VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education 2020

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

STUDENT NUMBER									Letter

CHEMISTRY

Written examination

Monday 23 November 2020

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

QUESTION AND ANSWER BOOK

Structure of book

Section	*Number of questions*	*Number of questions to be answered*	*Number of marks*
A	30	30	30
B	10	10	90
			Total 120

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

Materials supplied
- Question and answer book of 39 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

Glycogen breaks down into

A. glycerol.
B. amino acids.
C. triglycerides.
D. monosaccharides.

Question 2

Using large sample sizes in an experiment increases

A. reliability.
B. precision.
C. validity.
D. uncertainty.

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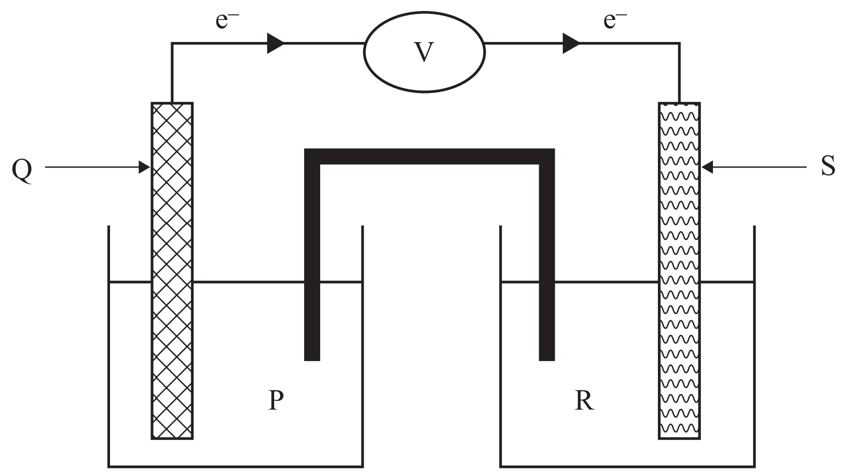
Question 3

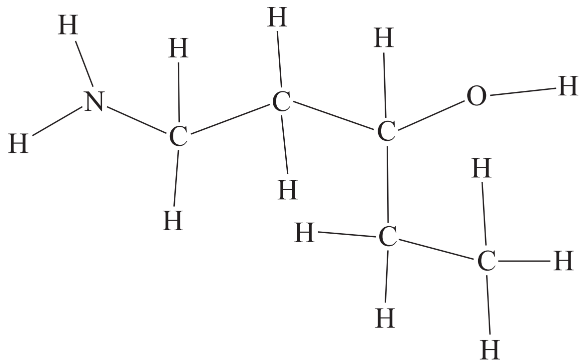
A diagram of an electrochemical cell is shown below.



Which of the following gives the correct combination of the electrode in the oxidation half-cell and the electrolyte in the reduction half-cell?

	Electrode (oxidation half-cell)	**Electrolyte (reduction half-cell)**
A.	S	P
B.	S	R
C.	Q	R
D.	Q	P

Question 4



What is the IUPAC name of the molecule shown above?

A. 3-hydroxy-3-ethyl-propan-1-amine

B. 3-amino-1-methylpropan-1-ol

C. 3-hydroxypentan-1-amine

D. 1-aminopentan-3-ol

Question 5

The metabolic process that produces water is

A. the digestion of fats.

B. cellular respiration.

C. the hydrolysis of starch.

D. the breakdown of protein into amino acids.

Question 6

Which one of the following pairs of statements is correct for both electrolysis cells and galvanic cells?

	Electrolysis cell	Galvanic cell
A.	Both electrodes are always inert.	Both electrodes are always made of metal.
B.	Electrical energy is converted to chemical energy.	The voltage of the cell is independent of the electrolyte concentration.
C.	Chemical energy is converted to electrical energy.	The products are dependent on the half-cell components.
D.	The products are dependent on the half-cell components.	Chemical energy is converted to electrical energy.

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Question 7

How many structural isomers have the molecular formula C_3H_6BrCl?

A. 4

B. 5

C. 6

D. 7

Question 8

Which one of the following is the most correct statement about fuel cells and secondary cells?

A. Fuel cells can be recharged like secondary cells.

B. Fuel cells produce thermal energy, whereas secondary cells do not produce thermal energy.

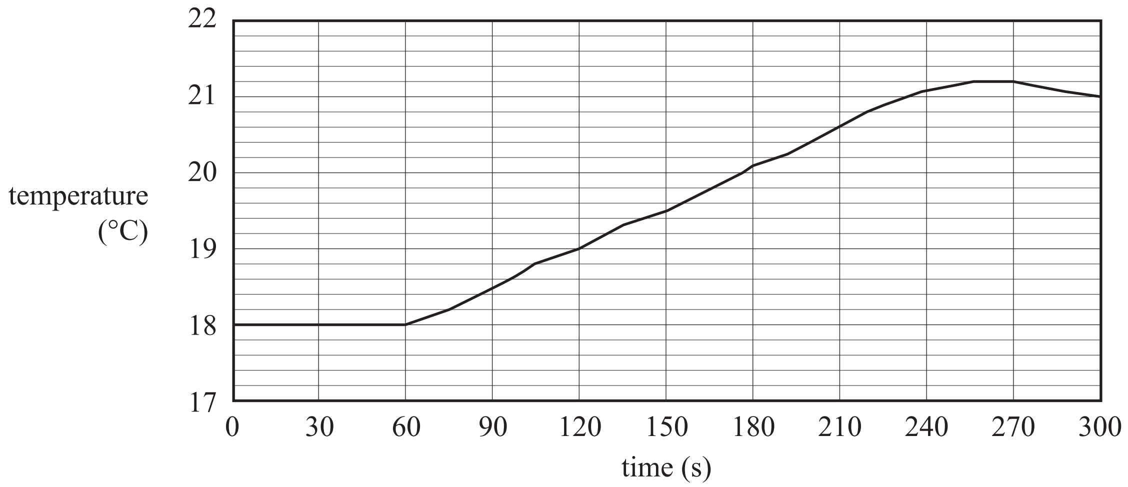
C. The anode in a fuel cell is positive, whereas the anode in a secondary cell is negative.

D. Fuel cells deliver a constant voltage during their operation, whereas secondary cells reduce in voltage as they discharge.

Use the following information to answer Questions 9 and 10.

A solution calorimeter containing 350 mL of water was set up. The calorimeter was calibrated electrically and the graph of the results is shown below.

Graph of temperature versus time during electrical calibration of solution calorimeter



The calorimeter was calibrated using a current of 2.7 A, starting at 60 s. The current was applied for 180 s and the applied voltage was 5.4 V.

Question 9

What is the calibration factor for this calorimeter?

A. 125 J °C^{-1}

B. 820 J °C^{-1}

C. 847 J °C^{-1}

D. 875 J °C^{-1}

Question 10

This type of calorimeter

A. has no heat loss.

B. can be used for bomb calorimetry.

C. requires electrical calibration in order to determine the calibration factor.

D. measures energy changes that can be measured in a bomb calorimeter.

Question 11

Which one of the following statements is correct?

A. Crude oil can be classified as a biofuel because it originally comes from plants.

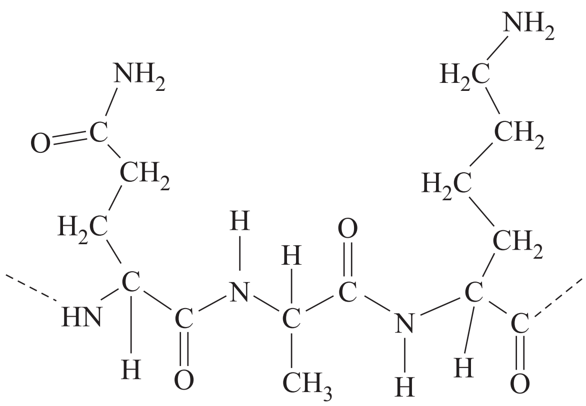
B. Methane, CH_4, can be classified as a fossil fuel because it has major environmental impacts.

C. Ethanol, CH_3CH_2OH, can be classified as a fossil fuel because it can be produced from crude oil.

D. Hydrogen, H_2, can be classified as a biofuel because, when it combusts, it does not produce carbon dioxide, CO_2.

Question 12

The diagram below represents a section of an enzyme.



The diagram can be described as a

A. secondary structure consisting of glutamine, glycine and lysine.

B. primary structure consisting of asparagine, glycine and lysine.

C. secondary structure consisting of asparagine, alanine and lysine.

D. primary structure consisting of glutamine, alanine and lysine.

Question 13

Hydrogen, H_2, fuel cells and H_2-powered combustion engines can both be used to power cars. Three statements about H_2 fuel cells and H_2-powered combustion engines are given below:

I Neither H_2 fuel cells nor H_2-powered combustion engines produce greenhouse gases.

II Less H_2 is required per kilometre travelled when using an H_2-powered combustion engine than when using H_2 fuel cells.

III More heat per kilogram of H_2 is generated in an H_2-powered combustion engine than in H_2 fuel cells.

Which of the statements above are correct?

A. II only

B. I and II only

C. III only

D. I and III only

Use the following information to answer Questions 14 and 15.

The magnitude of the equilibrium constant, K_c, at 25 °C for the following reaction is 640.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92.3 \text{ kJ mol}^{-1}$$

Question 14

For the reaction $\frac{1}{3}N_2(g) + H_2(g) \rightleftharpoons \frac{2}{3}NH_3(g)$, the magnitude of K_c at 25 °C is

A. 9 and $\Delta H = -30.8$ kJ mol^{-1}

B. 213 and $\Delta H = -30.8$ kJ mol^{-1}

C. 640 and $\Delta H = -30.8$ kJ mol^{-1}

D. 640 and $\Delta H = -92.3$ kJ mol^{-1}

Question 15

For the reaction $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

A. a catalyst increases the number of collisions between the reactants.

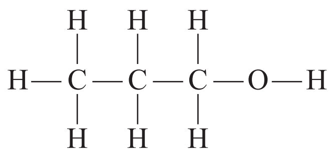
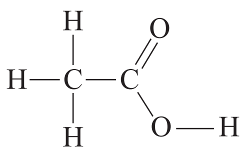
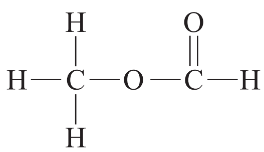
B. the rate of the forward reaction increases when the temperature increases.

C. a catalyst reduces the activation energy of the forward and backward reactions by the same proportion.

D. the activation energy of the forward reaction is greater than the activation energy of the reverse reaction.

Question 16

The following table provides information about three organic compounds, X, Y and Z.

Compound	Structural formula	Molar mass (g mol^{-1})	Boiling point (°C)
X		60	97
Y		60	118
Z		60	?

Which one of the following is the best estimate for the boiling point of Compound Z?

A. 31 °C

B. 101 °C

C. 114 °C

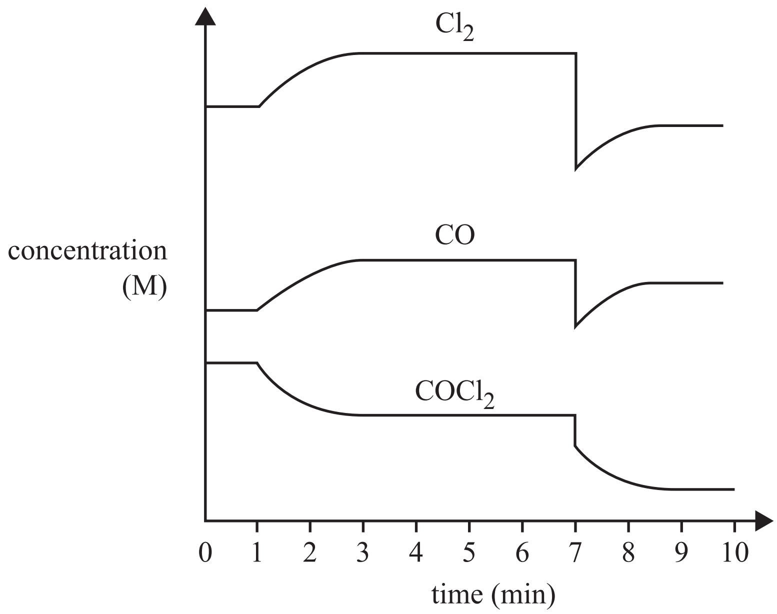
D. 156 °C

Question 17

The following equation represents the reaction between chlorine gas, Cl_2, and carbon monoxide gas, CO.

$$Cl_2(g) + CO(g) \rightleftharpoons COCl_2(g) \qquad \Delta H = -108 \text{ kJ mol}^{-1}$$

The concentration–time graph below represents changes to the system.



Which of the following identifies the changes to the system that took place at 1 minute and at 7 minutes?

	1 minute	7 minutes
A.	increase in temperature	increase in volume
B.	decrease in temperature	decrease in volume
C.	decrease in temperature	increase in volume
D.	increase in temperature	decrease in volume

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Question 18

An experiment was carried out to determine the enthalpy of combustion of propan-1-o1. Combustion of 557 mg of propan-1-o1 increased the temperature of 150 g of water from 22.1 °C to 40.6 °C.

The enthalpy of combustion is closest to

A. -2742 kJ mol^{-1}

B. -1208 kJ mol^{-1}

C. -1250 kJ mol^{-1}

D. -1540 kJ mol^{-1}

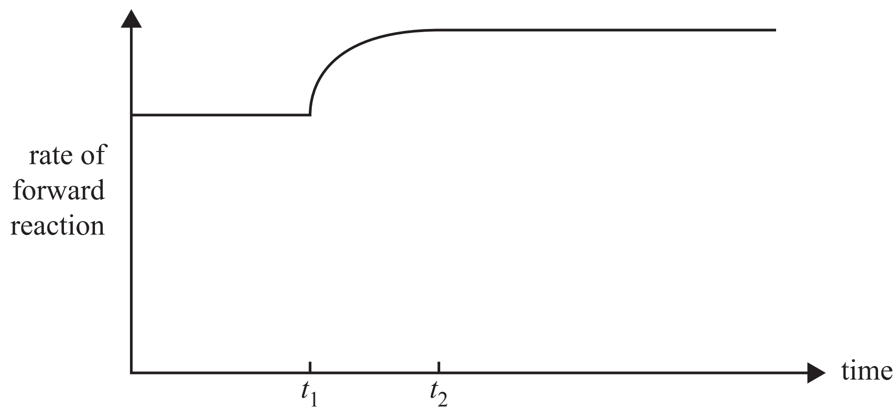
Question 19

Nitrogen dioxide, NO_2, and dinitrogen tetroxide, N_2O_4, form an equilibrium mixture represented by the following equation.

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad \Delta H = -57.2 \text{ kJ mol}^{-1}$$

brown colourless

A change was made at time t_1 to an equilibrium mixture of NO_2 and N_2O_4, which achieved a new equilibrium at time t_2. A graph showing the rate of the forward reaction is shown below.



Which one of the following describes the change that was made to the initial equilibrium system and the colour change that occurred between t_1 and t_2?

A. The temperature was increased and the colour lightened.

B. The temperature was increased and the colour darkened.

C. The temperature was decreased and the colour lightened.

D. The temperature was decreased and the colour darkened.

Question 20

Consider the following changes that could be applied to the operating parameters for a chromatogram set up to carry out high-performance liquid chromatography (HPLC) with a polar stationary phase and a non-polar mobile phase:

I decreasing the viscosity of the mobile phase

II using a more tightly packed stationary phase

III using a mobile phase that is more polar than the stationary phase

Which of the changes would be most likely to reduce the retention time of a sugar in the HPLC?

A. I only

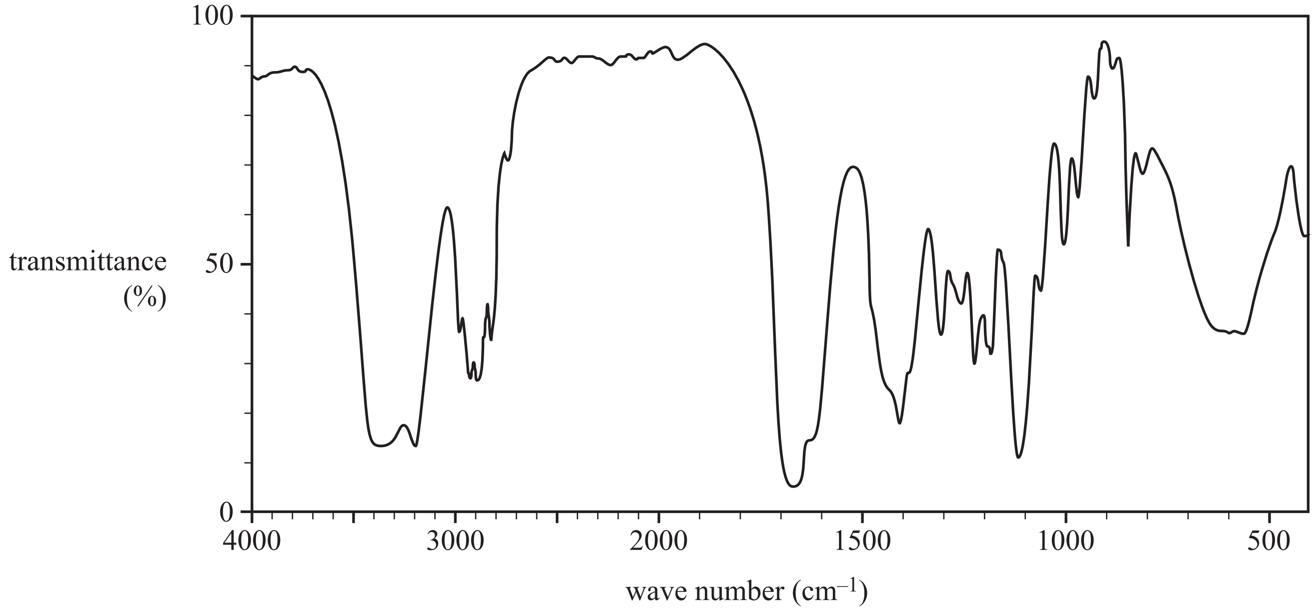
B. I and III only

C. III only

D. II and III only

Question 21

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



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

Referring to the IR spectrum above, the compound could be

A. $CH_3CH_2COOCH_3$

B. $CH_3CH_2CH_2CHO$

C. $NH_2CH_2CH_2CONH_2$

D. $NH_2CH_2CH_2CHOHCH_3$

Question 22

The combustion of which fuel provides the most energy per 100 g?

A. pentane (M = 72 g mol^{-1}), which releases 49 097 MJ $tonne^{-1}$

B. nitromethane (M = 61 g mol^{-1}), which releases 11.63 kJ g^{-1}

C. butanol (M = 74 g mol^{-1}), which releases 2670 kJ mol^{-1}

D. ethyne (M = 26 g mol^{-1}), which releases 1300 kJ mol^{-1}

Use the following information to answer Questions 23 and 24.

A solution of citric acid, $C_3H_5O(COOH)_3$, was analysed by titration.

25.0 mL aliquots of the $C_3H_5O(COOH)_3$ solution were titrated against a standardised solution of 0.0250 M sodium hydroxide, NaOH. Phenolphthalein indicator was used and the average titre was found to be 24.0 mL.

Question 23

Based on the titration, the concentration of $C_3H_5O(COOH)_3$ in the solution was

A. 8.0×10^{-3} M

B. 8.7×10^{-3} M

C. 2.6×10^{-2} M

D. 7.2×10^{-2} M

Question 24

Which one of the following would have resulted in a concentration that is higher than the actual concentration?

A. The pipette was rinsed with NaOH solution.

B. The pipette was rinsed with $C_3H_5O(COOH)_3$ solution.

C. The conical flask was rinsed with NaOH solution.

D. The conical flask was rinsed with $C_3H_5O(COOH)_3$ solution.

Question 25

Petrodiesel is made up of a number of different molecules, including $C_{12}H_{26}$. Biodiesel often contains $C_{11}H_{22}O_2$.

When comparing $C_{12}H_{26}$ and $C_{11}H_{22}O_2$, which one of the following statements is correct?

A. $C_{12}H_{26}$ has a higher viscosity due to the dispersion forces between the molecules.

B. $C_{12}H_{26}$ is less hygroscopic as it has only dispersion forces between the molecules.

C. $C_{11}H_{22}O_2$ has a higher energy content when it combusts as it contains oxygen atoms.

D. $C_{11}H_{22}O_2$ produces more carbon dioxide per mole when it combusts due to its higher molecular weight.

Question 26

The following reactions occur in a primary cell battery.

$$Zn + 2OH^- \rightarrow ZnO + H_2O + 2e^-$$
$$2MnO_2 + 2e^- + H_2O \rightarrow Mn_2O_3 + 2OH^-$$

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

A. The reaction produces heat and Zn reacts directly with MnO_2.

B. The reaction produces heat and Zn does not react directly with MnO_2.

C. The reaction does not produce heat and Zn reacts directly with MnO_2.

D. The reaction does not produce heat and Zn does not react directly with MnO_2.

Use the following information to answer Questions 27 and 28.

The heat of combustion of ethanoic acid, $C_2H_4O_2$, is −876 kJ mol^{-1} and the heat of combustion of methyl methanoate, $C_2H_4O_2$, is −973 kJ mol^{-1}. The auto-ignition temperature (the temperature at which a substance will combust in air without a source of ignition) of ethanoic acid is 485 °C and the auto-ignition temperature of methyl methanoate is 449 °C.

Question 27

Which one of the following pairs is correct?

	Compound with the lower chemical energy per mole	Compound with the lower activation energy of combustion per mole
A.	ethanoic acid	methyl methanoate
B.	ethanoic acid	ethanoic acid
C.	methyl methanoate	methyl methanoate
D.	methyl methanoate	ethanoic acid

Question 28

If 0.1 mol of ethanoic acid and 0.1 mol of methyl methanoate were completely combusted in two separate closed vessels under identical conditions, the Maxwell-Boltzmann distribution of the product gases from the combustion of ethanoic acid would be

A. broader than the Maxwell-Boltzmann distribution of the methyl methanoate product gases and the chemical energy of the product gases would be identical.

B. narrower than the Maxwell-Boltzmann distribution of the methyl methanoate product gases and the chemical energy of the product gases would be identical.

C. broader than the Maxwell-Boltzmann distribution of the methyl methanoate product gases and the chemical energy of the ethanoic acid product gases would be higher.

D. narrower than the Maxwell-Boltzmann distribution of the methyl methanoate product gases and the chemical energy of the ethanoic acid product gases would be higher.

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Question 29

Which of the following combinations of bonds can be broken during the breakdown of a protein that a person has eaten?

A. covalent bonds in the secondary structure and hydrogen bonds in the primary structure

B. covalent bonds in the tertiary structure and hydrogen bonds in the secondary structure

C. covalent bonds in the secondary structure and hydrogen bonds in the tertiary structure

D. covalent bonds in the quaternary structure and hydrogen bonds in the primary structure

Question 30

Consider the following half-equation.

$$ClO_2(g) + e^- \rightleftharpoons ClO_2^-(aq)$$

It is also known that:

- $ClO_2(g)$ will oxidise HI(aq), but not HCl(aq)
- $Fe^{3+}(aq)$ will oxidise HI(aq), but not $NaClO_2(aq)$.

Based on this information, $Fe^{2+}(aq)$ can be oxidised by

A. $Cl_2(g)$ and $I_2(aq)$.

B. $Cl_2(g)$, but not $ClO_2(g)$.

C. $ClO_2(g)$ and $Cl_2(g)$, but not $I_2(aq)$.

D. $Cl_2(g)$, $ClO_2(g)$ and $I_2(aq)$.

END OF SECTION A

TURN OVER

SECTION B

Instructions for Section B

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

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

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

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

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

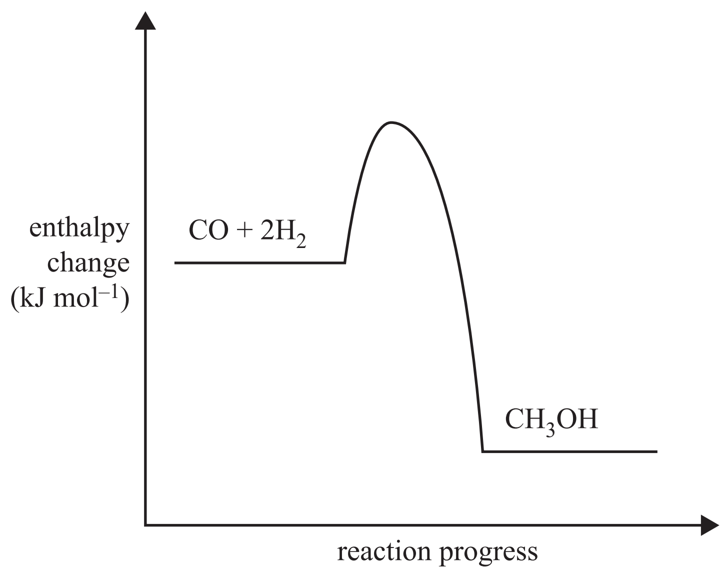
Question 1 (9 marks)

Methanol is a very useful fuel. It can be manufactured from biogas.

The main reaction in methanol production from biogas is represented by the following equation.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H < 0$$

This reaction requires the use of a catalyst to maximise the yield of methanol produced in optimum conditions. The energy profile diagram below represents the uncatalysed reaction.



a. On the energy profile diagram above, sketch how the catalyst would alter the reaction pathway. 1 mark

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b. **i.** How does the reaction temperature affect the yield of methanol from biogas? In your answer, refer to Le Chatelier's principle. 2 marks

ii. How does the reaction pressure affect the yield of methanol from biogas? In your answer, refer to Le Chatelier's principle. 2 marks

c. Write the expression for the equilibrium constant, K_c, for this reaction. 1 mark

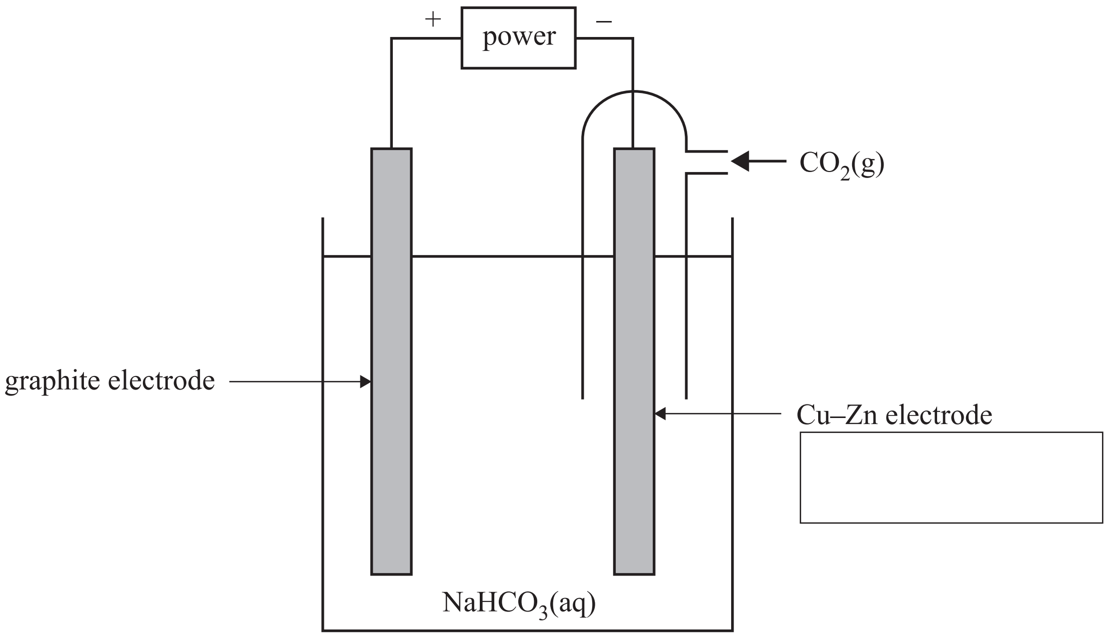
d. 0.760 mol of carbon monoxide, CO, and 0.525 mol of hydrogen, H_2, were allowed to reach equilibrium in a 500 mL container. At equilibrium the mixture contained 0.122 mol of methanol.

Calculate the equilibrium constant, K_c. 3 marks

Question 2 (8 marks)

The electrolysis of carbon dioxide gas, CO_2, in water is one way of making ethanol, C_2H_5OH.

The diagram below shows a CO_2–H_2O electrolysis cell. The electrolyte used in the electrolysis cell is sodium bicarbonate solution, $NaHCO_3(aq)$.



The following half-cell reactions occur in the CO_2–H_2O electrolysis cell.

$$O_2(g) + 2H_2O(l) + 4e^- \rightleftharpoons 4OH^-(aq) \qquad E^0 = +0.40 \text{ V}$$

$$2CO_2(g) + 9H_2O(l) + 12e^- \rightleftharpoons C_2H_5OH(l) + 12OH^-(aq) \qquad E^0 = -0.33 \text{ V}$$

a. Identify the Cu–Zn electrode as either the anode or the cathode in the box provided in the diagram above. 1 mark

b. Determine the applied voltage required for the electrolysis cell to operate. 1 mark

c. Write the balanced equation for the overall electrolysis reaction. 1 mark

SECTION B – **Question 2** – continued

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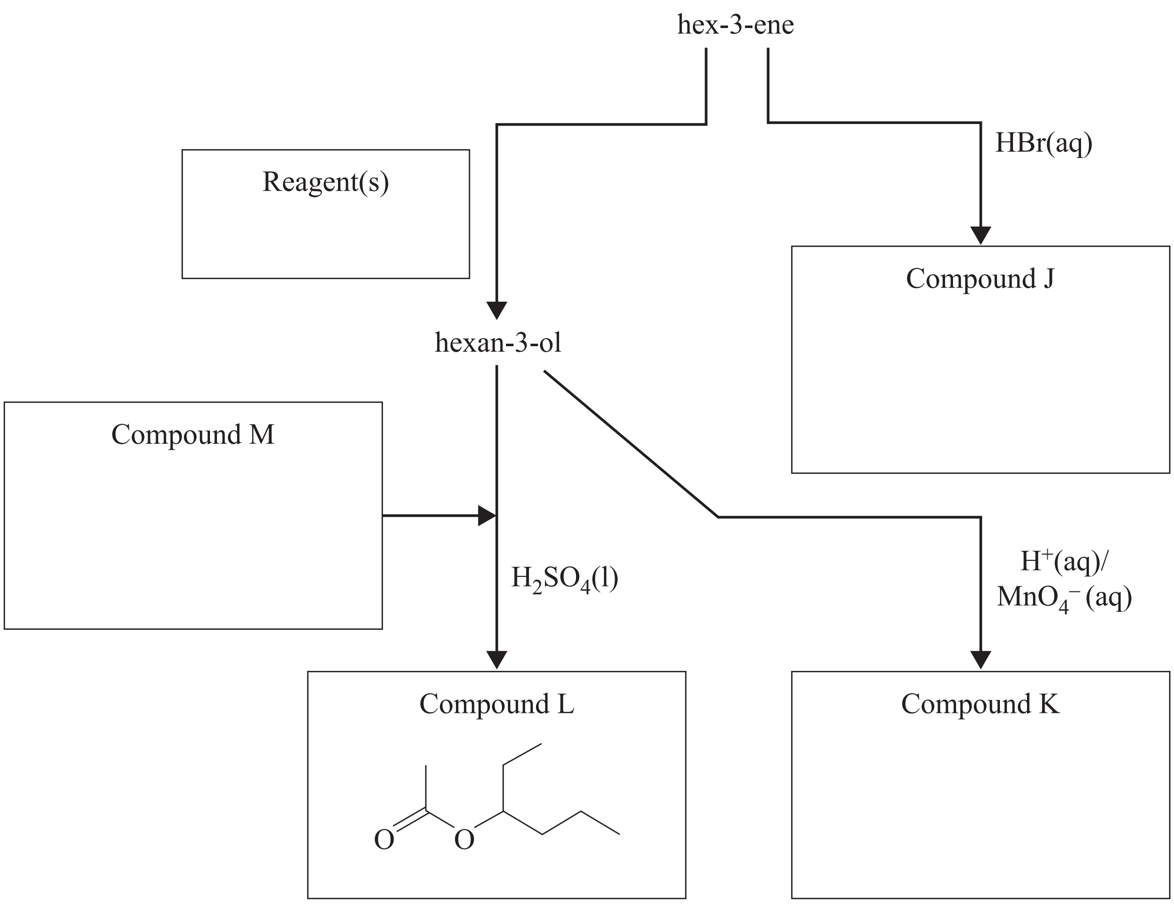
d. Identify the oxidising agent in the electrolysis reaction. Give your reasoning using oxidation numbers. 2 marks

e. A current of 2.70 A is passed through the CO_2–H_2O electrolysis cell. The cell has an efficiency of 58%.

Calculate the time taken, in minutes, for this cell to consume 6.05×10^{-3} mol of $CO_2(g)$. 3 marks

Question 3 (7 marks)

Below is a reaction pathway beginning with hex-3-ene.



a. Write the IUPAC name of Compound J in the box provided. 1 mark

b. State the reagent(s) required to convert hex-3-ene to hexan-3-ol in the box provided. 1 mark

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c. Draw the structural formula for a tertiary alcohol that is an isomer of hexan-3-ol. 1 mark

d. Hexan-3-ol is reacted with Compound M under acidic conditions to produce Compound L.

Draw the semi-structural formula for Compound M in the box provided on page 20. 1 mark

e. **i.** Draw the semi-structural formula for Compound K in the box provided on page 20. 1 mark

ii. Name the class of organic compound (homologous series) to which Compound K belongs. 1 mark

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f. What type of reaction produces Compound K from hexan-3-ol? 1 mark

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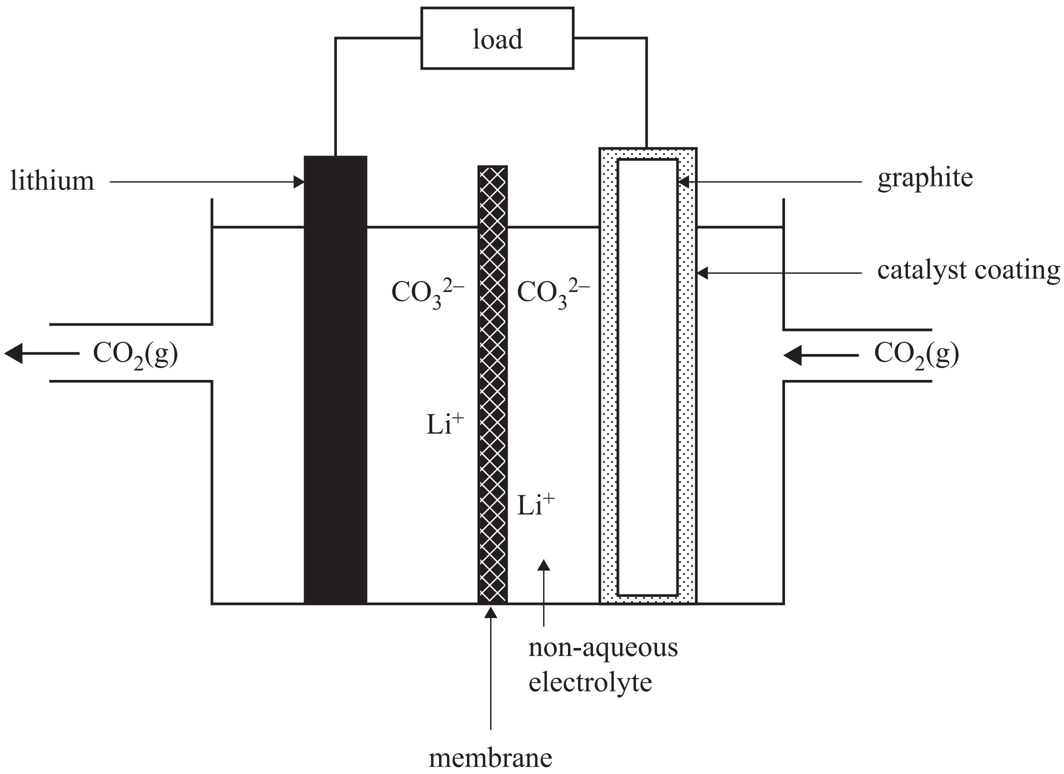
Question 4 (7 marks)

Research scientists are developing a rechargeable lithium–carbon dioxide, Li–CO_2, battery. The rechargeable Li–CO_2 battery is made of lithium metal, carbon in the form of graphite (coated with a catalyst) and a non-aqueous electrolyte that absorbs CO_2.

A diagram of the rechargeable Li–CO_2 cell is shown below. One Li–CO_2 cell generates 4.5 V.



a. When the Li–CO_2 cell generates electricity, the two half-cell reactions are

$$4Li^+ + 3CO_2 + 4e^- \rightarrow 2Li_2CO_3 + C$$
$$Li \rightarrow Li^+ + e^-$$

Write the equation for the overall recharge reaction. 1 mark

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b. During discharge, lithium carbonate, Li_2CO_3, deposits break away from the electrode.

Describe how this might affect the performance of the battery. 2 marks

c. Explain why it is unsafe to use an aqueous electrolyte in the design of the Li–CO_2 battery. Include appropriate equations in your answer. 3 marks

d. Could the Li–CO_2 battery be used to reduce the amount of CO_2(g) in the atmosphere? Give your reasoning. 1 mark

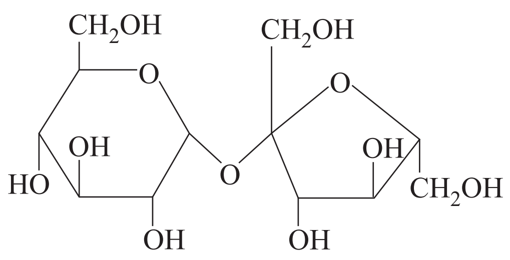
Question 5 (9 marks)

Bananas provide essential vitamins and minerals, such as vitamin B_6 and vitamin C, along with dietary fibre and energy. During the ripening process, the banana changes in appearance, texture and taste.

A ripe banana contains a high amount of glucose, whereas an unripe banana contains up to 80% starch.

a. Write a balanced equation for cellular respiration. 1 mark

b. The structure of a disaccharide found in a ripe banana is shown below.



i. On the structure above, circle and name the link that joins the two sugar units that make up the disaccharide. 1 mark

ii. Name the two sugar units that make up this disaccharide. 1 mark

iii. Banana skins are primarily composed of cellulose.

Suggest why cellulose cannot be used as a source of energy in the human body. 1 mark

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c. The table below shows the amount of each nutrient in 100 g of banana.

Nutrient	Per 100 g
protein	1.1 g
carbohydrates	22.8 g
fat	0.3 g
dietary fibre	2.6 g

An athlete uses 300 kJ of energy for a five-minute run. A typical ripe banana has an average mass of 116 g after it is peeled.

How many typical ripe bananas, correct to two decimal places, would the athlete need to consume to replace the energy used during the run? Show your working. 3 marks

d. During the ripening process, the enzyme amylase breaks down starch molecules into disaccharides and monosaccharides.

i. What name is given to this type of reaction? 1 mark

ii. The amino acid lysine is present in the primary sequence of amylase.

Draw the structural formula for the amino acid lysine in a low-pH solution. 1 mark

Question 6 (8 marks)

Methane gas, CH_4, can be captured from the breakdown of waste in landfills. CH_4 is also a primary component of natural gas. CH_4 can be used to produce energy through combustion.

a. Write the equation for the incomplete combustion of CH_4 to produce carbon monoxide, CO. 1 mark

b. If 20.0 g of CH_4 is kept in a 5.0 L sealed container at 25 °C, what would be the pressure in the container? 2 marks

c. A Bunsen burner is used to heat a beaker containing 350.0 g of water. Complete combustion of 0.485 g of CH_4 raises the temperature of the water from 20 °C to 32.3 °C.

Calculate the percentage of the Bunsen burner's energy that is lost to the environment. 3 marks

d. Compare the environmental impact of CH_4 obtained from landfill to the environmental impact of CH_4 obtained from natural gas. 2 marks

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Question 7 (15 marks)

Inside the shell of an egg is egg white that encircles egg yolk. The nutrition information for egg yolk and egg white is given in Table 1.

Table 1

Nutrient	Per 100 g of egg yolk	Per 100 g of egg white
energy	1437 kJ	184 kJ
fat	27.0 g	trace amounts
carbohydrate	0.0 g	0.0 g
protein	16.4 g	10.8 g

a. Poaching an egg involves cracking an egg and carefully placing the contents in a pan of hot water. This allows the egg white to solidify around the egg yolk.

Using your knowledge of chemistry, explain why vinegar is sometimes added to the water to produce a poached egg with a runny yolk. 3 marks

b. The composition of fatty acids found in an egg yolk sample is given in Table 2. The melting points for the first three fatty acids are provided.

Table 2

Fatty acid	Percentage (%)	Melting point (°C)
palmitic	25.9	63
stearic	9.1	69
palmitoleic	3.4	0
oleic	40.9	
linoleic	16.3	
linolenic	2.9	
arachidonic	1.5	

i. The composition of fatty acids in an egg yolk was determined by reacting the fatty acids with methanol to produce methyl esters and then analysing the methyl esters using chromatography.

Explain, using the principles of chromatography, how each fatty acid in the egg yolk sample can be identified and the percentage determined. 3 marks

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ii. Identify the fatty acid in Table 2 that would have the lowest flash point. Explain your answer in terms of both the:

- melting point trends shown in Table 2
- structure and bonding of the fatty acids. 4 marks

c. **i.** Give the molecular formula and the molar mass of the triglyceride formed from three palmitoleic acid molecules. 2 marks

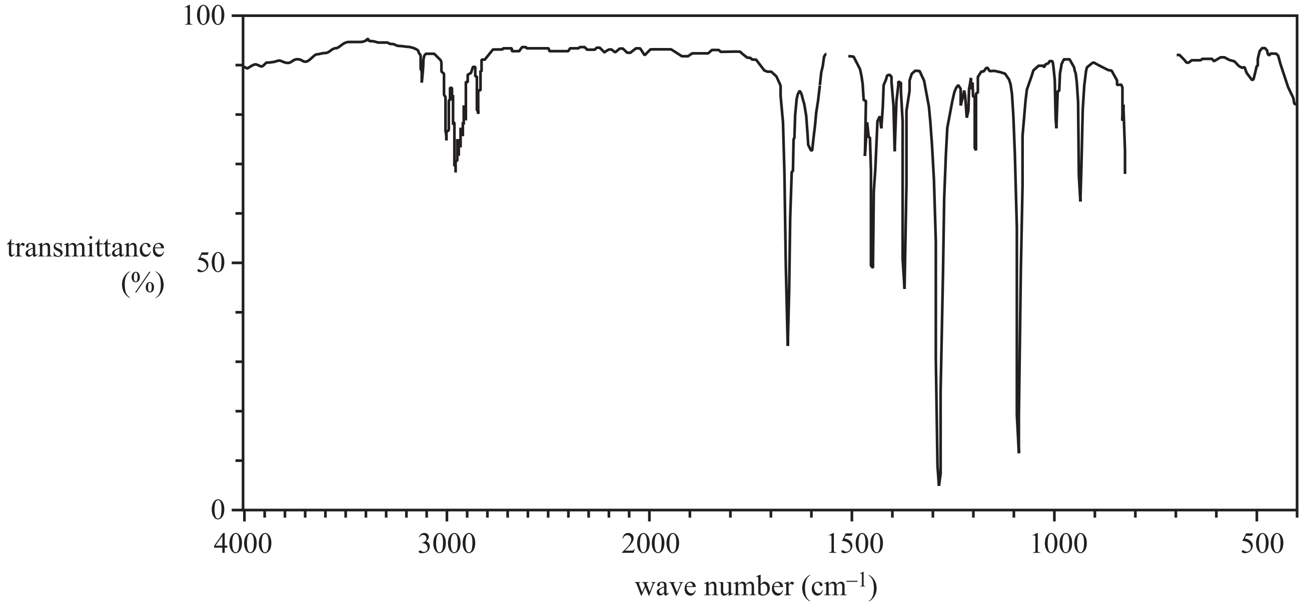
ii. Calculate the mass of iodine, I_2, in grams, that reacts in an addition reaction with 100.0 g of the triglyceride formed from three palmitoleic acid molecules. 3 marks

Question 8 (7 marks)

An unknown organic compound has a molecular formula of C_4H_8O.

The compound is **non-cyclic** and contains a **double bond**.

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



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

a. What does the region 3100–4000 cm^{-1} indicate about the bonds in C_4H_8O? Give your reasoning. 2 marks

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b. The ^{13}C NMR spectrum of the unknown compound has four distinct peaks.

Draw **two** possible structural formulas of the unknown compound using the information provided. 2 marks

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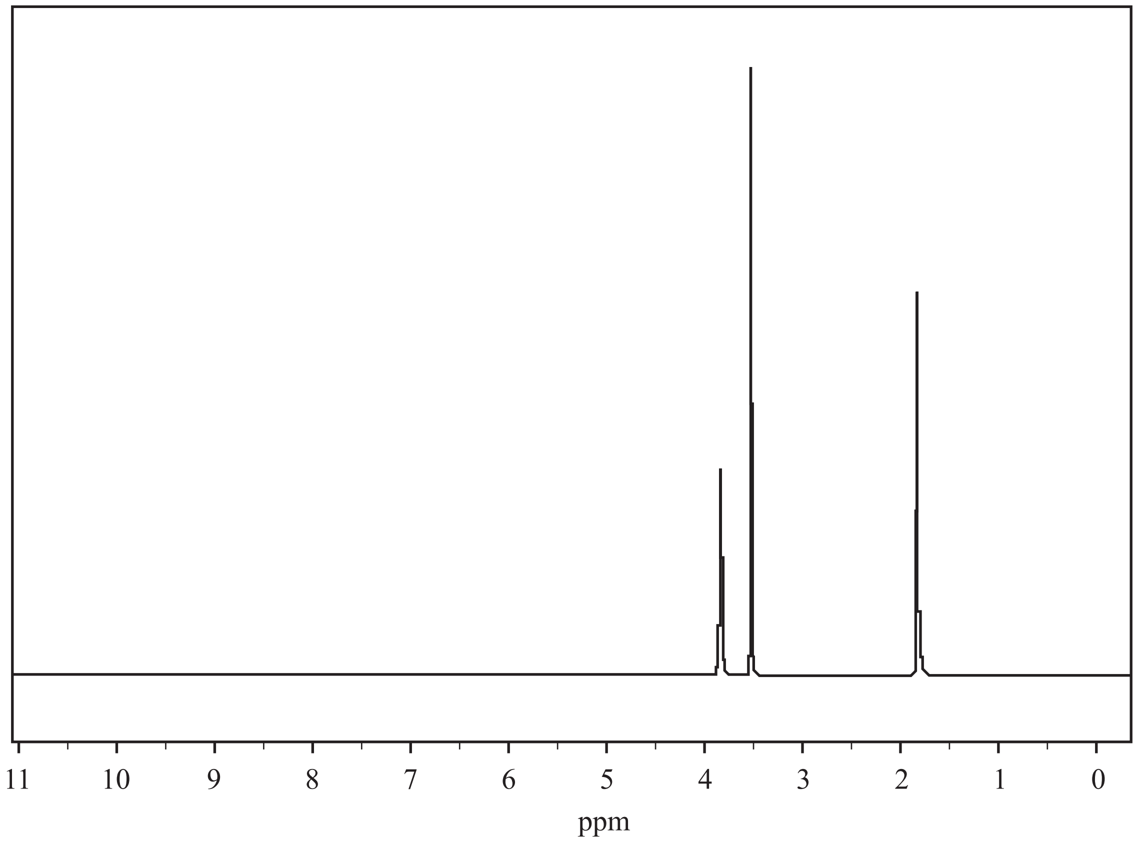
c. The high-resolution ^{1}H NMR spectrum of the unknown compound has three single peaks, as shown below.



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

Chemical shift (ppm)	Relative peak area
1.82	3
3.53	3
3.85	2

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Refer to the ^{1}H NMR spectrum and the table of spectrum information provided on page 32.

Identify three pieces of information about the unknown compound and indicate how each would assist in determining its structure. 3 marks

1. ______________________________

____

2. ______________________________

____

3. ______________________________

____

Question 9 (13 marks)

A student decided to investigate the effect of temperature on the rate of the following reaction.

$$2HCl(aq) + CaCO_3(s) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

Part of the student's experimental report is provided below.

Effect of temperature on the rate of production of carbon dioxide gas

Aim

To find out how temperature affects the rate of production of carbon dioxide gas, CO_2, when a solution of hydrochloric acid, HCl, is added to chips of calcium carbonate, $CaCO_3$

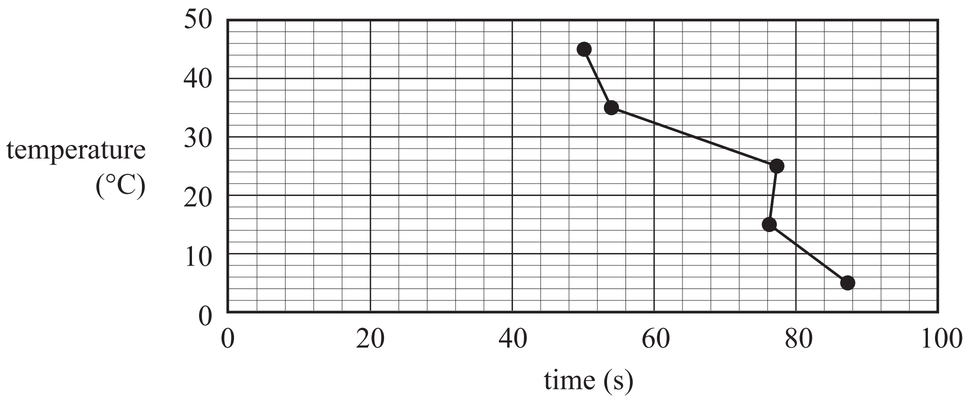
Method

1. Put 0.6 g of $CaCO_3$ chips into a conical flask.
2. Put a reagent bottle containing 2 M HCl into a water bath at 5 °C.
3. When the temperature of the HCl solution has stabilised at 5 °C, use a pipette to put 10.0 mL of the HCl solution into the conical flask containing the $CaCO_3$ chips.
4. Put a balloon over the conical flask and begin timing.
5. When the top of the balloon has inflated so that it is 10 cm over the conical flask, stop timing and record the time.
6. Repeat steps 1–5 using temperatures of 15 °C, 25 °C, 35 °C and 45 °C.

Results

The following graph gives the experimental results.

Graph of experimental results



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a. What does the student need to do to ensure that they comply with all applicable safety guidelines during the investigation? 2 marks

b. What is the independent variable? 1 mark

c. What is the dependent variable and how is it measured? 2 marks

d. **i.** Predict the relationship between the independent variable and the dependent variable. Explain your prediction. 3 marks

ii. Is the graph of the student's results consistent with your prediction? Give your reasoning. 1 mark

e. Identify **two** ways in which the graph could have been presented differently to better illustrate the relationship between the independent variable and the dependent variable. 2 marks

f. Identify **two** changes that could be made to the experimental method to improve the precision of the results if the experiment was repeated. For each change, explain how it would improve precision. 2 marks

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Question 10 (7 marks)

> Analytical chemistry deals with methods for determining the chemical composition of samples of matter. A qualitative method yields information about the identity of atomic or molecular species or the functional groups in the sample …
>
> Analytical methods are often classified as being either *classical* or *instrumental*.

Source: DA Skoog, FJ Holler and SR Crouch, *Principles of Instrumental Analysis*, 6th edition, Thomson Brooks/Cole, Belmont (CA), 2007, p. 1

Classical methods include qualitative analysis, such as treating a compound with reagents to observe any reaction, and quantitative methods, such as volumetric analysis, where the amount of a compound is determined by its reaction with a standard reagent.

Instrumental methods include a variety of spectroscopy, such as IR spectroscopy and NMR spectroscopy.

a. Explain how the classical methods of analytical chemistry can be used to determine information about alcohols. In your answer, refer to:

- qualitative analysis and how it can be used to determine whether a compound is an alcohol and, if it is, the type of alcohol
- quantitative analysis. 3 marks

b. C_3H_6O can exist as a ketone or as a primary alcohol.

Explain how the principles of IR spectroscopy and ^{1}H NMR spectroscopy lead to different spectra for the ketone and primary alcohol isomers of C_3H_6O, which can then be used to differentiate between the two molecules. 4 marks

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END OF QUESTION AND ANSWER BOOK

VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education
2020

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

Key: atomic number (79); symbol of element (**Au**); relative atomic mass (197.0); name of element (gold)

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

57 **La** 138.9 lanthanum	**58** **Ce** 140.1 cerium	**59** **Pr** 140.9 praseodymium	**60** **Nd** 144.2 neodymium	**61** **Pm** (145) promethium	**62** **Sm** 150.4 samarium	**63** **Eu** 152.0 europium	**64** **Gd** 157.3 gadolinium	**65** **Tb** 158.9 terbium	**66** **Dy** 162.5 dysprosium	**67** **Ho** 164.9 holmium	**68** **Er** 167.3 erbium	**69** **Tm** 168.9 thulium	**70** **Yb** 173.1 ytterbium	**71** **Lu** 175.0 lutetium
89 **Ac** (227) actinium	**90** **Th** 232.0 thorium	**91** **Pa** 231.0 protactinium	**92** **U** 238.0 uranium	**93** **Np** (237) neptunium	**94** **Pu** (244) plutonium	**95** **Am** (243) americium	**96** **Cm** (247) curium	**97** **Bk** (247) berkelium	**98** **Cf** (251) californium	**99** **Es** (252) einsteinium	**100** **Fm** (257) fermium	**101** **Md** (258) mendelevium	**102** **No** (259) nobelium	**103** **Lr** (262) lawrencium

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

2. Electrochemical series

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

3. Chemical relationships

Name	Formula
number of moles of a substance	$n = \frac{m}{M}$; $n = cV$; $n = \frac{V}{V_m}$
universal gas equation	$pV = nRT$
calibration factor (CF) for bomb calorimetry	$\text{CF} = \frac{VIt}{\Delta T}$
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	$n(e^-) = \frac{Q}{F}$

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

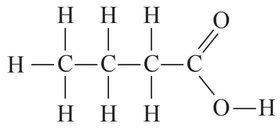
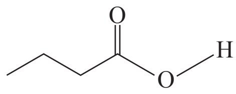
Metric (including SI) prefixes	Scientific notation	Multiplying factor
giga (G)	10^9	1 000 000 000
mega (M)	10^6	1 000 000
kilo (k)	10^3	1000
deci (d)	10^{-1}	0.1
centi (c)	10^{-2}	0.01
milli (m)	10^{-3}	0.001
micro (μ)	10^{-6}	0.000001
nano (n)	10^{-9}	0.000000001
pico (p)	10^{-12}	0.000000000001

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

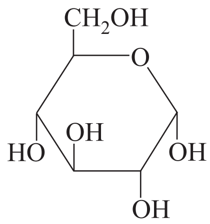
The following table shows different representations of organic molecules, using butanoic acid as an example.

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	

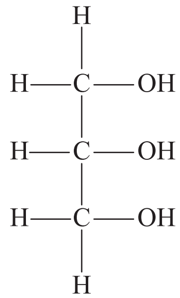
9. Formulas of some fatty acids

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

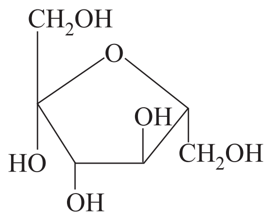
10. Formulas of some biomolecules



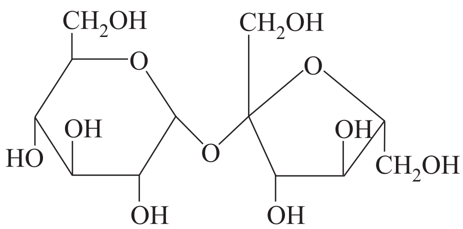
α-glucose



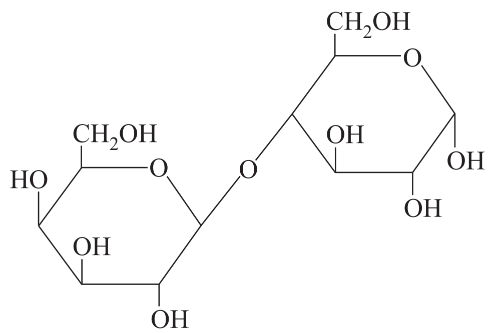
glycerol



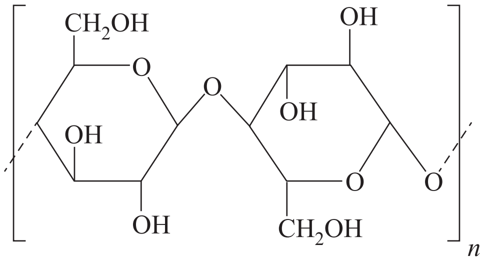
β-fructose



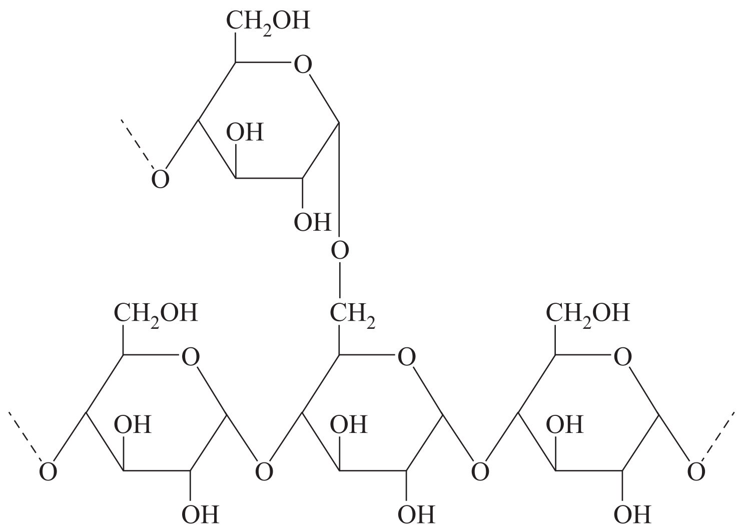
sucrose



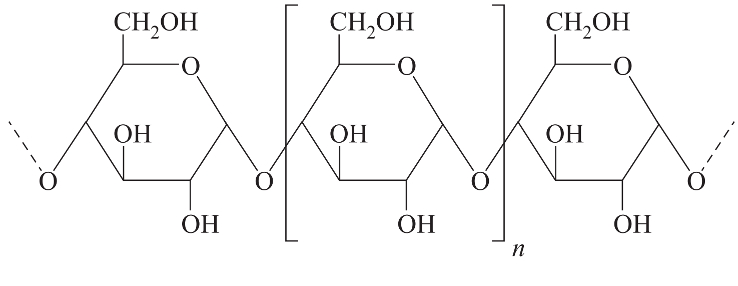
α-lactose



cellulose



amylopectin (starch)



amylose (starch)

11. Heats of combustion of common fuels

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

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

12. Heats of combustion of common blended fuels

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

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

13. Energy content of food groups

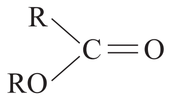
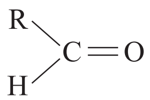
Food	Heat of combustion ($kJ\ g^{-1}$)
fats and oils	37
protein	17
carbohydrate	16

14. Characteristic ranges for infra-red absorption

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

15. ^{13}C NMR data

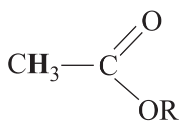
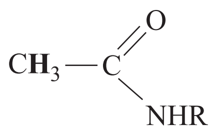
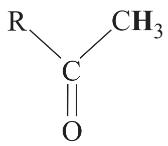
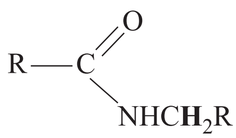
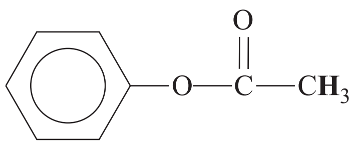
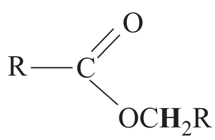
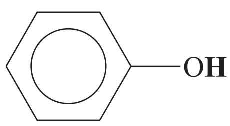
Typical ^{13}C shift values relative to TMS = 0
These can differ slightly in different solvents.

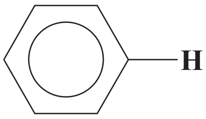
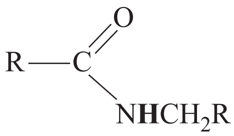
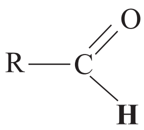
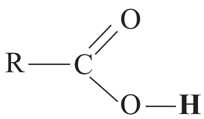
Type of carbon	Chemical shift (ppm)
$R–CH_3$	8–25
$R–CH_2–R$	20–45
$R_3–CH$	40–60
$R_4–C$	36–45
$R–CH_2–X$	15–80
$R_3C–NH_2$, $R_3C–NR$	35–70
$R–CH_2–OH$	50–90
RC≡CR	75–95
$R_2C=CR_2$	110–150
RCOOH	160–185
	165–175
	190–200
$R_2C=O$	205–220

16. ^{1}H NMR data

Typical proton shift values relative to TMS = 0

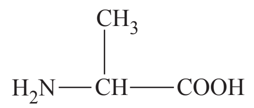
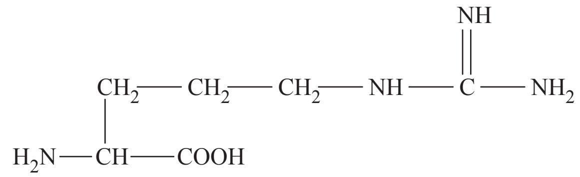
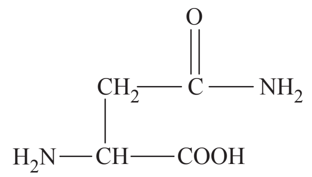
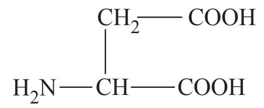
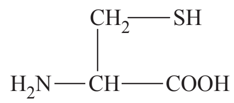
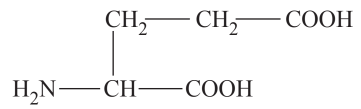
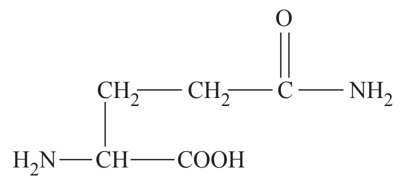
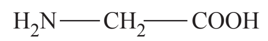
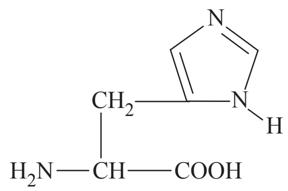
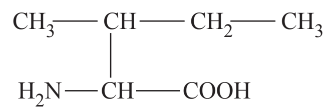
These can differ slightly in different solvents. The shift refers to the proton environment that is indicated in bold letters in the formula.

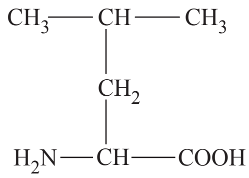
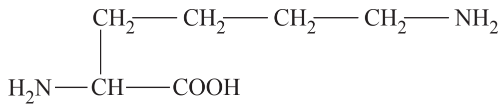
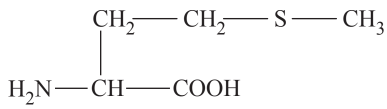
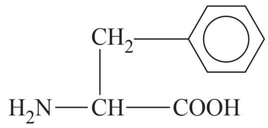
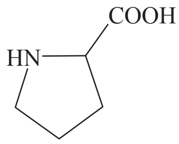
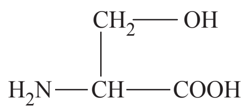
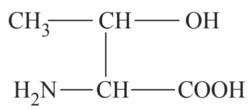
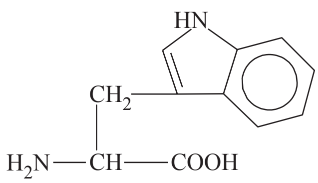
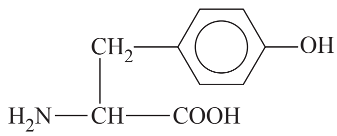
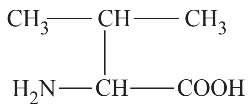
Type of proton	Chemical shift (ppm)
$\mathrm{R{-}C}\mathbf{H}_3$	0.9–1.0
$\mathrm{R{-}C}\mathbf{H}_2\mathrm{{-}R}$	1.3–1.4
$\mathrm{RCH{=}CH{-}C}\mathbf{H}_3$	1.6–1.9
$\mathrm{R_3{-}C}\mathbf{H}$	1.5
 or 	2.0
	2.1–2.7
$\mathrm{R{-}C}\mathbf{H}_2\mathrm{{-}X}$ (X = F, Cl, Br or I)	3.0–4.5
$\mathrm{R{-}C}\mathbf{H}_2\mathrm{{-}OH}$,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

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

17. 2-amino acids (*α*-amino acids)

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

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

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

END OF DATA BOOK