VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education 2023

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

STUDENT NUMBER									Letter

CHEMISTRY

Written examination

Wednesday 24 May 2023

Reading time: 2.00 pm to 2.15 pm (15 minutes)
Writing time: 2.15 pm to 4.45 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 one of the following is an equation for the combustion of a fuel?

A. $N_2(g) + O_2(g) \rightarrow 2NO(g)$ $\Delta H = +181 \text{ kJ mol}^{-1}$

B. $CO(g) + \frac{1}{2}O_2(g) \rightarrow CO_2(g)$ $\Delta H = -284 \text{ kJ mol}^{-1}$

C. $CH_4(g) + H_2O(g) \rightarrow CO(g) + 3H_2(g)$ $\Delta H = +206 \text{ kJ mol}^{-1}$

D. $2NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(l) + CO_2(g)$ $\Delta H = -129 \text{ kJ mol}^{-1}$

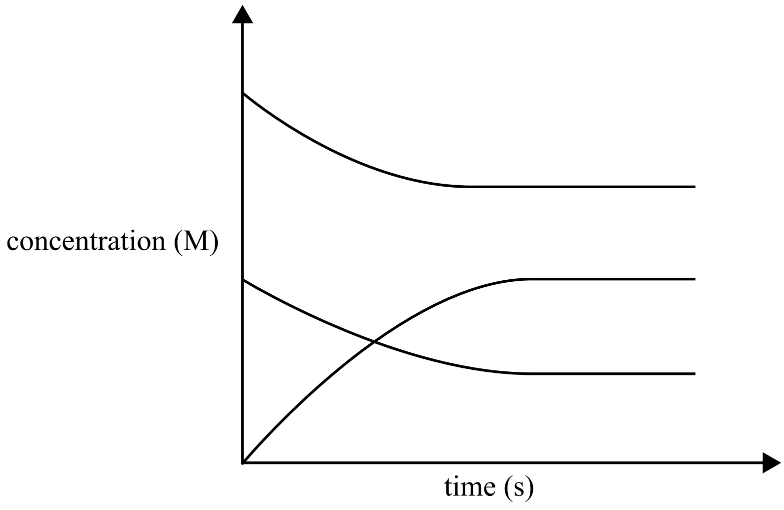
Question 2

Which one of the following is true of secondary cells?

A. Side reactions do not occur.
B. Fuel cells are a type of secondary cell.
C. The cathodes are always positively charged.
D. Electrical energy is transformed into chemical energy.

Question 3

Consider the following concentration versus time graph.



Which one of the following reactions could produce the graph shown above?

A. $2NO_2(g) \rightleftharpoons N_2O_4(g)$

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

C. $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

D. $2NOBr(g) \rightleftharpoons 2NO(g) + Br_2(g)$

Question 4

Bioethanol is a fuel produced by

A. fermentation.

B. anaerobic digestion.

C. transesterification of fats.

D. a substitution reaction of ethene.

Question 5

Which one of the following is the percentage atom economy of the reaction that converts propene to propane?

A. 91%

B. 93%

C. 95%

D. 100%

Question 6

The reaction between sulfuric acid, H_2SO_4, and sodium chloride, NaCl, to produce hydrogen chloride gas, HCl, is given below.

$$H_2SO_4(l) + 2\ NaCl(s) \rightarrow 2\ HCl(g) + Na_2SO_4(s)$$

A beaker of H_2SO_4(l) was placed on a balance in a fume cupboard. NaCl(s) was added to the beaker in the stoichiometric ratio shown in the equation. The following observations were made.

- The reading on the balance immediately decreased, but stabilised at a constant value after 10 seconds.
- The liquid level in the beaker increased when the NaCl(s) was added, but no further change in the liquid level was observed.

The reaction has

A. a fast reaction rate and a high extent of reaction.

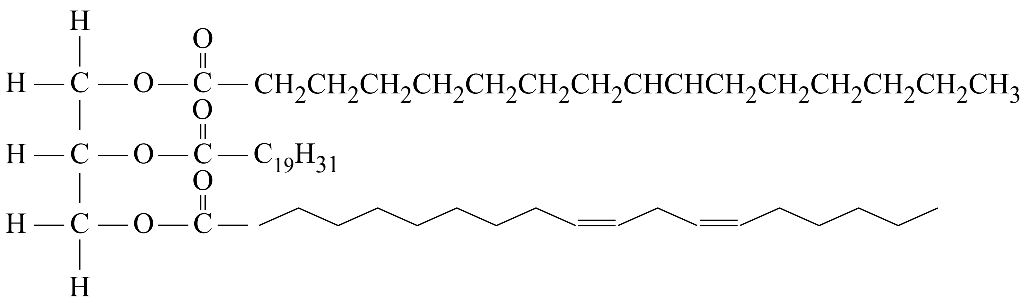
B. a fast reaction rate and a low extent of reaction.

C. a slow reaction rate and a high extent of reaction.

D. a slow reaction rate and a low extent of reaction.

Question 7

A triglyceride is shown below.



The number of C=C double bonds in the triglyceride is

A. 3

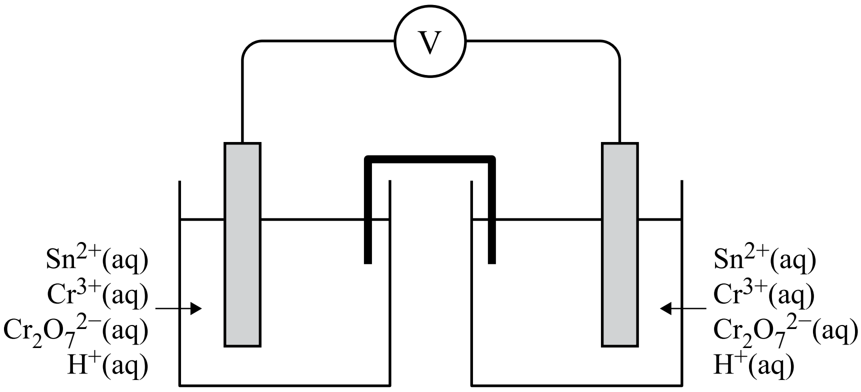
B. 5

C. 7

D. 9

Question 8

A diagram of a galvanic cell at standard conditions is shown below.



Some half-reactions relevant to this galvanic cell are given in the following table.

Half-reaction	Standard electrode potential at 25 °C
$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightleftharpoons 2Cr^{3+}(aq) + 7H_2O(l)$	+1.36
$Sn^{2+}(aq) + 2e^- \rightleftharpoons Sn(s)$	−0.14
$Cr^{3+}(aq) + e^- \rightleftharpoons Cr^{2+}(aq)$	−0.42
$Cr^{3+}(aq) + e^- \rightleftharpoons Cr(s)$	−0.74

If the galvanic cell produces 1.5 V, the anode and cathode should be made from which of the following?

	Anode	Cathode
A.	Pt(s)	Sn(s)
B.	Sn(s)	Sn(s)
C.	Pt(s)	Pt(s)
D.	Sn(s)	Pt(s)

Question 9

A galvanic cell has the following set-up:

- Half-cell 1: acidified 1M hydrogen peroxide, H_2O_2, solution with a Pt electrode
- Half-cell 2: 1M nickel nitrate, $Ni(NO_3)_2$, solution with a Ni electrode

When the cell is operating, the oxidising agent is

A. Ni
B. Ni^{2+}
C. H_2O
D. H_2O_2

Question 10

Which one of the following statements is correct?

A. Reducing agents help to prevent oxidative rancidity.

B. All fatty acids undergo oxidative rancidity at the same rate.

C. Temperature does not affect the rate of oxidative rancidity of fatty acids.

D. Antioxidants react with the carbon–carbon double bond in unsaturated fatty acids.

Question 11

Consider the following statements:

I The half-cells must be separated for this cell to operate.

II This cell requires reactants.

III The anode in this cell is always negative.

Which one of the following combinations of statements applies to secondary cells and fuel cells?

	Secondary cells	Fuel cells
A.	I and II only	I, II and III
B.	I and II only	II and III only
C.	I and III only	I, II and III
D.	I and III only	II and III only

Question 12

An electrolysis cell contains a dilute solution of potassium chloride, KCl(aq), and potassium bromide, KBr(aq). Both electrodes are made of graphite.

Which one of the following options shows the initial observations at the anode and cathode?

	Anode observations	Cathode observations
A.	no change	colourless bubbles
B.	colourless bubbles	brown colour appears
C.	colourless bubbles	no change
D.	brown colour appears	colourless bubbles

Question 13

A reaction has an activation energy of +50 kJ mol^{-1} and an enthalpy change of +10 kJ mol^{-1}.

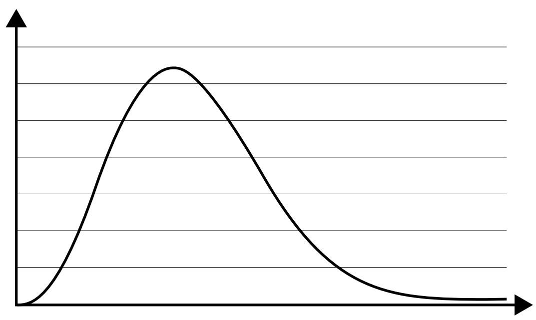
A catalyst is added to the reaction to increase the reaction rate.

Which one of the following options could represent the catalysed reaction?

	Potential energy of the reactants (kJ mol^{-1})	Maximum potential energy of the energy profile (kJ mol^{-1})	Potential energy of the products (kJ mol^{-1})
A.	10	60	20
B.	10	60	0
C.	20	40	30
D.	20	50	10

Question 14

A Maxwell–Boltzmann distribution curve is given below.



Which one of the following statements about the curve is true?

A. The temperature is constant.

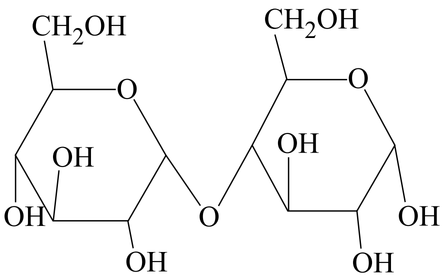
B. The gradient of the curve is the reaction rate.

C. The peak of the curve is the maximum energy.

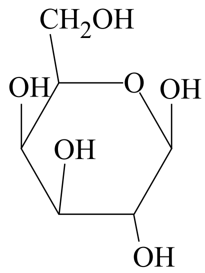
D. The area under the curve is the activation energy.

Question 15

Consider the following structures in addition to those on page 8 of the Data Book.



maltose



galactose

Which two monosaccharides combine to make maltose?

A. β-fructose and galactose

B. galactose and α-glucose

C. β-fructose and α-glucose

D. α-glucose and α-glucose

Question 16

Consider the following statements:

I Hydrogen bonds exist between aspartame molecules.

II A glycosidic link exists within a molecule of aspartame.

III The energy content per gram of aspartame is similar to the energy content per gram of sucrose.

Which of the statements above are correct?

A. I only

B. I and II only

C. I and III only

D. II and III only

Question 17

In the electrolysis of 6 M sodium chloride solution, NaCl(aq), the amount of charge required to form one mole of NaOH(aq) is

A. 4.8×10^4 C

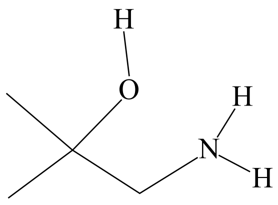
B. 9.7×10^4 C

C. 1.9×10^5 C

D. 3.9×10^5 C

Question 18

Consider the following molecule.



What is the International Union of Pure and Applied Chemistry (IUPAC) name of the molecule shown above?

A. 3-hydroxy-3-methylbutan-1-amine

B. 2-hydroxy-methylpropan-1-amine

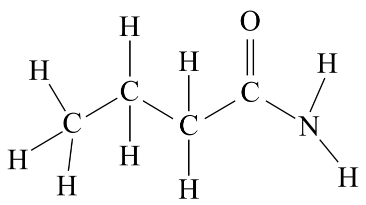
C. 1-amino-2-methylpropan-2-ol

D. 4-amino-2-methylbutan-2-ol

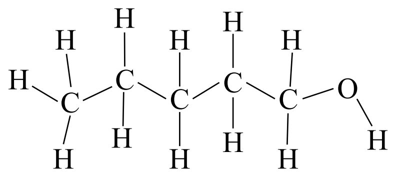
Question 19

Consider the following molecules, J and L.

Molecule J



Molecule L



The boiling point of J is

A. higher than L because J has weaker dispersion forces.

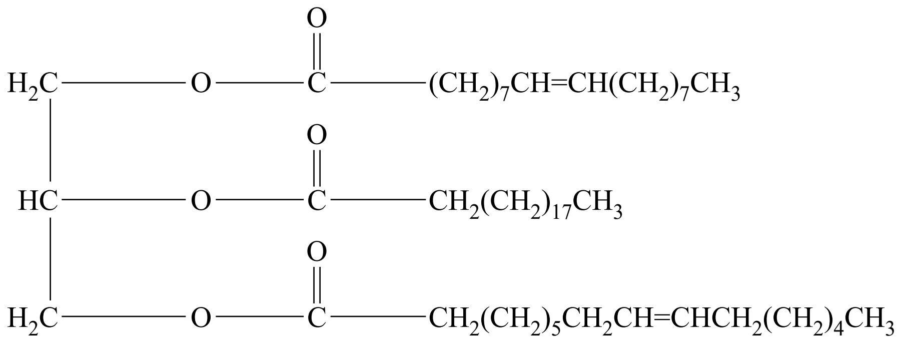
B. higher than L because J has more hydrogen bonding sites.

C. lower than L because J has weaker dispersion forces.

D. lower than L because J has more hydrogen bonding sites.

Question 20

Consider the following triglyceride.



When this triglyceride is hydrolysed, one of the products

A. is $CH_3CH_2CH_3$

B. is linoleic acid

C. is an omega-6 fatty acid

D. has the molecular formula $C_{16}H_{30}O_2$

Question 21

Consider reactions 1 and 2 at standard laboratory conditions (SLC).

- Reaction 1: $CO(g) + 3H_2(g) \rightleftharpoons CH_4(g) + H_2O(g)$ $K_1 = 3.90\ M^{-2}$
- Reaction 2: $3CH_4(g) + 3H_2O(g) \rightleftharpoons 3\ CO(g) + 9H_2(g)$

Which one of the following is the equilibrium constant for reaction 2?

A. $3K_1$

B. $\frac{1}{\sqrt[3]{K_1}}$

C. $\frac{1}{(K_1)^3}$

D. $\frac{1}{3K_1}$

Question 22

The following reaction takes place under certain conditions to produce ethanamide, CH_3CONH_2.

$$CH_3COOH + NH_3 \rightarrow CH_3CONH_2 + H_2O$$

3.00 g of acetic acid, CH_3COOH, reacts to produce 2.40 g of CH_3CONH_2.

$M(CH_3COOH) = 60 \text{ g mol}^{-1}$, $M(NH_3) = 17 \text{ g mol}^{-1}$, $M(CH_3CONH_2) = 59 \text{ g mol}^{-1}$, $M(H_2O) = 18 \text{ g mol}^{-1}$

The percentage yield for this reaction is

A. 76.6%

B. 78.7%

C. 80.0%

D. 81.4%

Question 23

A student performed a titration using a solution of 0.103 M ethanoic acid, CH_3COOH, and a solution of 0.236 M sodium hydroxide, NaOH. The aliquot of CH_3COOH was 25.00 mL and the titre of NaOH was 11.60 mL.

What could explain the titre obtained by the student?

A. The burette was rinsed with the NaOH solution.

B. The indicator used was phenolphthalein.

C. There were air bubbles in the burette.

D. The pipette was rinsed with water.

Question 24

Sulfur trioxide, SO_3, can be produced from oxygen, O_2, and sulfur dioxide, SO_2, in the following equilibrium reaction.

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

Consider the following statements about the production of SO_3 in a closed system:

I Increasing the temperature of the system will increase both the reaction rate and the equilibrium constant.

II Increasing the volume of the system will reduce the reaction rate and reduce the equilibrium yield of SO_3.

III Increasing the pressure of the system by adding nitrogen gas, N_2, will increase the equilibrium yield of SO_3.

IV Adding a suitable catalyst to the system will have no effect on the equilibrium constant.

Which of the statements above are correct?

A. I and II only

B. I and III only

C. II and IV only

D. III and IV only

Question 25

1.3 g of ethanol was burned in a fuel burner. The temperature of 500 g of water in a beaker placed above the fuel burner increased by 20.3 °C.

The following events could have occurred:

I The ethanol was diluted so that it contained 10% water.

II Octane instead of ethanol was placed in the fuel burner.

III Heat was lost to the environment.

Which of the possible event/s best explain the result?

A. I only

B. III only

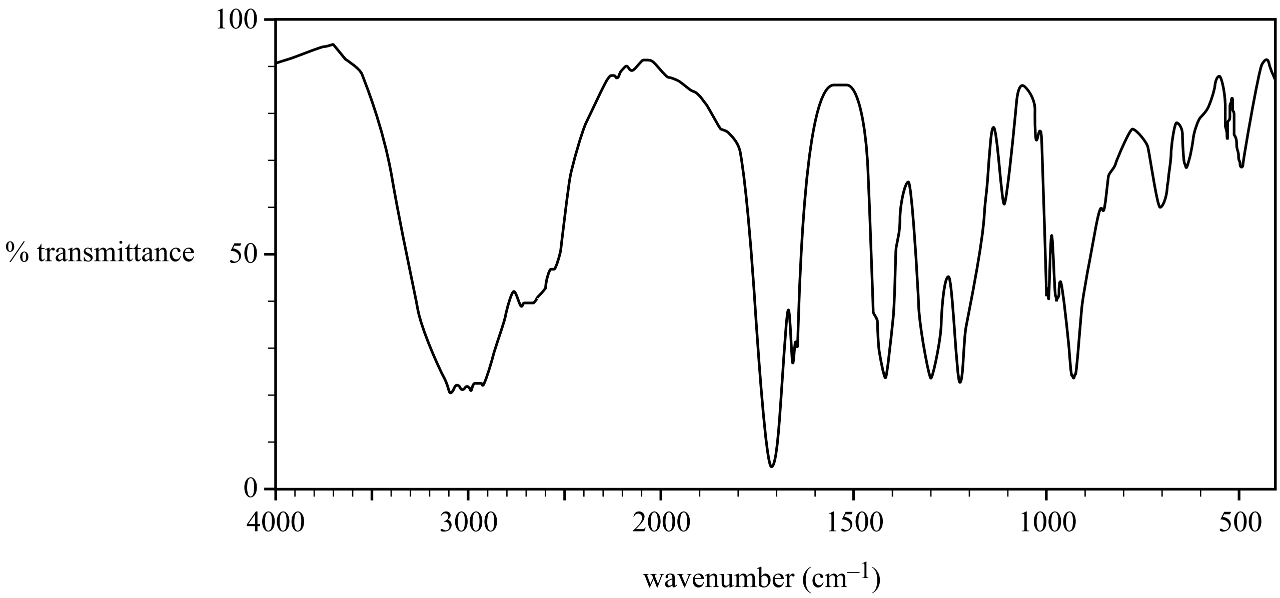
C. Both I and III

D. Both II and III

Question 26

The organic compound, Z, reacts with hydrogen iodide, HI(aq), in an addition reaction.

The infra-red (IR) spectrum of compound Z is shown below.



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

Compound Z could be

A. CH_2CHCH_2COOH

B. $CH_3CH_2CH_2COOH$

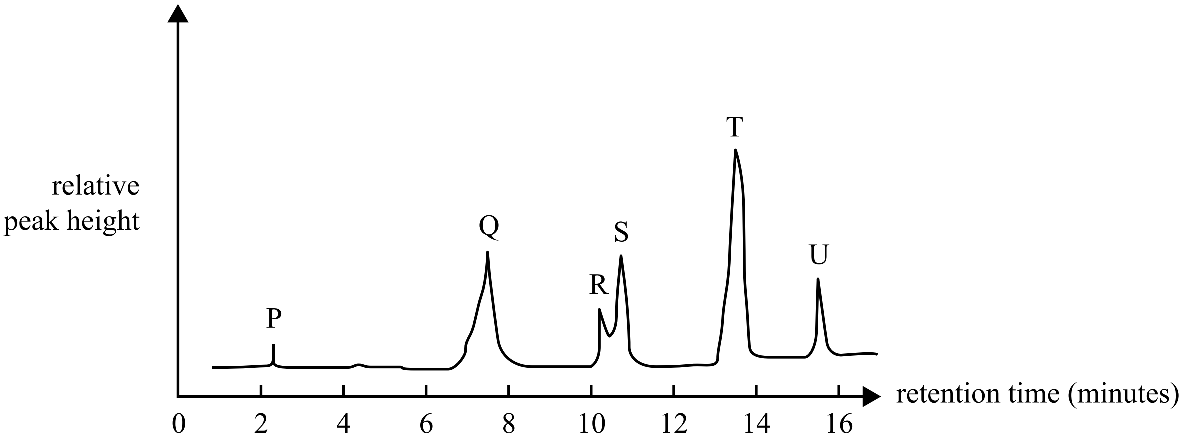
C. $CH_3CH_2CH_2CONH_2$

D. $NH_2CH_2CHCHCHO$

Use the following information to answer Questions 27 and 28.

The proteins in a sample of cow's milk are analysed using high-performance liquid chromatography (HPLC) using a non-polar stationary phase and a polar mobile phase.

The results are shown in the chromatogram below.



Question 27

Which of the following options correctly describes how a change to the experimental conditions affects the retention time of T and the separation of peaks R and S?

	Change to the experimental conditions	Retention time of T	Separation of peaks R and S
A.	decreasing the column length	decreases	decreases
B.	decreasing the column length	increases	increases
C.	increasing the column temperature	decreases	increases
D.	increasing the column temperature	increases	decreases

Question 28

A manufacturer claims that there is 2.60 g of protein Q in 240 mL of cow's milk.

Standard solutions of protein Q, ranging from 0 mg L^{-1} to 50 mg L^{-1}, are analysed using HPLC.
A calibration curve is constructed from the results. The calibration curve is used to accurately determine the concentration of compound Q in the cow's milk.

What size volumetric flask should be used to dilute a 1.0 mL aliquot of cow's milk?

A. 50.00 mL

B. 100.00 mL

C. 200.00 mL

D. 500.00 mL

Question 29

Consider the following equilibrium reaction.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$$

In system X, 2 mol of CH_4(g) and 1 mol of H_2O(g) were added to an evacuated 1.0 L container at 25 °C.

In system Y, 1 mol of CH_4(g) and 1 mol of H_2O(g) were added to a different evacuated 1.0 L container at 25 °C.

Which one of the following statements is correct?

A. The initial rate of the forward reaction would be higher in system Y than in system X.

B. The concentration of H_2O(g) would be lower in system X than in system Y at equilibrium.

C. The rate of the backward reaction would be the same for the two systems at equilibrium.

D. The concentration of H_2(g) in system X would be triple the concentration of H_2O(g) in system X at equilibrium.

Question 30

Which molecule can exist as a cis and trans isomer?

A. pent-1-ene

B. pent-2-ene

C. 2-methyl-but-1-ene

D. 2-methyl-but-2-ene

END OF SECTION A

CONTINUES OVER PAGE

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 (6 marks)

Kombucha is a fermented tea that is produced by mixing tea, water and sucrose with bacteria and yeast. The bacteria and yeast break down the sucrose.

The yeast in kombucha produces the invertase enzyme, which metabolises the sucrose present in the kombucha.

a. Name the type of reaction that breaks down the sucrose into simpler molecules. 1 mark

b. In the kombucha process, bacteria produce cellulose, which is removed prior to bottling.

State why removing the cellulose makes no difference to the nutritional value of the final product for humans. 1 mark

c. A kombucha manufacturer is considering adding Vitamin C or D to the kombucha.

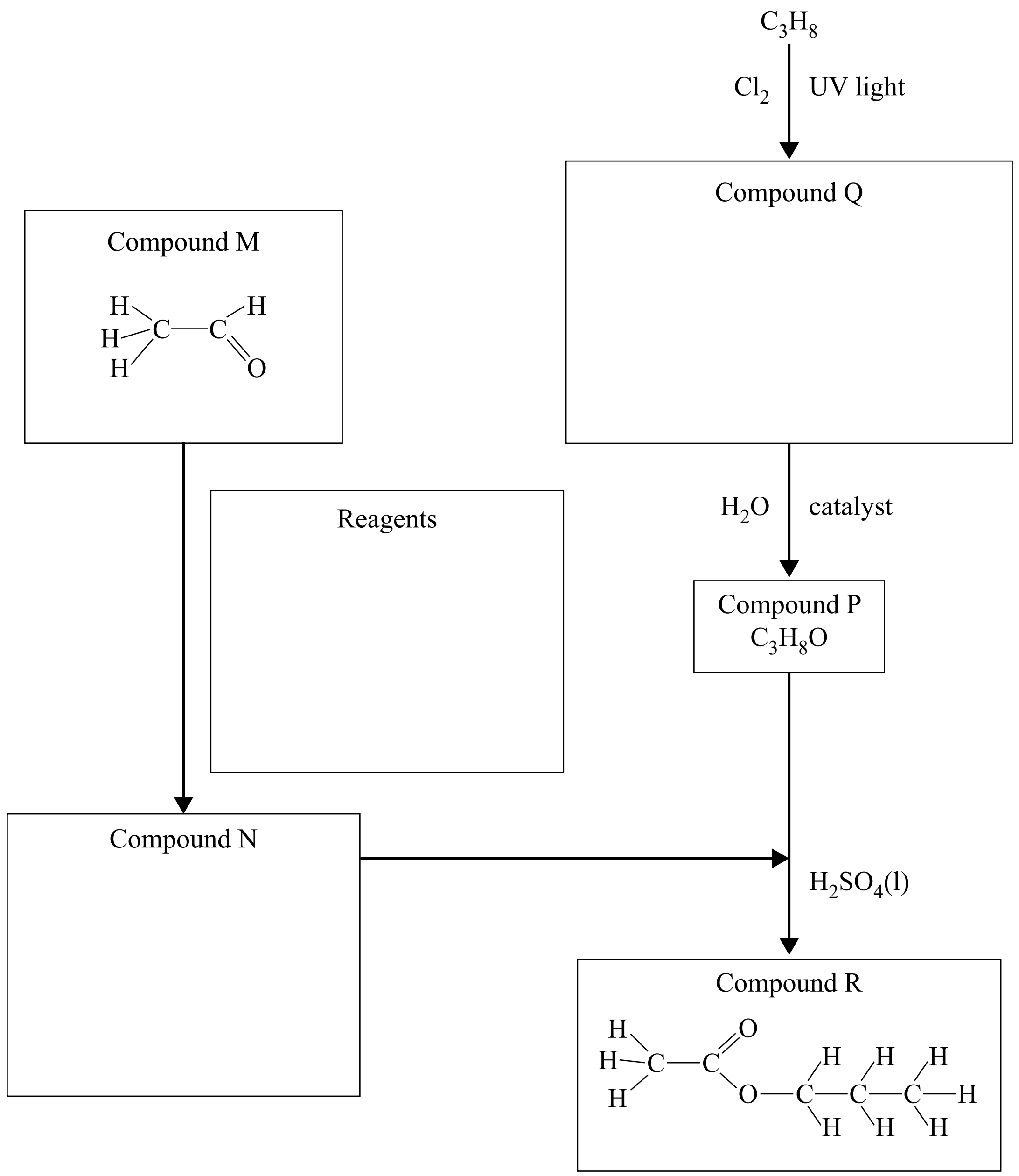
Explain the advantages of choosing Vitamin C over Vitamin D. In your answer, use your understanding of the chemistry that you have studied this year. 2 marks

d. Vitamins can act as coenzymes.

Describe the role of coenzymes in enzyme reactions. 2 marks

Question 2 (8 marks)

Consider the reactions shown in the diagram below.



a. State the International Union of Pure and Applied Chemistry (IUPAC) systematic name of Compound R. 1 mark

___

b. Name the functional group in Compound M. 1 mark

___

c. Identify the reagent(s) required to convert Compound M to Compound N in the box provided in the diagram above. 1 mark

d. Draw the structural formula of Compound N in the box provided in the diagram above. 1 mark

e. What is the name of the reaction type that produces Compound Q? 1 mark

f. Compound Q is converted to Compound P when reacted with water. Compound P reacts with Compound N to produce Compound R.

i. Draw the skeletal formula of Compound Q in the box provided. 1 mark

ii. Does Compound Q have a chiral carbon? Justify your answer. 2 marks

DO NOT WRITE IN THIS AREA

Question 3 (10 marks)

A galvanic cell can be constructed from a Ni^{2+}(aq)/ Ni(s) half-cell and an Ag^{+}(aq)/Ag(s) half-cell.

a. State the maximum cell voltage, under standard conditions, of the Ag^{+}(aq)/Ag(s)/ /Ni^{2+}(aq)/ Ni(s) galvanic cell. 1 mark

____

b. Write the overall equation for the Ag^{+}(aq)/Ag(s)/ /Ni^{2+}(aq)/ Ni(s) galvanic cell. 1 mark

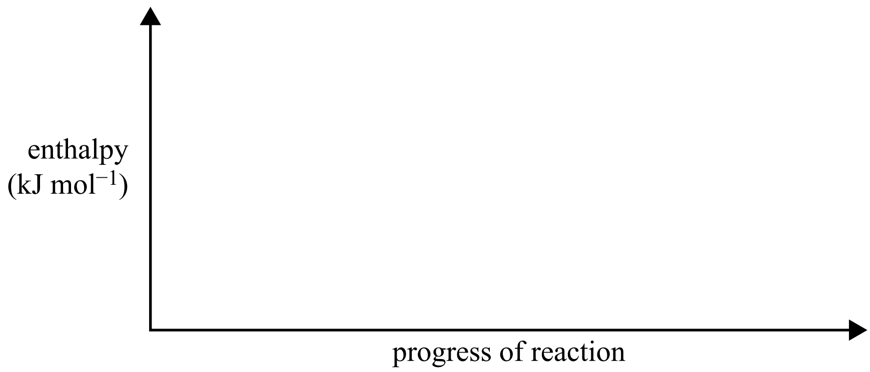
____

c. Microbial fuel cells, MFC, use bacteria to metabolise biomass. In an MFC, the bacteria decompose biomass, in the absence of oxygen, through a process called anaerobic cellular respiration.

i. Write the equation for respiration that occurs in the cells of the human body. 1 mark

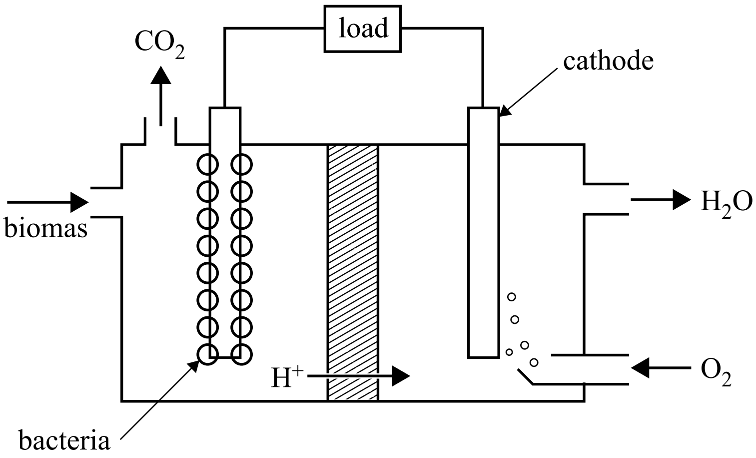
____

ii. On the axes below, sketch the energy profile diagram for respiration. 1 mark



DO NOT WRITE IN THIS AREA

The MFC anode has bacteria growing on it. The bacteria decompose organic matter and produce H^+ ions and electrons. The bacteria transfer electrons directly to the anode. One half-cell has oxygen bubbled into it. In the other half-cell, oxygen is excluded. A diagram of an MFC is given below.



d. Write the balanced half-equation for the reaction occurring at the cathode. 1 mark

e. Explain why the two half-cells are separated. 2 marks

f. For the cell shown in the diagram above, state the feature that causes the overall movement of H^+ ions across the membrane. Explain your answer. 2 marks

g. State an advantage of an MFC over the Ag^+(aq)/Ag(s)/ /Ni^{2+}(aq)/ Ni(s) galvanic cell. 1 mark

Question 4 (8 marks)

A bomb calorimeter has a calibration factor of 3540 J °C^{-1}.

a. The calibration factor was determined using an electric heater operating for 240.0 seconds at 6.50 volts. During the calibration, the temperature increased by 1.77 °C.

Calculate the current that passed through the heater. 2 marks

b. A 2.50 g sample of muesli was placed in the calorimeter and completely burnt. No significant amount of ash remained at the end. A temperature increase of 5.00 °C was measured.

i. Calculate the energy content, in kJ, of 100.0 g of muesli. 2 marks

ii. 20.0% of the energy content of muesli is due to the protein present.

Calculate the mass of protein in 100.0 g of muesli. 2 marks

DO NOT WRITE IN THIS AREA

c. When muesli is consumed, it is metabolised by the body.

i. State how the products of metabolism are used by the body to produce large biomolecules. 1 mark

ii. Other than the chemicals produced by metabolism, with what else does metabolism provide the body? 1 mark

Question 5 (9 marks)

A student wrote the following partial experimental report.

Experimental report

Introduction

Luminol, $C_8H_7N_3O_2$, is an organic molecule that produces light when it oxidises. It is used in glow sticks. Luminol oxidises when it reacts with sodium hypochlorite, NaOCl.

Light sensors can be used to measure the intensity of light hitting a surface. The amount of light is measured in lumens and the light intensity is measured in lumens per square metre (lx).

Aim

To investigate how the oxidation rate of luminol is affected by temperature.

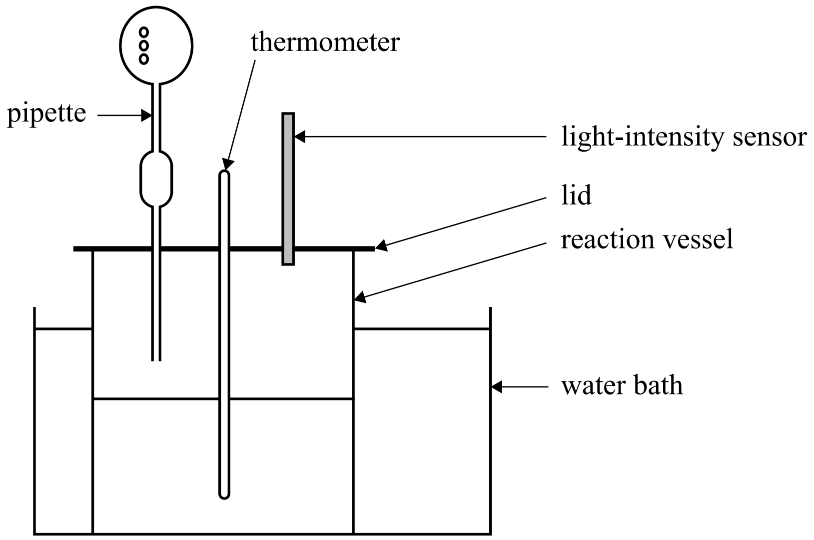
Materials

0.2500 M sodium hypochlorite solution

98.5% luminol solution

Apparatus

The reaction vessel is sealed and its inside surface is black. It has a detachable black lid that contains three rubber-lined holes. The holes are sized to exactly fit a thermometer, a pipette and a light-intensity sensor.



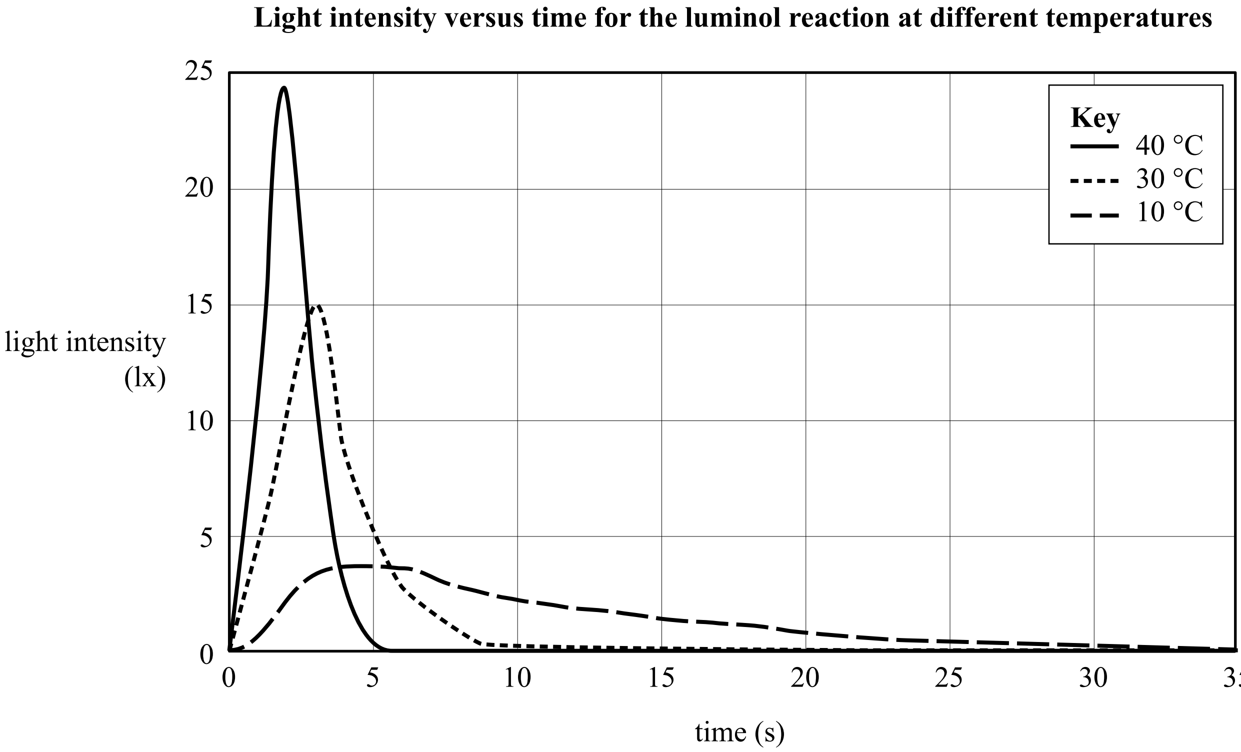
Method

1. Add 200.0 mL of luminol solution to the reaction vessel.
2. Clamp the lid over the top of the reaction vessel.
3. Place the reaction vessel in a water bath at 10 °C.
4. Put a thermometer into the luminol in the reaction vessel through the appropriate hole in the lid.
5. Put the light-intensity sensor into the top of the reaction vessel through the appropriate hole in the lid.
6. Place 100 mL of 0.2500 M sodium hypochlorite solution into a beaker and place the beaker in the water bath.

Experimental report – continued

7. When the temperatures of the sodium hypochlorite solution and the luminol in the reaction vessel have both reached 10 °C, rinse a 40.00 mL pipette with the sodium hypochlorite solution.
8. Fill the rinsed pipette with 40.00 mL of sodium hypochlorite solution and put the pipette into the top of the reaction vessel through the appropriate hole in the lid.
9. Push the pipette plunger to put the sodium hypochlorite solution into the reaction vessel, and at the same time start the data logger timer for the light-intensity sensor.
10. Repeat steps 1 to 9 using a 30 °C water bath.
11. Repeat steps 1 to 9 using a 40 °C water bath.

Results



a. How can the graph above be used to compare the reaction rate at the different temperatures? 2 marks

b. The graph on page 25 shows the experimental results for the first 35 seconds, from the moment the sodium hypochlorite is first pushed into the reaction vessel.

Describe how the reaction rate of the reaction mixture at 30 °C changes over the 35 seconds. Explain why these changes occur. 4 marks

c. Write a conclusion for this experiment that is consistent with the results shown in the graph on page 25. 1 mark

d. State two possible sources of error for this experiment. When answering this question, assume that the experimental method is followed correctly and the equipment is calibrated accurately. 2 marks

DO NOT WRITE IN THIS AREA

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Question 6 (13 marks)

In some countries, most cars are powered by petrol engines, whereas most trucks are powered by diesel engines.

Petrol is a mixture of saturated hydrocarbons, including octane, C_8H_{18}, and dodecane, $C_{12}H_{26}$.

a. Write the balanced thermochemical equation for the complete combustion of C_8H_{18} at standard laboratory conditions (SLC). 2 marks

b. One mole of C_8H_{18} is completely combusted and the carbon dioxide, CO_2, produced is captured in a 100.0 L gas cylinder. The pressure in the cylinder is 255 kPa.

Calculate the temperature of the CO_2 in the cylinder. 2 marks

c. A tank contains 11.75 L of water at SLC. 34.0 g of $C_{12}H_{26}$ is completely combusted and all of the energy is used to heat the water in the tank. After being heated, the final temperature of the water is 57.2 °C.

Use this information to calculate the heat of combustion of the $C_{12}H_{26}$ in kJ g^{-1}. 4 marks

DO NOT WRITE IN THIS AREA

Modern trucks can run on a mixture of petrodiesel and biodiesel or, in some cases, pure biodiesel.

d. Compare the renewability of petrodiesel and biodiesel. In your answer, refer to the sourcing of petrodiesel and biodiesel. 2 marks

____

____

____

____

e. **i.** What is meant by the 'hygroscopic properties of a fuel'? 1 mark

____

____

ii. Explain the difference in the hygroscopic properties of biodiesel and petrodiesel. 2 marks

____

____

____

____

Question 7 (8 marks)

Copper metal, Cu, is used to conduct electricity through a printed circuit board (PCB). One use of PCBs is in computers. Electrolysis can be used to deposit Cu on PCBs.

a. State the structural feature that is present in an electrolytic cell but absent in a galvanic cell. 1 mark

b. State an advantage of using Cu over platinum, Pt, as the anode in an electrolysis cell used to deposit Cu on PCBs. 1 mark

c. In a particular electrolysis cell, a number of PCBs have copper deposited on them. The electrolyte used in the cell is $Cu(NO_3)_2(aq)$. The electrolysis cell is operating at 4.0 amps.

Assuming 100% cell efficiency, for how many seconds does the cell need to operate in order to deposit 5.08 g of copper on the PCBs? 4 marks

d. Another electrolysis cell is set up, at standard conditions, with two Pt electrodes and 1M sodium hydroxide, NaOH, as the electrolyte.

Write the equations for the two half-reactions that occur. 2 marks

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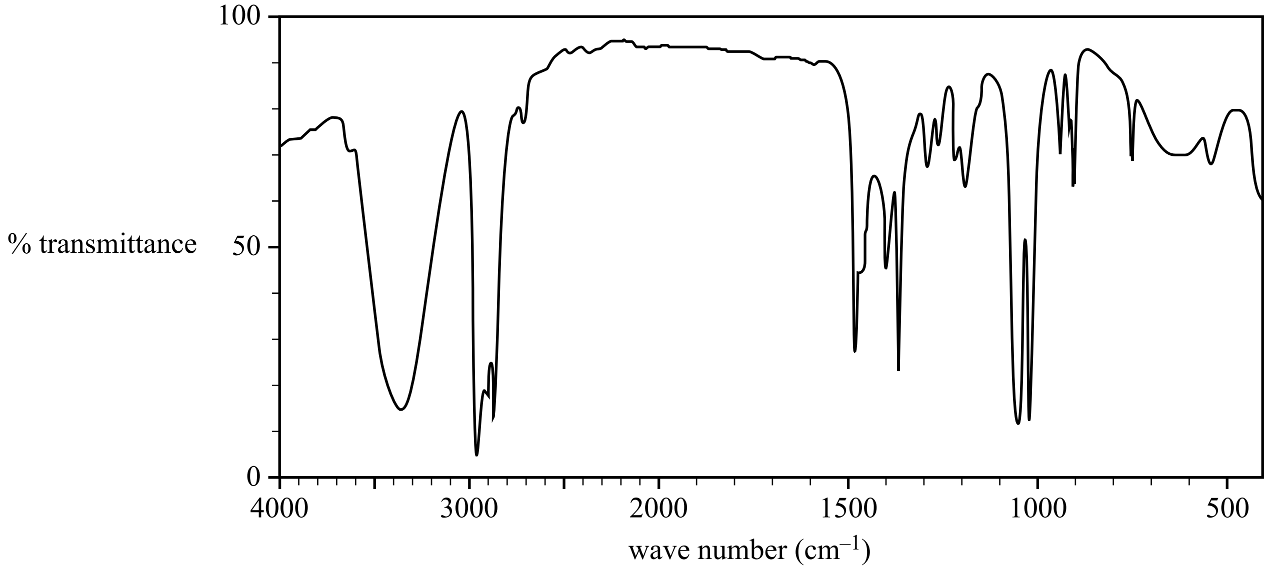
Question 8 (10 marks)

Chemical P contains only carbon, C, hydrogen, H, and oxygen, O. There is one oxygen atom in chemical P.

The infra-red (IR) spectrum is shown below.

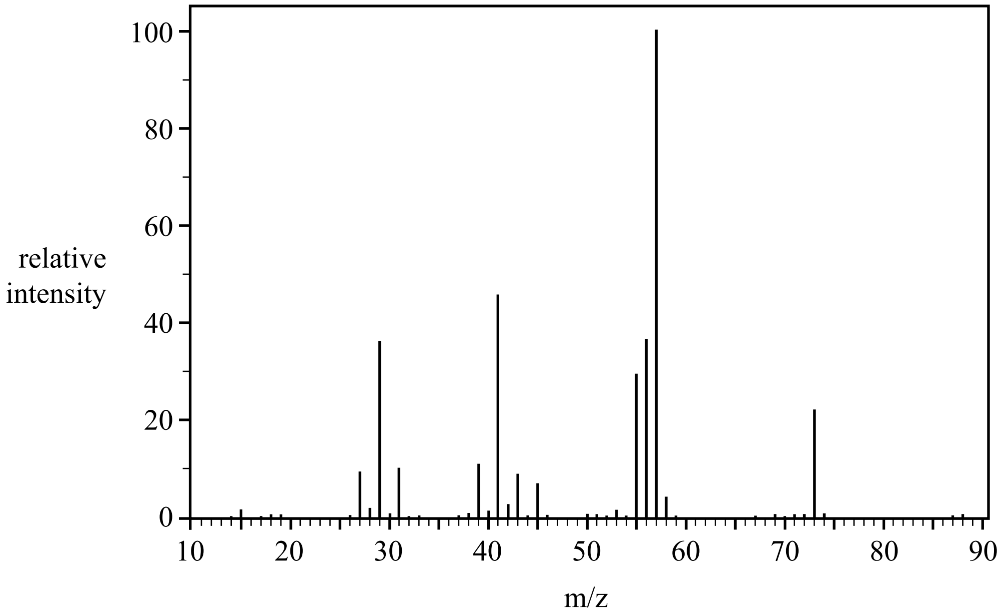


Data: SDBS Web, <https://sdbs.db.aist.go.jp>,
National Institute of Advanced Industrial Science and Technology

a. Identify the type of bond in chemical P around 3350 cm^{-1} in the IR spectrum. 1 mark

___

b. The mass spectrum of chemical P is shown below. The molecular ion has a very small peak at m/z 88.



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

i. Write the molecular formula of chemical P. 1 mark

____

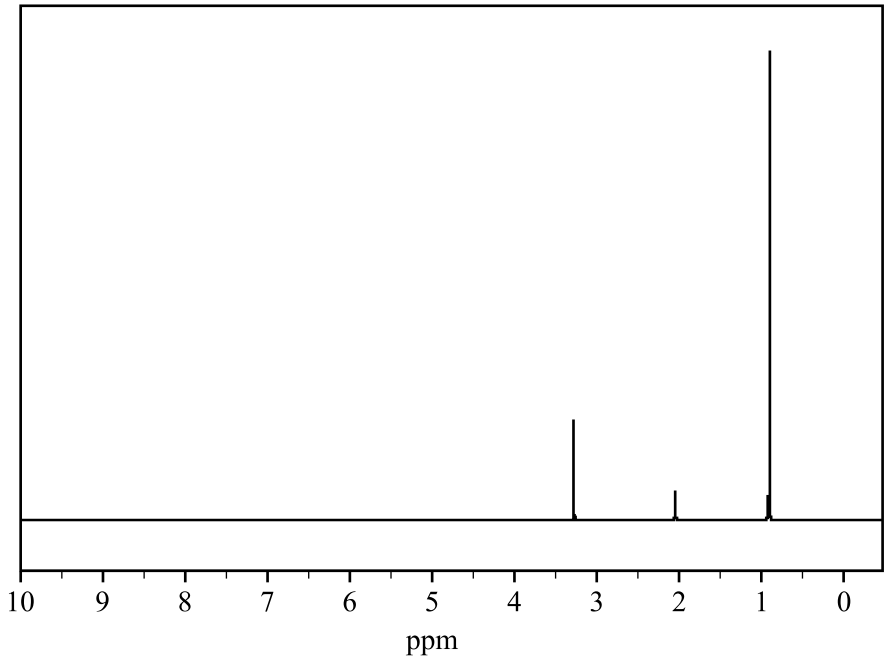
ii. Identify the m/z of the base peak. 1 mark

____

iii. State the formula of the fragment that is removed from the molecular ion to form the base peak ion. 2 marks

____

The ^{1}H NMR spectrum of chemical P is shown below.



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

c. Identify one feature of the ^{1}H nuclei that enables peaks to be produced in the ^{1}H NMR spectrum. 1 mark

d. The ^{13}C NMR of chemical P has three single peaks.

i. Draw the structural formula for chemical P. 2 marks

ii. Explain, with reference to the structure of chemical P, why there is a singlet around 0.9 ppm in the ^{1}H NMR spectrum. 2 marks

Question 9 (11 marks)

Anhydrous cobalt(II) chloride, $CoCl_2(s)$, is a light blue solid that hydrates in the presence of water. When anhydrous $CoCl_2$ hydrates, water molecules attach to it. Dissolving $CoCl_2(s)$ in water will create the aqueous equilibrium system shown below.

$$\underset{\text{pink}}{Co(H_2O)_6^{2+}(aq)} + 4Cl^-(aq) \rightleftharpoons \underset{\text{blue}}{CoCl_4^{2-}(aq)} + 6H_2O(l)$$

The hydrated $Co(H_2O)_6^{2+}(aq)$ ion is pink and the $CoCl_4^{2-}(aq)$ ion is blue. This equilibrium system is useful when investigating equilibrium because of the different coloured ions.

A teacher demonstrates the cobalt(II) chloride aqueous equilibrium system to their class using a fume cupboard.

a. Cobalt(II) chloride solution has several hazards associated with it.

State the reference material that the teacher should read when planning their demonstration, to ensure that the cobalt(II) chloride solution is handled safely. 1 mark

___

The following table details the experimental procedure followed by the teacher, and the observations made by a student.

Step	Experimental procedure	Student observations
1	Use a beaker to dissolve 2.6 g of anhydrous $CoCl_2$ crystals in 100 mL of distilled water.	The $CoCl_2$ crystals are light blue. When the crystals are dissolved in water a light pink solution is formed.
2	Put 5 mL of the solution into a test tube.	Light pink solution in test tube.
3	Add 6 M hydrochloric acid solution, HCl(aq), dropwise to the test tube.	As more HCl is added, the pink colour of the solution changed to purple and then to blue.
4	Place the test tube from Step 3 into a beaker of ice water.	The blue colour of the solution changes back to pink.

b. State the dependent variable in the experimental procedure. 1 mark

___

c. Consider Steps 1 to 3 of the experimental procedure. What is the independent variable in this first part of the experimental procedure? 1 mark

___

d. Use Le Chatelier's principle to explain the student observations in Step 3 of the experimental procedure. 3 marks

e. **i.** State what is meant by accurate data. 1 mark

ii. Explain whether the observational data obtained in Step 3 of the experimental procedure can be described as accurate. 2 marks

f. Use the student observations in Step 4 to identify the thermochemical nature of the equilibrium reaction. Justify your answer. 2 marks

Question 10 (7 marks)

From a chemical point of view, proteins are by far the most structurally complex and functionally sophisticated molecules known. This is perhaps not surprising, once one realizes that the structure and chemistry of each protein has been developed and fine-tuned over billions of years of evolutionary history.

Source: B Alberts, A Johnson, J Lewis et al., *Molecular Biology of the Cell*, 4th edition, Garland Science, New York, 2002, Ch. 3, <www.ncbi.nlm.nih.gov/books/NBK26830/>

a. Discuss how the structure and bonding of each protein makes its shape unique. 4 marks

b. Discuss, using the lock-and-key model, how the structure and bonding of enzymes allows them to catalyse only a specific reaction. Refer to optical isomers and chirality in your response. 3 marks

END OF QUESTION AND ANSWER BOOK

VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education
2023

CHEMISTRY

Written examination

DATA BOOK

Instructions

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

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

Table of contents

1. Periodic table of the elements

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

Key:

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

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

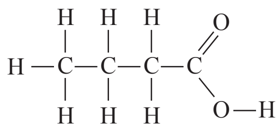
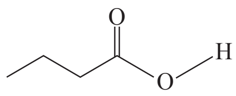
Metric (including SI) prefixes	Scientific notation	Multiplying factor
giga (G)	10^9	1 000 000 000
mega (M)	10^6	1 000 000
kilo (k)	10^3	1000
deci (d)	10^{-1}	0.1
centi (c)	10^{-2}	0.01
milli (m)	10^{-3}	0.001
micro (μ)	10^{-6}	0.000001
nano (n)	10^{-9}	0.000000001
pico (p)	10^{-12}	0.000000000001

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

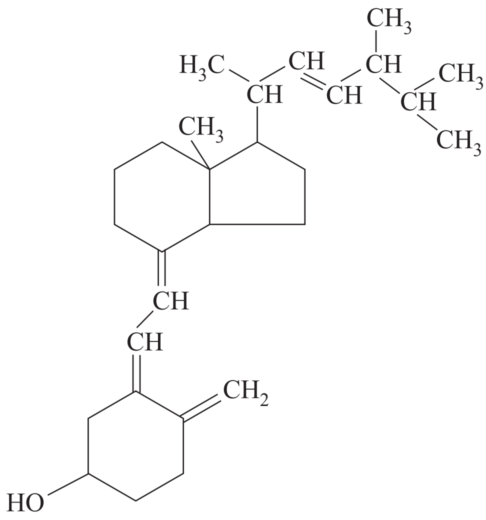
The following table shows different representations of organic molecules, using butanoic acid as an example.

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	

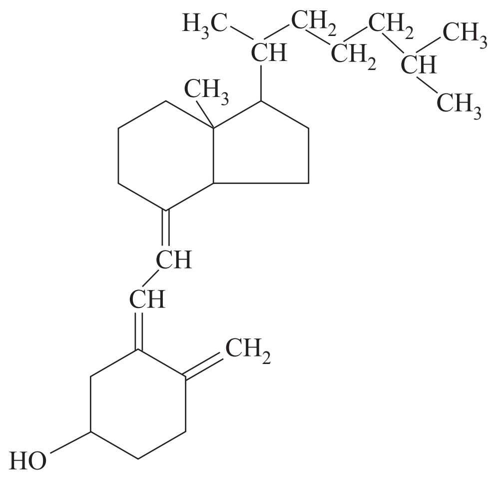
9. Formulas of some fatty acids

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

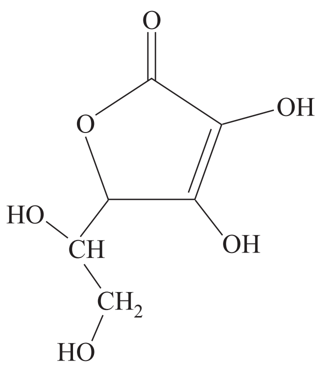
10. Formulas of some biomolecules



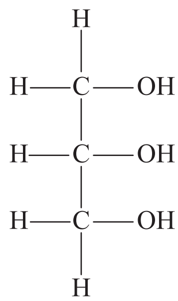
vitamin D_2 (ergocalciferol)



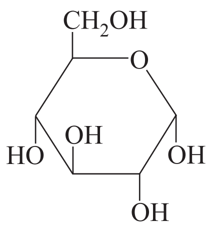
vitamin D_3 (cholecalciferol)



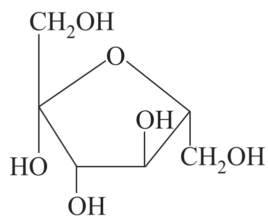
vitamin C (ascorbic acid)



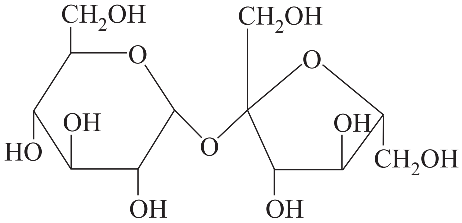
glycerol



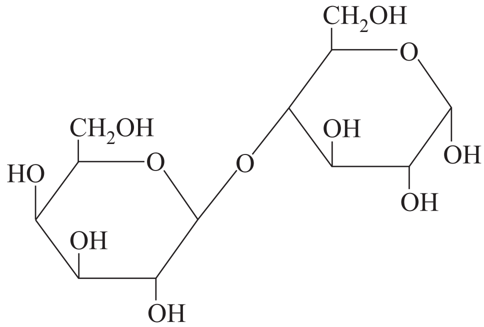
α-glucose



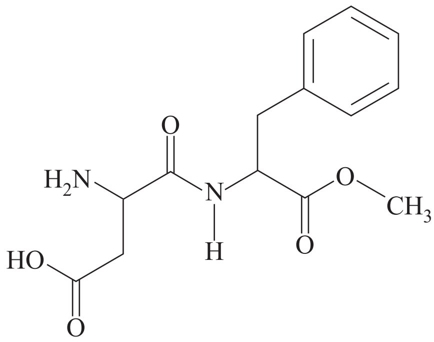
β-fructose



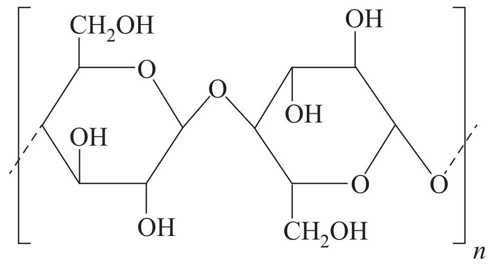
sucrose



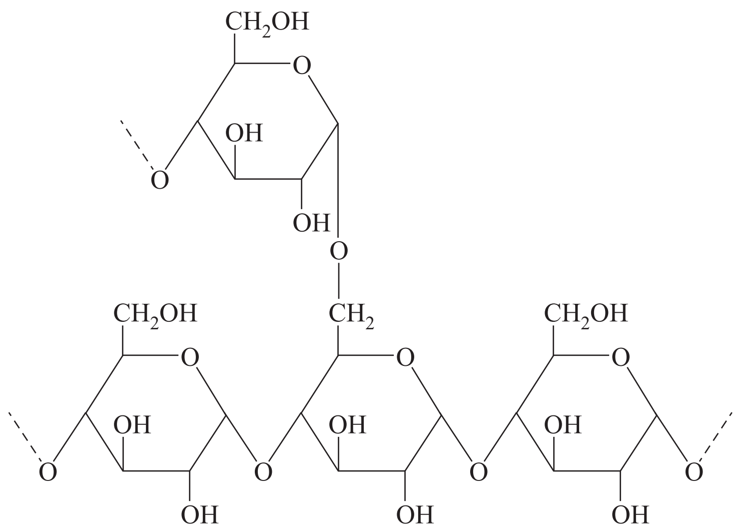
α-lactose



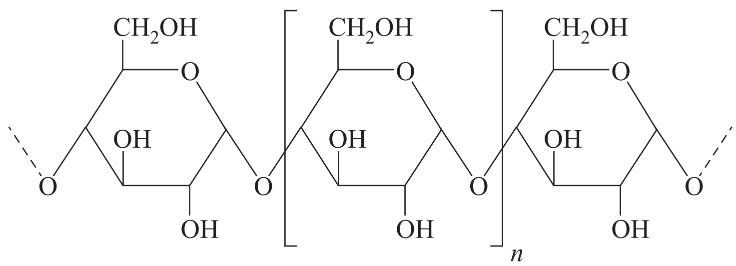
aspartame



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

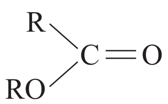
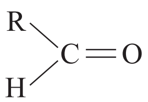
14. Characteristic ranges for infra-red absorption

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

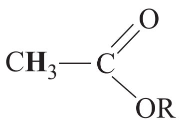
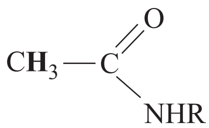
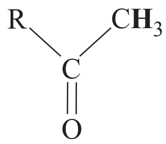
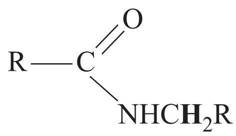
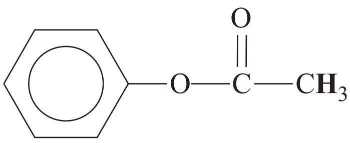
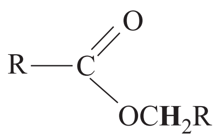
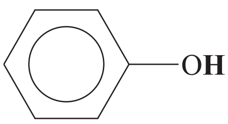
These can differ slightly in different solvents.

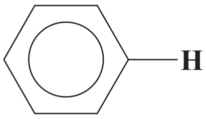
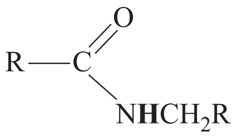
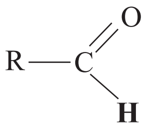
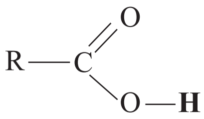
Type of carbon	**Chemical shift (ppm)**
$R–CH_3$	8–25
$R–CH_2–R$	20–45
$R_3–CH$	40–60
$R_4–C$	36–45
$R–CH_2–X$	15–80
$R_3C–NH_2$, $R_3C–NR$	35–70
$R–CH_2–OH$	50–90
RC≡CR	75–95
$R_2C=CR_2$	110–150
RCOOH	160–185
	165–175
	190–200
$R_2C=O$	205–220

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.

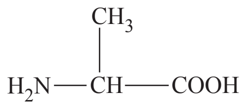
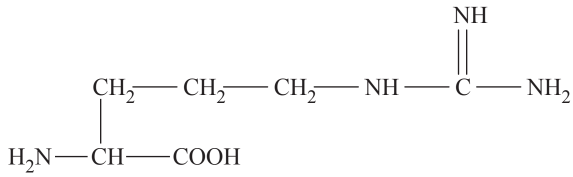
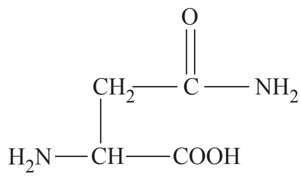
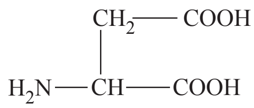
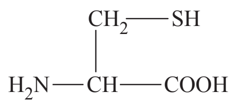
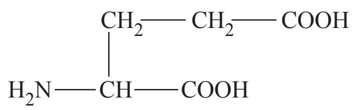
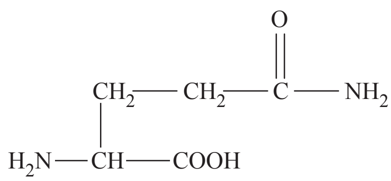
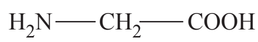
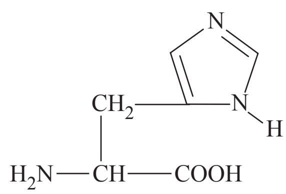
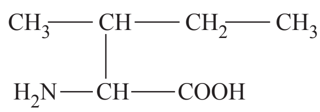
Type of proton	Chemical shift (ppm)
$R{-}C\mathbf{H}_3$	0.9–1.0
$R{-}C\mathbf{H}_2{-}R$	1.3–1.4
$RCH{=}CH{-}C\mathbf{H}_3$	1.6–1.9
$R_3{-}C\mathbf{H}$	1.5
 or 	2.0
	2.1–2.7
$R{-}C\mathbf{H}_2{-}X$ (X = F, Cl, Br or I)	3.0–4.5
$R{-}C\mathbf{H}_2{-}OH$, $R_2{-}C\mathbf{H}{-}OH$	3.3–4.5
	3.2
$R{-}O{-}C\mathbf{H}_3$ or $R{-}O{-}C\mathbf{H}_2R$	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

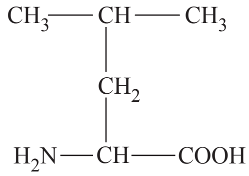
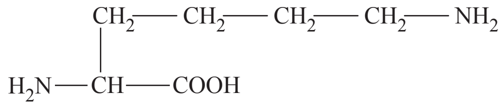
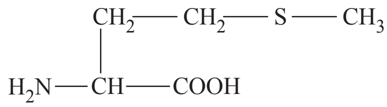
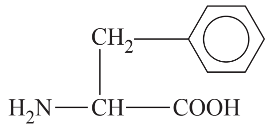
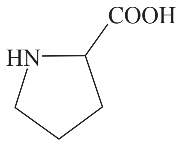
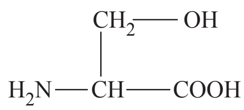
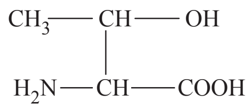
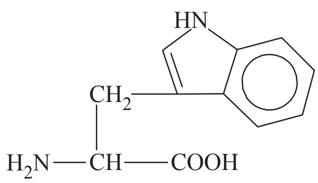
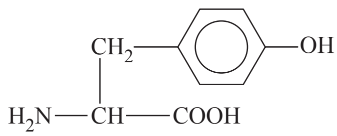
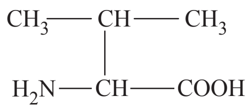
Type of proton	Chemical shift (ppm)
	6.9–9.0
	8.1
	9.4–10.0
	9.0–13.0

TURN OVER

17. 2-amino acids (*α*-amino acids)

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

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

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

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