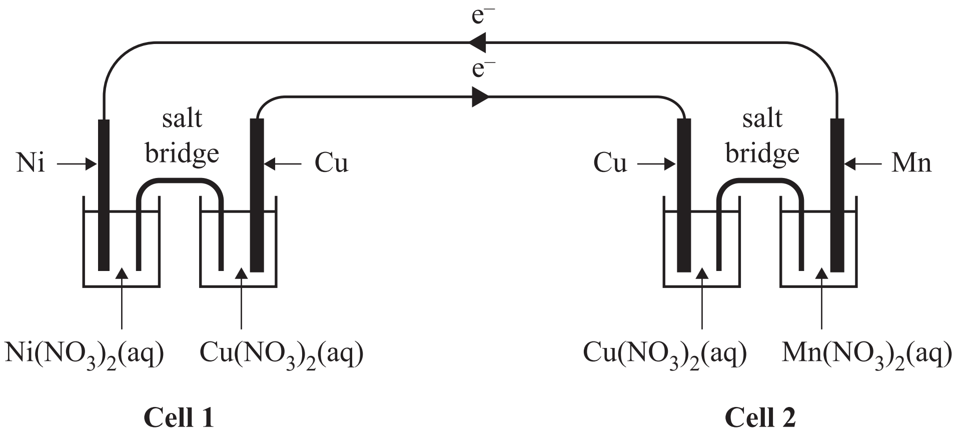
Fluorine can be produced commercially by the electrolysis of a mixture of potassium hydrogen difluoride, KHF_2, and hydrogen fluoride, HF. HF is a molecular gas at standard laboratory conditions (SLC).

Which of the following about the electrolysis of HF to produce fluorine is correct?

	Molten HF is not used in electrolysis to produce fluorine because	**Aqueous HF is not used in electrolysis to produce fluorine because**
A.	HF is a molecule.	oxygen would be produced.
B.	HF is a molecule.	hydrogen would be produced.
C.	the melting temperature of HF is too high.	oxygen would be produced.
D.	the melting temperature of HF is too high.	hydrogen would be produced.

Question 30

The diagram below shows two electrochemical cells connected together under standard conditions. The colour of the copper(II) nitrate, $Cu(NO_3)_2(aq)$, solution in each cell is blue at the beginning of the experiment.



Which one of the following is correct?

- **A.** The colour of the $Cu(NO_3)_2$ solution deepens in Cell 1.
- **B.** Electrical energy is converted to chemical energy in Cell 2.
- **C.** Copper is produced at the negative electrode in Cell 2.
- **D.** The mass of metal deposited at the cathode is identical in each cell.

END OF SECTION A

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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)

The table below shows nutritional information for the edible flesh of an avocado.

Nutrient	**Amount per 100 g of edible flesh of an avocado**
total carbohydrates, including: *total digestible carbohydrates (including 0.5 g sugar)*	8.5 g *1.8 g*
protein	2.0 g
water	73.2 g
fats	14.7 g

a. Avocados contain condensation polymers of monosaccharides.

i. Name **one** condensation polymer of monosaccharides that humans cannot metabolise. 1 mark

ii. Name the link formed when monosaccharides polymerise. 1 mark

b. Half of an average avocado weighs approximately 100 g.

Calculate the energy released when 100 g of avocado is digested. 2 marks

SECTION B – Question 1 – continued

c. Avocados contain 10 mg of vitamin C per 100 g of edible flesh.

State whether vitamin C is fat-soluble or water-soluble. Justify your answer with reference to the structure of vitamin C. 2 marks

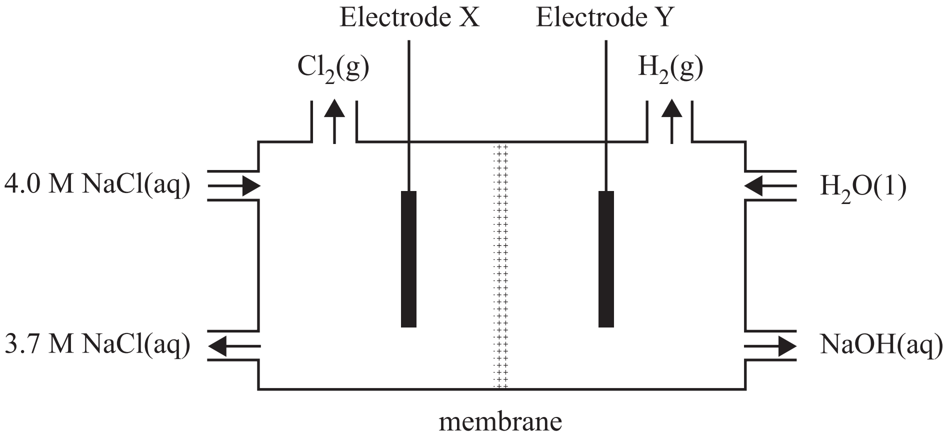
d. The glycaemic index (GI) of avocados is in the low category (less than 55).

i. What is GI a measure of? 1 mark

ii. Use the nutritional information given in the table on page 16 and your knowledge of metabolism to explain why avocados have a low GI. 2 marks

Question 2 (8 marks)

Chlorine gas, Cl_2, can be produced from the electrolysis of 4.0 M sodium chloride, NaCl(aq). The diagram below shows a simplified model of the electrolysis cell for this process.



a. **i.** Which electrode – X or Y – is the anode when the electrolysis cell is operating? 1 mark

ii. Name or write the formula for the ion that passes through the membrane between the half-cells to allow the electrolysis cell to operate. 1 mark

b. **i.** Write the half-equation for the production of $Cl_2(g)$. 1 mark

ii. With reference to the electrochemical series, explain why $Cl_2(g)$ is produced instead of $O_2(g)$. 2 marks

iii. Calculate the mass of $Cl_2(g)$ that would be produced from 1.80×10^6 coulombs of charge. Assume that $Cl_2(g)$ is the only product at Electrode X. 3 marks

Question 3 (8 marks)

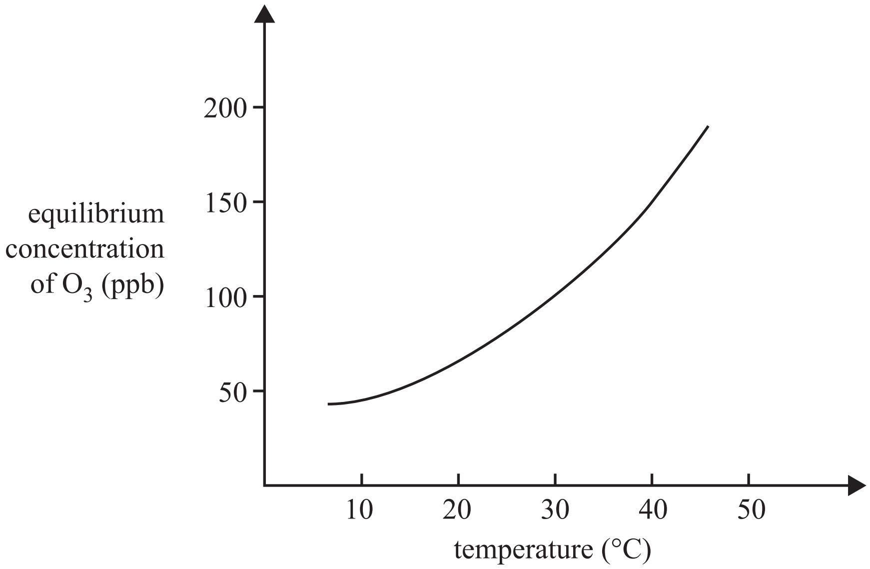
In the upper atmosphere, ozone, $O_3(g)$, is formed from oxygen, $O_2(g)$, in the presence of ultraviolet (UV) light.

An equation that represents this chemical reaction is given below.

$$3O_2(g) \overset{\text{UV light}}{\rightleftharpoons} 2O_3(g)$$

Graph 1 shows the effect of temperature on the equilibrium concentration of $O_3(g)$ in a sealed container containing only $O_2(g)$ and $O_3(g)$. The container is clear and exposed to UV light.

Graph 1



a. **i.** With reference to Graph 1, state whether the forward reaction is endothermic or exothermic. 1 mark

____

ii. Explain your answer to **part a.i.** 2 marks

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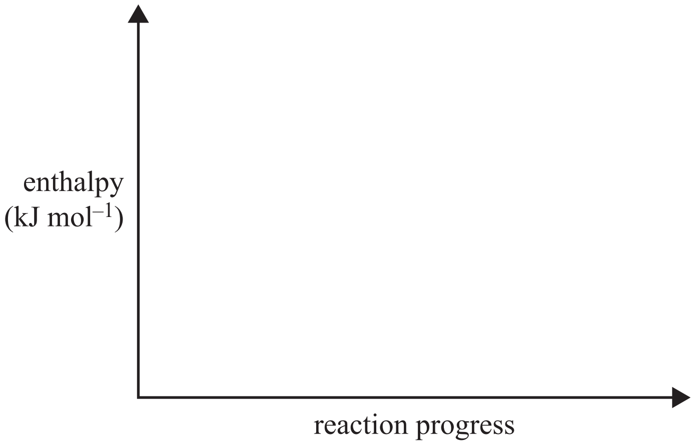
iii. Decomposition of O_3 to produce O_2 is the reverse reaction.

Sketch the energy profile for the decomposition of O_3 on the axes provided in Graph 2. 1 mark

Graph 2 – Energy profile



b. 7.50×10^{-2} mol of O_2 was placed in an evacuated and sealed 3.00 L container at 30 °C. This clear container was exposed to UV light. At equilibrium, 1.56×10^{-7} mol of O_3 had formed in the container.

Calculate the equilibrium constant at 30 °C. 4 marks

Question 4 (9 marks)

Ethyne, C_2H_2, is a chemical compound that can be used as a fuel.

a. Write the balanced thermochemical equation for the complete combustion of C_2H_2. 2 marks

b. How many moles of carbon dioxide, CO_2, are produced when 200.0 L of C_2H_2 is completely combusted at standard laboratory conditions (SLC)? 2 marks

c. What mass of C_2H_2, in kilograms, will produce 25 MJ of energy when completely combusted at SLC? 2 marks

d. 112.5 kJ of energy is absorbed by 500.0 mL of water when an amount of C_2H_2 is combusted. The water was initially at SLC.

What is the temperature of the water after the combustion energy is absorbed? 3 marks

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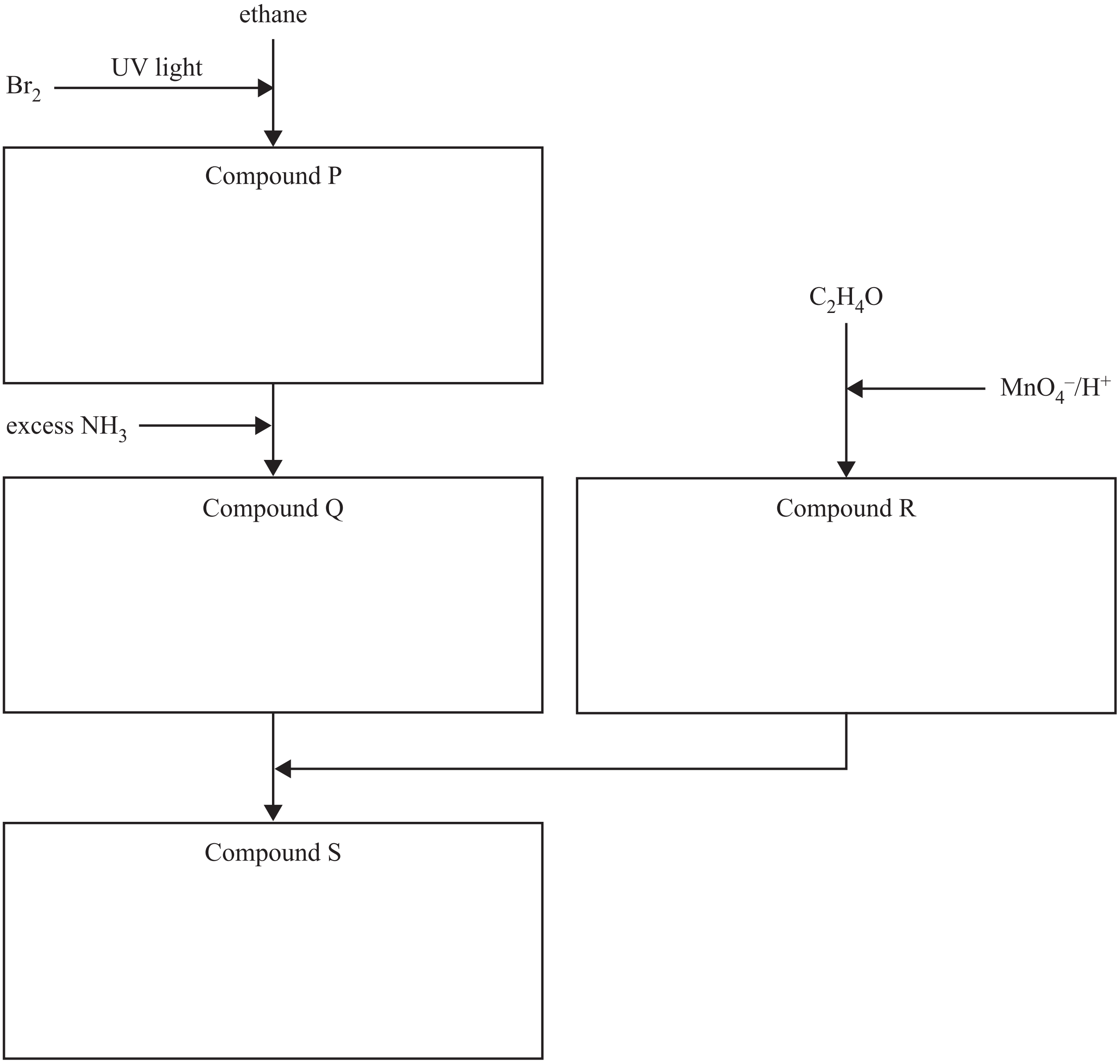
Question 5 (11 marks)

The diagram below shows a reaction pathway starting with ethane and C_2H_4O.



a. Compound P has one single functional group.

i. Give the IUPAC name of Compound P in the box provided on page 24. 1 mark

ii. Calculate the percentage atom economy of the reaction to produce Compound P from ethane. 3 marks

iii. Name the type of reaction that produces Compound Q from Compound P. 1 mark

iv. Write the semi-structural formula of Compound Q in the box provided on page 24. 1 mark

b. When C_2H_4O is mixed with potassium permanganate, $KMnO_4$, and sulfuric acid, H_2SO_4, a carboxylic acid, Compound R, is produced.

i. What is the function of the H_2SO_4 in the reaction? 1 mark

ii. State the IUPAC name of Compound R. 1 mark

iii. Draw the skeletal formula of Compound R in the box provided on page 24. 1 mark

c. Compound Q reacts with Compound R in a condensation reaction to produce Compound S.

Draw the structural formula for Compound S in the box provided on page 24. 2 marks

Question 6 (8 marks)

The typical composition of cow's milk is shown in the table below.

Component	**Percentage (%)**
water	87.8
lactose	4.9
fat	3.5
protein	3.1

Data: CW Bamforth and DJ Cook, *Food, Fermentation, and Micro-organisms*, 2nd edition, John Wiley & Sons Ltd, Hoboken (NJ), 2019, p. 175

a. The fat in cow's milk contains small quantities of omega-6 fatty acids.

Give **one** example of an omega-6 fatty acid. 1 mark

b. Oleic acid is found in the fat in cow's milk.

Write the equation for the hydrolysis of the triglyceride containing only oleic acid. 2 marks

The protein in cow's milk is approximately 80% casein and 20% whey. Casein and whey are two different families of protein.

c. Whey proteins contain all nine essential amino acids.

State what is meant by the term 'essential amino acid'. 1 mark

Whey proteins are soluble in cow's milk. Casein proteins are insoluble in cow's milk. Casein molecules are evenly dispersed throughout the milk because they are folded. The amino acids – glutamic acid and aspartic acid – are at the surface of the folded molecules. This structure allows casein proteins to be held in the milk as a suspension.

If an acid is added to the milk, the milk curdles, separating into a yellow liquid and white, solid curd. Whey proteins remain in solution and casein proteins are contained in the curd.

d. Explain why some people who have difficulty metabolising the carbohydrates in milk find it easier to metabolise curd. 2 marks

e. With reference to the surface structure of casein proteins, explain why casein separates from the liquid to form a solid curd if an acid is added to milk. 2 marks

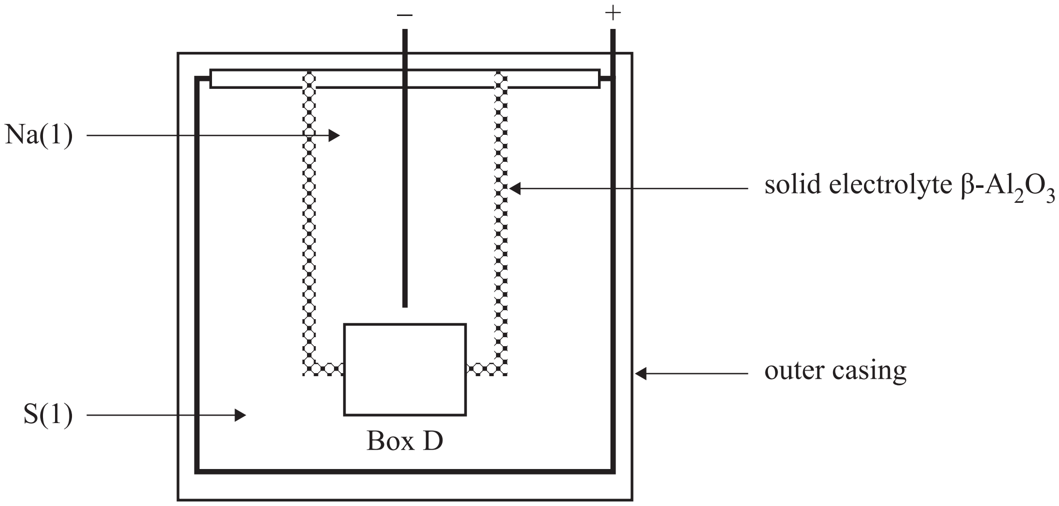
Question 7 (10 marks)

Researchers are developing rechargeable cells containing sodium, Na, and sulfur, S.

A simplified diagram of a fully charged Na–S cell is shown below.

The solid electrolyte consists of ceramic beta-alumina, β-Al_2O_3. β-Al_2O_3 separates the two half-cells and selectively conducts sodium ions, Na^+.

Fully charged Na–S cell



a. **i.** Draw an arrow in Box D to show the direction of flow of Na^+ across the membrane when the cell is charging. 1 mark

ii. Identify and explain **one** of the features of the Na–S cell that would make it suitable to power electric vehicles. 2 marks

SECTION B – Question 7 – continued

b. Environmental conditions can influence reactions during the discharge of the battery. When a particular Na–S test cell is discharging, the half-equation for the reaction at one of the electrodes is

$$3S + 2e^- \rightarrow S_3^{2-}$$

i. Write the half-equation that occurs for the reaction at the other electrode. 1 mark

ii. When the Na–S test cell is discharging, solid sodium trisulfide, Na_2S_3, is formed.

Write the overall equation for the charging process in this cell. 1 mark

iii. Identify and explain **one** factor that may affect the useful life of the Na–S test cell. 2 marks

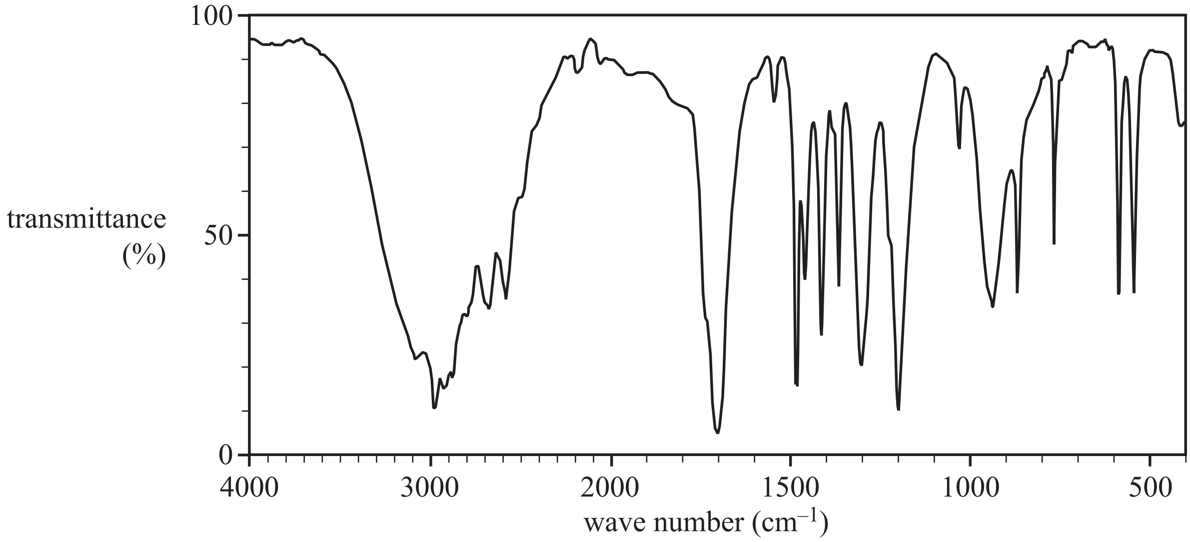
c. The Na–S cell contains pure Na metal. Safety information for an Na–S cell includes the requirement that the system must be protected from water.

Explain why this would be one of the safety requirements. Include any relevant equations in your answer. 3 marks

Question 8 (9 marks)

A researcher is analysing an unknown, non-cyclic molecule. The molecule contains five carbon atoms as well as oxygen and hydrogen atoms.

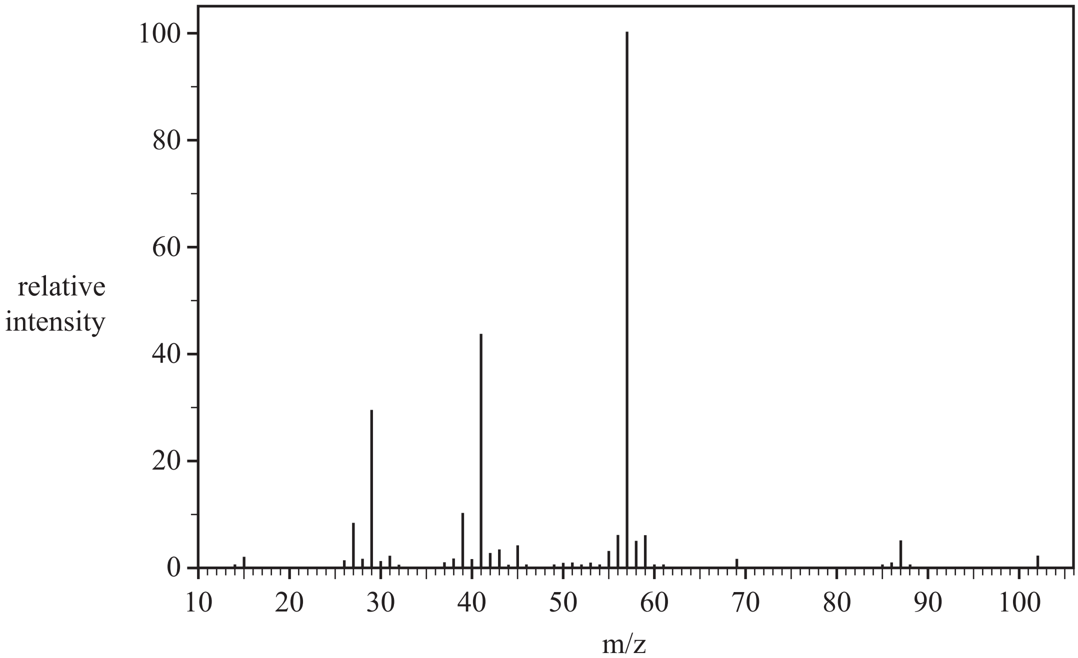
The infra-red (IR) spectrum of the unknown molecule is shown below.



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

a. Circle **one** peak in the IR spectrum and state the bond responsible for this peak. 1 mark

b. The mass spectrum of the unknown molecule is shown below. The molecular ion peak is at 102 m/z on the spectrum.



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

i. What is the molecular formula of the unknown molecule that is consistent with all the information provided on page 30? 1 mark

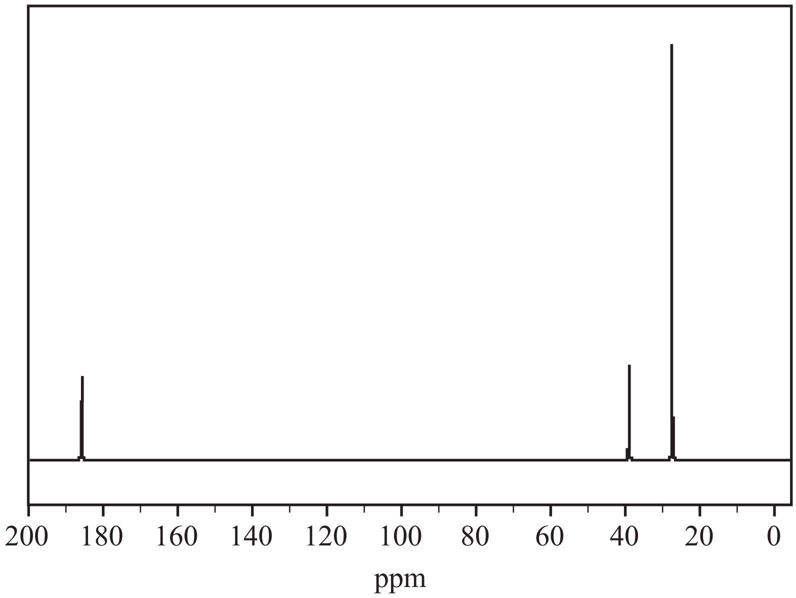
____

ii. Identify both the m/z value of the base peak of the spectrum and the fragment of the unknown molecule that can produce this base peak. 2 marks

____

____

c. The ^{13}C NMR spectrum of the unknown molecule contains three peaks. The spectrum is shown below.



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

What does the number of peaks in the ^{13}C NMR spectrum indicate about the structure of the unknown molecule? 1 mark

____

____

d. The chemical shifts of the two peaks in the ^{1}H NMR spectrum of the unknown molecule are shown below.

^{1}H NMR chemical shift (ppm)
1.233
11.49

Identify the hydrogen environments in the unknown molecule. 2 marks

____

____

e. Draw the complete structural formula for the unknown molecule. 2 marks

CONTINUES OVER PAGE

Question 9 (10 marks)

Soybean biodiesel is biodiesel that is produced from soybeans.

Two students developed a method to investigate the effect of temperature on the viscosity of soybean biodiesel and petrodiesel. The students' method is given below.

Aim

To determine how temperature affects the viscosity of soybean biodiesel and petrodiesel

Method

1. Set up four water baths at temperatures of 10 °C, 20 °C, 30 °C and 40 °C.
2. Label four 250 mL beakers with 'soybean biodiesel'. Add about 120 mL of soybean biodiesel to each beaker and then place one beaker into each of the four water baths.
3. Label four 250 mL beakers with 'petrodiesel'. Add about 120 mL of petrodiesel to each beaker and then place one beaker into each of the four water baths.
4. Use a 100 mL measuring cylinder to collect approximately 50 mL of soybean biodiesel from the 10 °C water bath.
5. Close the burette tap and fill the burette with the soybean biodiesel. Record the initial volume of soybean biodiesel.
6. Open the burette tap and use a stopwatch to measure the time it takes to deliver 20.00 mL of soybean biodiesel from the burette.
7. Repeat step 6 to obtain two more measurements at the same temperature. (Refill the burette with soybean biodiesel as necessary.)
8. Repeat steps 4 to 7 with the soybean biodiesel from the 20 °C, 30 °C and 40 °C water baths.
9. Repeat steps 4 to 7 with petrodiesel from the 10 °C, 20 °C, 30 °C and 40 °C water baths.

a. How should the students safely dispose of the waste petrodiesel? 1 mark

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

c. **i.** State a variable that has not been controlled in the method used by the students. 1 mark

ii. Explain the impact that the variable in **part c.i.** has on the dependent variable. 2 marks

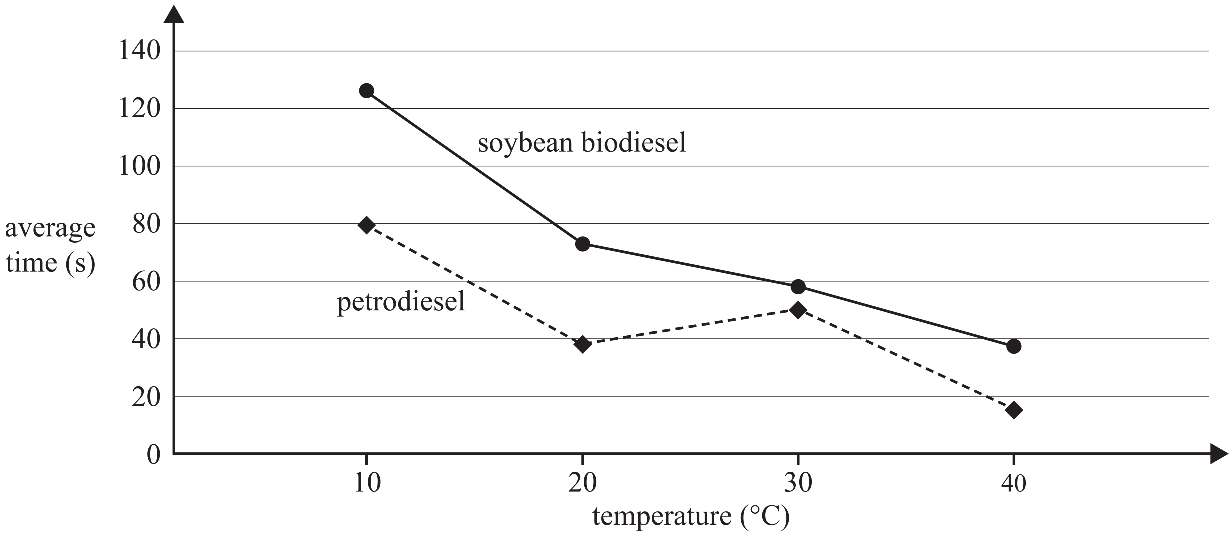
d. The two students performed the investigation independently. Some of the data collected by the first student is given in the table below.

Temperature (°C)	**Time (s)**					
	Trial 1		**Trial 2**		**Trial 3**	
	soybean biodiesel	petrodiesel	soybean biodiesel	petrodiesel	soybean biodiesel	petrodiesel
10	123	74	116	70	130	66

Explain what the data in the table above indicates about the relative viscosity of soybean biodiesel and petrodiesel. 2 marks

e. The second student drew the graph shown below to represent their data.

Viscosity of soybean biodiesel and petrodiesel



i. Identify the trend in the results for soybean biodiesel shown in the graph above. Explain the trend using your knowledge of chemistry. 2 marks

ii. Suggest **one** reason, related to the method used by the students, for the outlier at 30 °C for petrodiesel. 1 mark

Question 10 (8 marks)

'Coal seam gas (CSG), also known as coal bed methane, is a form of natural gas typically extracted from coal seams …

CSG is a mixture of a number of gases, but is mostly made up of methane (generally 95–97 per cent pure methane).'

Source: Gas Industry Social and Environmental Research Alliance (GISERA), 'What is coal seam gas?', <https://gisera.csiro.au>; © Commonwealth Scientific and Industrial Research Organisation, 2015–2020

'Landfill gas (LFG) is a natural byproduct of the decomposition of organic material in landfills. LFG is composed of roughly 50 per cent methane (the primary component of natural gas), 50 per cent carbon dioxide (CO_2) and a small amount of non-methane organic compounds …

LFG can be upgraded … through treatment processes by increasing its methane content and, conversely, reducing its CO_2, nitrogen and oxygen contents.'

Source: United States Environmental Protection Agency (EPA), 'Basic information about landfill gas', <www.epa.gov/lmop/basic-information-about-landfill-gas#landfill>

'Biogas can also be produced under controlled conditions in special tanks called anaerobic digesters.'

Source: US Energy Information Administration (EIA), 'Biomass explained: Landfill gas and biogas', <www.eia.gov/energyexplained/biomass/landfill-gas-and-biogas.php>

a. Methane is a fuel that can be obtained from a number of different sources.

Discuss the effect that the sourcing of methane has on its:

- renewability
- environmental impact.

4 marks

‘The concerns on climate change, the high energy prices and the dwindling oil reserves and supplies have necessitated a strong interest in the research for alternative fuel sources. Biodiesel is an alternative renewable fuel that has gained massive attention in recent years …

… biodiesel is not dangerous to the environment.’

Source: I Demshemino, D Sylvester, M Yahaya, L Isiomanwadike and L Okoro, ‘Comparative analysis of biodiesel and petroleum diesel’, *International Journal of Education and Research*, vol. 1, no. 8, August 2013, <www.researchgate.net/publication/301552040_COMPARATIVE_ANALYSIS_OF_BIODIESEL_AND_PETROLEUM_DIESEL>

‘The reality is, biodiesel may not be clean at all. Biodiesel may be more damaging to the environment than petrodiesel, far more. There is a strong possibility [petrodiesel] is the superior fuel in the [petrodiesel] vs biodiesel debate.’

Source: Rentar Fuel Catalyst, ‘Diesel vs biodiesel: Which is better for the environment and why?’, 25 September 2018, <https://rentar.com/diesel-vs-biodiesel-better-environment/>

b. Compare the impact of biodiesel and petrodiesel on the environment. State which fuel you consider to be better for the environment and explain why. 4 marks

END OF QUESTION AND ANSWER BOOK

VICTORIA
State
Government

VICTORIAN CURRICULUM
AND ASSESSMENT AUTHORITY

Victorian Certificate of Education
2022

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**
relative atomic mass — 197.0
symbol of element — **Au**
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	$n = \frac{m}{M}; \quad n = cV; \quad n = \frac{V}{V_m}$
universal gas equation	$pV = nRT$
calibration factor (CF) for bomb calorimetry	$\text{CF} = \frac{VIt}{\Delta T}$
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

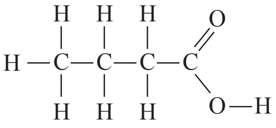
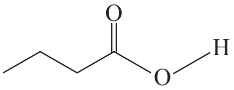
Metric (including SI) prefixes	Scientific notation	Multiplying factor
giga (G)	10^9	1 000 000 000
mega (M)	10^6	1 000 000
kilo (k)	10^3	1000
deci (d)	10^{-1}	0.1
centi (c)	10^{-2}	0.01
milli (m)	10^{-3}	0.001
micro (μ)	10^{-6}	0.000001
nano (n)	10^{-9}	0.000000001
pico (p)	10^{-12}	0.000000000001

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

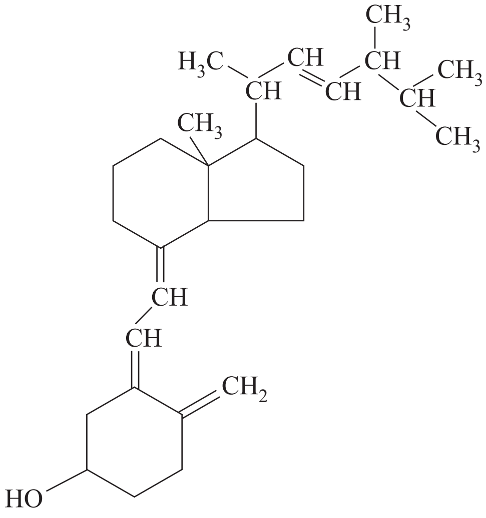
The following table shows different representations of organic molecules, using butanoic acid as an example.

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	

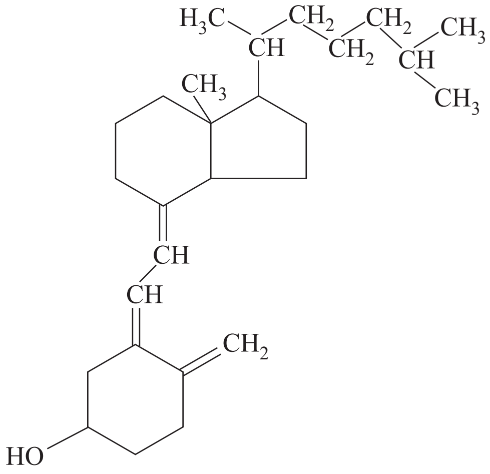
9. Formulas of some fatty acids

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

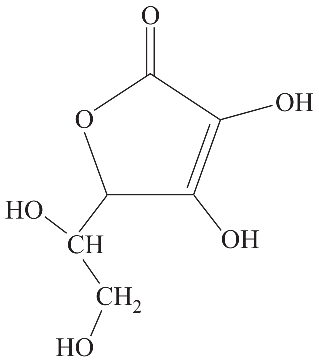
10. Formulas of some biomolecules



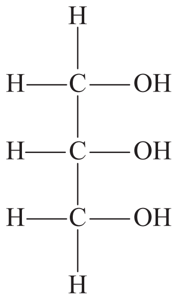
vitamin D_2 (ergocalciferol)



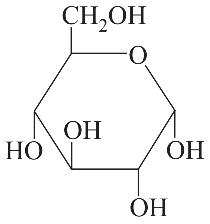
vitamin D_3 (cholecalciferol)



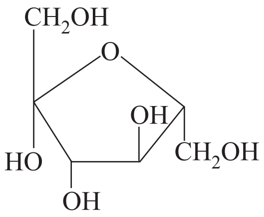
vitamin C (ascorbic acid)



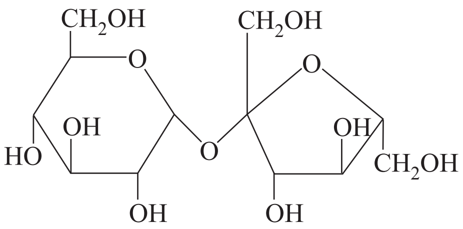
glycerol



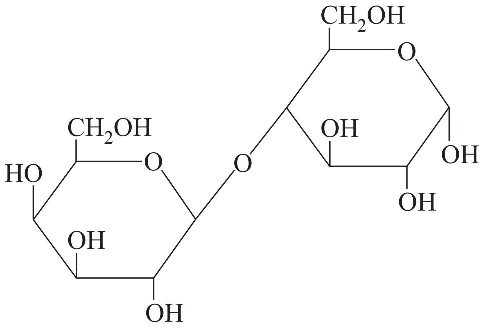
α-glucose



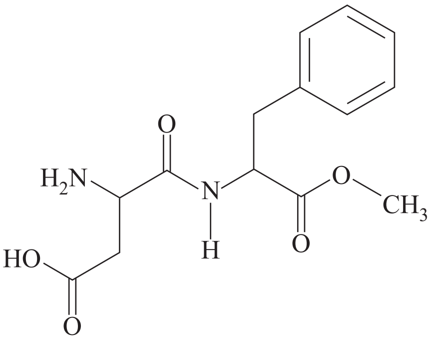
β-fructose



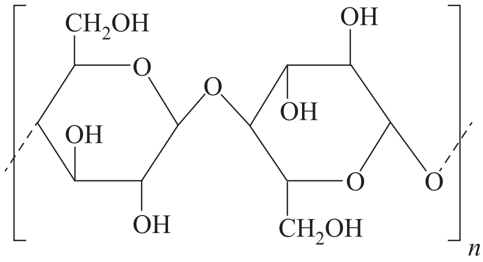
sucrose



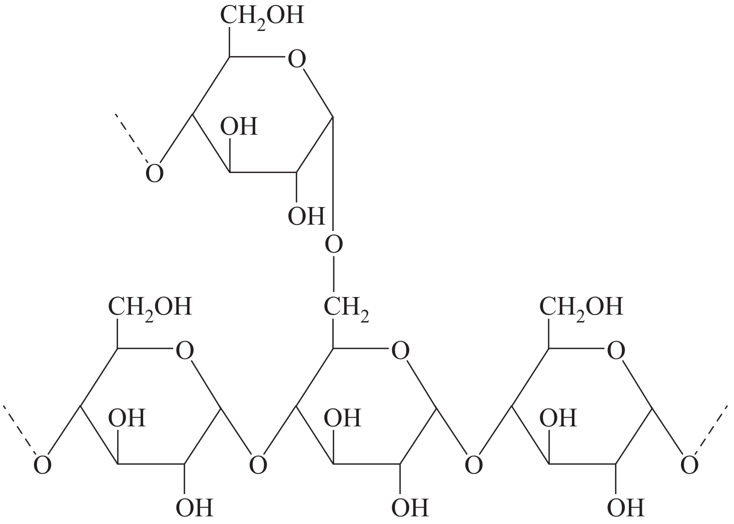
α-lactose



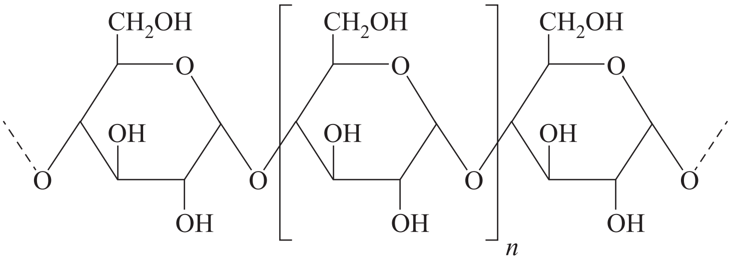
aspartame



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

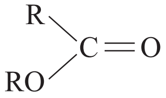
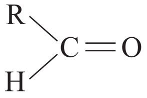
Food	**Heat of combustion (kJ g^{-1})**
fats and oils	37
protein	17
carbohydrate	16

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

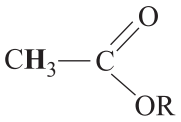
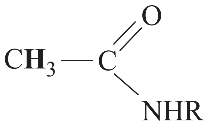
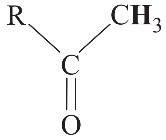
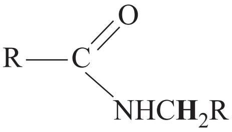
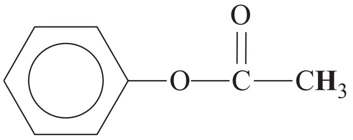
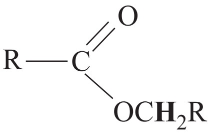
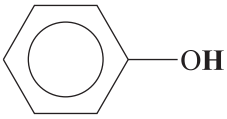
Typical ^{13}C shift values relative to TMS = 0
These can differ slightly in different solvents.

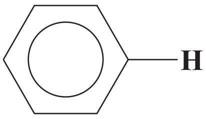
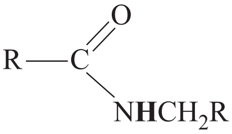
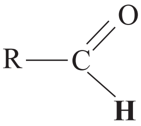
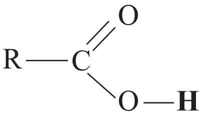
Type of carbon	Chemical shift (ppm)
$R{-}CH_3$	8–25
$R{-}CH_2{-}R$	20–45
$R_3{-}CH$	40–60
$R_4{-}C$	36–45
$R{-}CH_2{-}X$	15–80
$R_3C{-}NH_2$, $R_3C{-}NR$	35–70
$R{-}CH_2{-}OH$	50–90
$RC{\equiv}CR$	75–95
$R_2C{=}CR_2$	110–150
RCOOH	160–185
 $R(RO)C{=}O$	165–175
 $R(H)C{=}O$	190–200
$R_2C{=}O$	205–220

16. ^{1}H NMR data

Typical proton shift values relative to TMS = 0

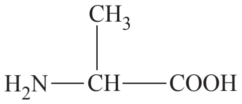
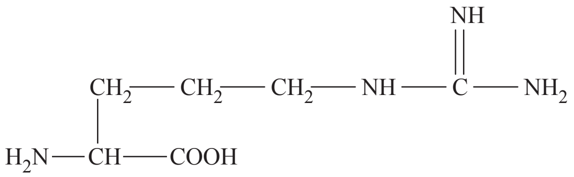
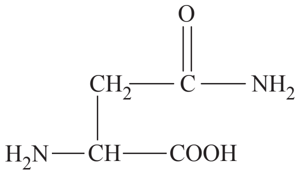
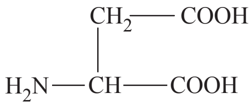
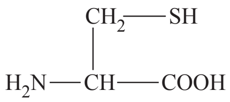
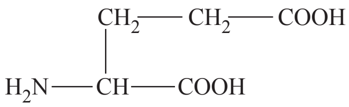
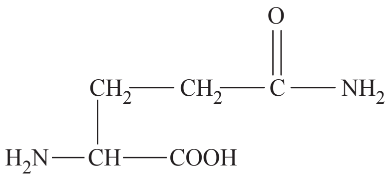
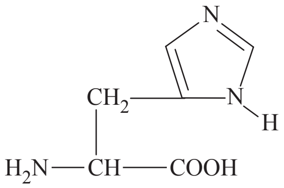
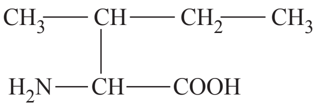
These can differ slightly in different solvents. The shift refers to the proton environment that is indicated in bold letters in the formula.

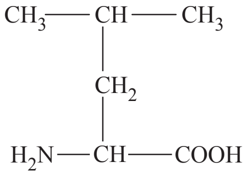
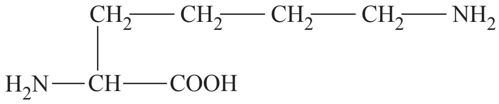
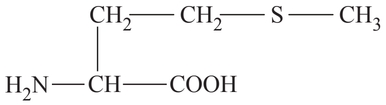
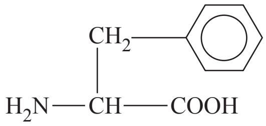
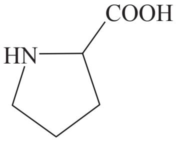
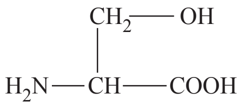
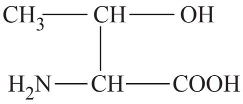
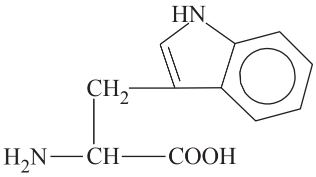
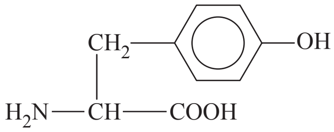
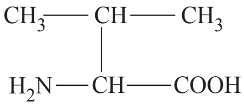
Type of proton	Chemical shift (ppm)
$R{-}\mathbf{CH_3}$	0.9–1.0
$R{-}\mathbf{CH_2}{-}R$	1.3–1.4
$RCH{=}CH{-}\mathbf{CH_3}$	1.6–1.9
$R_3{-}C\mathbf{H}$	1.5
 or 	2.0
	2.1–2.7
$R{-}\mathbf{CH_2}{-}X$ (X = F, Cl, Br or I)	3.0–4.5
$R{-}\mathbf{CH_2}{-}OH$, $R_2{-}C\mathbf{H}{-}OH$	3.3–4.5
	3.2
$R{-}O{-}\mathbf{CH_3}$ or $R{-}O{-}\mathbf{CH_2}R$	3.3–3.7
	2.3
	3.7–4.8
$R{-}O{-}\mathbf{H}$	1–6 (varies considerably under different conditions)
$R{-}N\mathbf{H_2}$	1–5
$RHC{=}C\mathbf{H}R$	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	 $H_2N-CH(CH_3)-COOH$
arginine	Arg	 $H_2N-CH(CH_2-CH_2-CH_2-NH-C(=NH)-NH_2)-COOH$
asparagine	Asn	 $H_2N-CH(CH_2-C(=O)-NH_2)-COOH$
aspartic acid	Asp	 $H_2N-CH(CH_2-COOH)-COOH$
cysteine	Cys	 $H_2N-CH(CH_2-SH)-COOH$
glutamic acid	Glu	 $H_2N-CH(CH_2-CH_2-COOH)-COOH$
glutamine	Gln	 $H_2N-CH(CH_2-CH_2-C(=O)-NH_2)-COOH$
glycine	Gly	H_2N-CH_2-COOH
histidine	His	
isoleucine	Ile	 $H_2N-CH(CH(CH_3)-CH_2-CH_3)-COOH$

Name	**Symbol**	**Structure**
leucine	Leu	 $\begin{array}{c} \mathrm{CH_3-CH-CH_3} \\ \mathrm{CH_2} \\ \mathrm{H_2N-CH-COOH} \end{array}$
lysine	Lys	 $\begin{array}{l} \mathrm{CH_2-CH_2-CH_2-CH_2-NH_2} \\ \mathrm{H_2N-CH-COOH} \end{array}$
methionine	Met	 $\begin{array}{l} \mathrm{CH_2-CH_2-S-CH_3} \\ \mathrm{H_2N-CH-COOH} \end{array}$
phenylalanine	Phe	
proline	Pro	
serine	Ser	 $\begin{array}{l} \mathrm{CH_2-OH} \\ \mathrm{H_2N-CH-COOH} \end{array}$
threonine	Thr	 $\begin{array}{c} \mathrm{CH_3-CH-OH} \\ \mathrm{H_2N-CH-COOH} \end{array}$
tryptophan	Trp	
tyrosine	Tyr	
valine	Val	 $\begin{array}{c} \mathrm{CH_3-CH-CH_3} \\ \mathrm{H_2N-CH-COOH} \end{array}$

END OF DATA BOOK

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