VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education
2019

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

Letter

STUDENT NUMBER

CHEMISTRY

Written examination

Tuesday 4 June 2019

Reading time: 10.00 am to 10.15 am (15 minutes)
Writing time: 10.15 am to 12.45 pm (2 hours 30 minutes)

QUESTION AND ANSWER BOOK

Structure of book

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

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

Materials supplied
- Question and answer book of 37 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

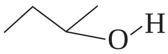
Instructions for Section A

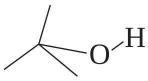
Answer **all** questions in pencil on the answer sheet provided for multiple-choice questions.
Choose the response that is **correct** or that **best answers** the question.
A correct answer scores 1; an incorrect answer scores 0.
Marks will **not** be deducted for incorrect answers.
No marks will be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

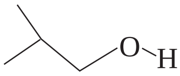
Question 1

Which one of the following isomers of $C_4H_{10}O$ has a chiral carbon?

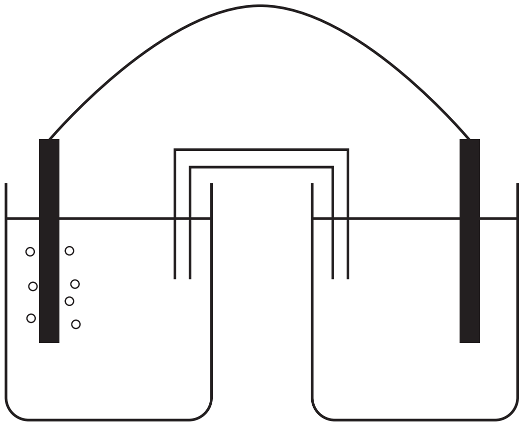
A. 

B. 

C. 

D. 

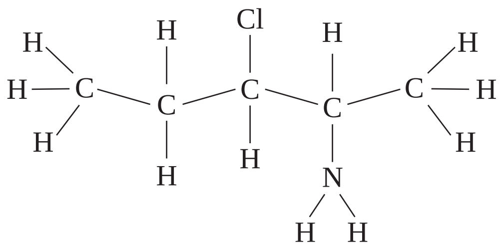
Question 2



A galvanic cell is set up as shown in the diagram above. Bubbling is observed at one of the electrodes. From this evidence it can be stated that

A. the bubbles observed must be hydrogen, H_2.
B. electrons must be flowing across the salt bridge.
C. the two electrodes cannot be made of the same material.
D. there is not enough information to form a valid conclusion.

Question 3



The correct IUPAC name for the molecule shown above is

A. 3-chloro-pentan-2-amine

B. 3-chloro-pentan-4-amine

C. 2-chloro-methylbutanamine

D. 4-amino-3-chloropentane

Question 4

A catalyst for a reaction will

A. reduce the difference between the energy of the products and the energy of the reactants.

B. increase the proportion of successful collisions at a given temperature.

C. require an increase in temperature in order to work successfully.

D. only work for gaseous reactions.

Question 5

The table below gives the heat content, in kilojoules per gram, of a number of different fuels.

Fuel	Heat content (kJ g^{-1})
biogas	33
biodiesel	42
black coal	34
bioethanol	30
petroleum gas	54

Given the information above, it can be stated that

A. petroleum gas is pure methane.

B. all of the fossil fuels produce more energy by mass than the renewable energy sources.

C. the renewable energy source that produces the most energy by mass is biodiesel.

D. biogas can be produced from renewable energy sources and produces more energy by mass than petroleum gas.

Question 6

A sample of food contains 12 g of carbohydrate, 7 g of protein and 5 g of fat.

The energy content of this sample is

A. 496 kJ

B. 501 kJ

C. 536 kJ

D. 643 kJ

Question 7

Which one of the following statements indicates why ethanol produced from sugar cane is defined as a biofuel and ethanol produced from coal is not?

A. Ethanol produced from sugar cane generates less greenhouse gases when used as a fuel than ethanol produced from coal.

B. Ethanol produced from coal can be used to generate electrical energy whereas ethanol produced from sugar cane cannot.

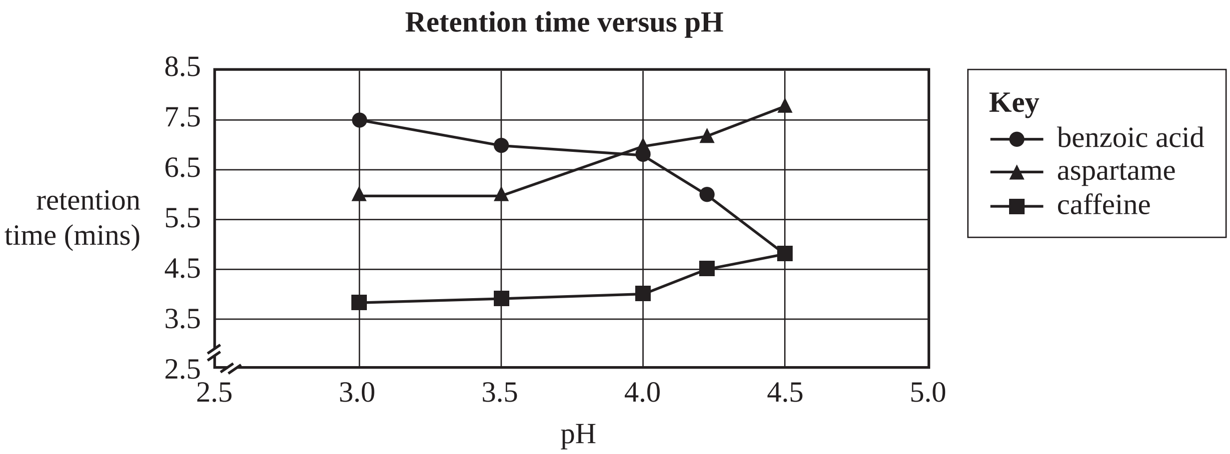
C. Sugar cane is recently living organic matter whereas coal is formed over millions of years.

D. Sugar cane is a natural resource whereas coal is not.

Use the following information to answer Questions 8 and 9.

A student is designing an experiment to determine the concentration of aspartame in soft drinks using high-performance liquid chromatography (HPLC).

Aspartame, benzoic acid and caffeine are all common components of soft drinks. Under some conditions they have similar retention times in an HPLC column. The graph below shows the retention times for these substances at different pH values.



Question 8

According to the graph, which pH value would provide the largest separation of aspartame, benzoic acid and caffeine?

A. 3.0

B. 4.0

C. 4.3

D. 4.5

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Question 9

Which one of the following would minimise sources of error and uncertainty in the student's experiment?

A. Dilute the samples of soft drinks prior to analysis by HPLC.

B. Use a different mobile phase for each type of soft drink investigated.

C. Analyse three aliquots of each sample of soft drink through the HPLC instrument.

D. Increase the pH of the samples of soft drinks by adding hydrochloric acid.

Question 10

A researcher uses a combination of spectroscopic techniques to determine the structure of a molecule.

Which combination of spectroscopic techniques provides the most information about the molecule's functional groups and number of carbon environments?

A.	mass spectrometry	^{13}C NMR
B.	infra-red	^{13}C NMR
C.	infra-red	mass spectrometry
D.	mass spectrometry	^{1}H NMR

Question 11

Ethane-1,2-diol, $C_2H_6O_2$, is commonly used in antifreeze and is a precursor for polyester fibres. It is synthesised from the reaction of oxirane, C_2H_4O, with water, H_2O, according to the following equation.

$$C_2H_4O + H_2O \rightarrow C_2H_6O_2$$

In an industrial process, 86.0 g of C_2H_4O reacts to produce 86.0 g of $C_2H_6O_2$.

$M(C_2H_4O) = 44.0$ g mol^{-1} $M(H_2O) = 18.0$ g mol^{-1} $M(C_2H_6O_2) = 62.0$ g mol^{-1}

The percentage yield for this process is

A. 124%

B. 100%

C. 82.3%

D. 71.0%

Question 12

The cathode reaction for a particular alkaline fuel cell is given below.

$$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$$

The only product of the overall fuel cell reaction is water, H_2O.

The half-equation that represents the anode reaction is

A. $H_2 \rightarrow 2H^+ + 2e^-$

B. $H_2 + O^{2-} \rightarrow H_2O + 2e^-$

C. $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$

D. $H_2 + 2OH^- \rightarrow 2H_2O + 2e^-$

Question 13

Which one of the following fatty acids would be expected to have the highest melting point?

A. oleic acid

B. stearic acid

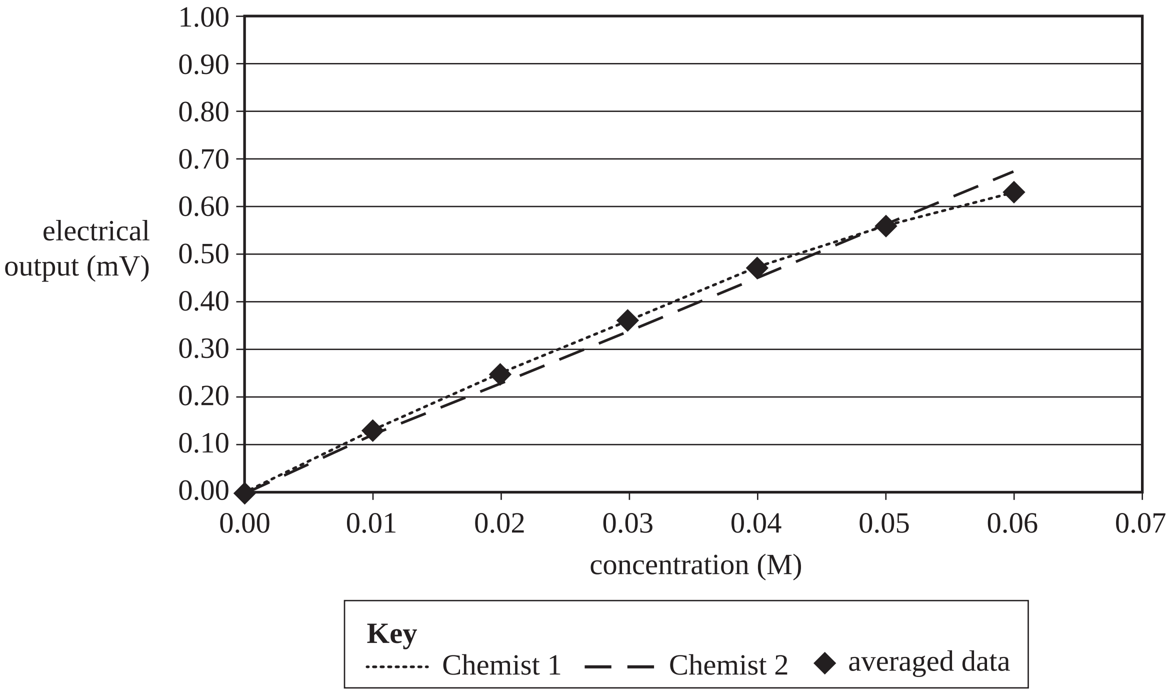
C. linoleic acid

D. linolenic acid

Question 14

Two chemists are developing a new analytical technique. They are collecting data from experiments to determine the relationship between the electrical output of an instrument and the concentration of a chemical in solution. Test solutions were all prepared by dilution of the same freshly standardised solution of the chemical.

The chemists took **four** measurements at each concentration and averaged the results. The same instrument was used for all of the measurements. The averaged data is plotted on the graph below, as indicated by the symbol ◆.



Using the same data plots, the two chemists made different hypotheses. Chemist 1 hypothesises that the relationship between electrical output and concentration is a curved graph, indicated by the dotted line. Chemist 2 hypothesises that the relationship is a straight line graph, indicated by the dashed line.

What should the chemists do to test their hypotheses?

A. Measure new test solutions.

B. Standardise the chemical solution again.

C. Take six measurements at each concentration.

D. Take measurements at higher concentrations of the chemical.

Question 15

How many structural isomers can be drawn for C_3H_6BrCl?

A. 3

B. 4

C. 5

D. 6

Question 16

The only gaseous product in a reaction is carbon dioxide, CO_2. This gas is collected in a sealed and previously evacuated 750 mL container at a temperature of 28 °C. The pressure in the container is 200 kPa.

The mass of CO_2 produced is closest to

A. 0.060 g

B. 2.64 g

C. 28.4 g

D. 2640 g

Question 17

Which one of the following statements regarding titrations is correct?

A. Phenolphthalein is an appropriate indicator to use for a titration of ethanol against acidified potassium permanganate.

B. The most appropriate indicator for the titration of a weak acid with a strong base is methyl red.

C. Dilute solutions of strong bases can be titrated more accurately than concentrated solutions.

D. Distilled water should be used for the final rinse of all glassware that will be used in a titration.

Question 18

A compound with the formula $C_6H_{12}O_2$ has the following features:

- It is unbranched.
- It has only **one** type of functional group.
- All carbon-to-carbon bonds are single bonds.

The compound could be classified as an

A. ester.

B. amide.

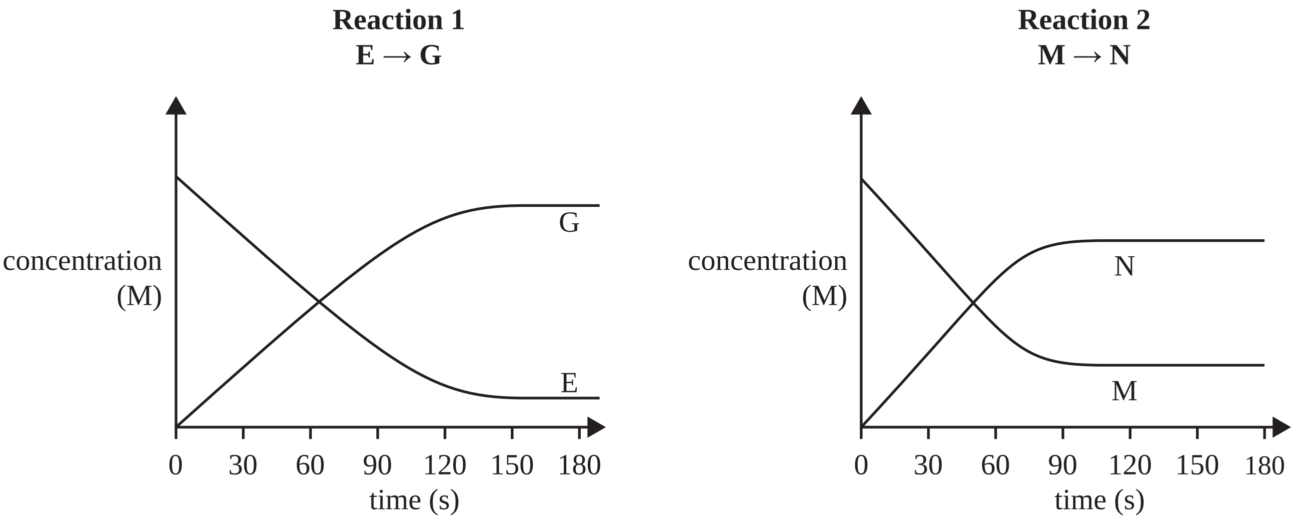
C. alcohol.

D. aldehyde.

Question 19

The diagrams below show concentration versus time graphs for two different reactions under identical conditions.

The graphs can be used to determine whether each reaction is reversible or irreversible and which reaction has a faster rate of reaction.

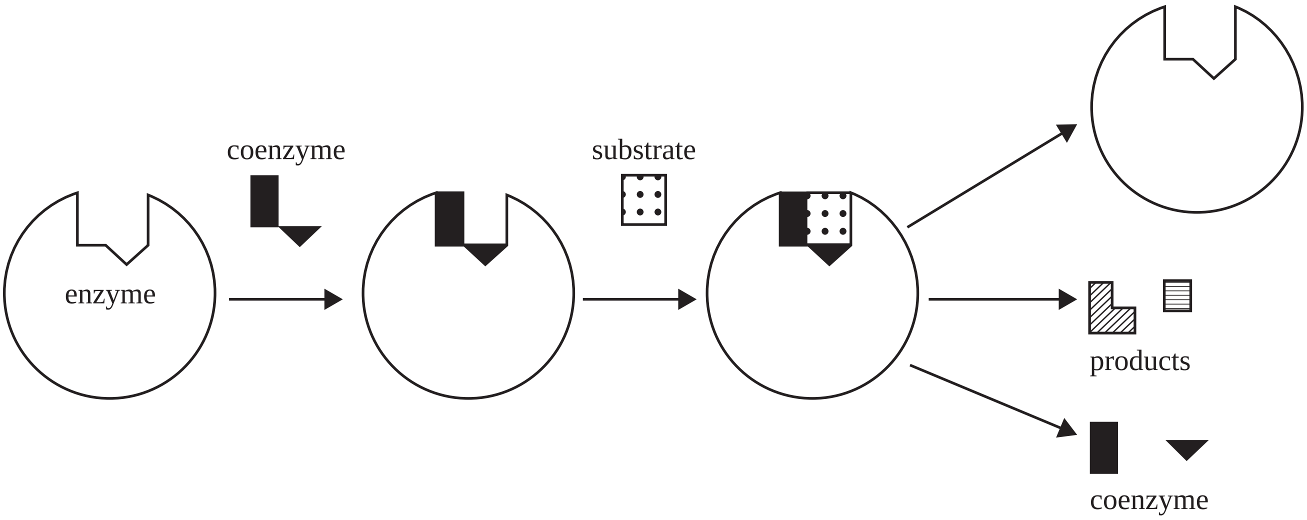


Which of the following conclusions matches the data presented in the graphs?

	Reaction 1	Rate of reaction
A.	reversible	Reaction 1 is slower than Reaction 2.
B.	effectively irreversible	Reaction 1 is faster than Reaction 2.
C.	effectively irreversible	Reaction 1 is slower than Reaction 2.
D.	reversible	Reaction 1 is faster than Reaction 2.

Question 20

A Year 12 Chemistry student is revising enzymes and coenzymes, and produces the diagram below to summarise what occurs during a reaction. Unfortunately, the student has made a significant mistake.



Which one of the following statements describes the significant mistake represented in the student's diagram?

A. An enzyme's active site is specific and will fit only one substrate.

B. A coenzyme binds with the enzyme to change the shape of the active site.

C. An enzyme's structure is irreversibly changed by the reaction.

D. A coenzyme breaks apart during a reaction.

Question 21

Chromate, CrO_4^{2-}, and dichromate, $Cr_2O_7^{2-}$, ions in solution reach equilibrium as shown in the following equation.

$$2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(l)$$

To increase the concentration of CrO_4^{2-} in a solution at equilibrium, a student could add a few drops of

A. H_2O

B. 1 M HCl

C. 1 M NaCl

D. 1 M NaOH

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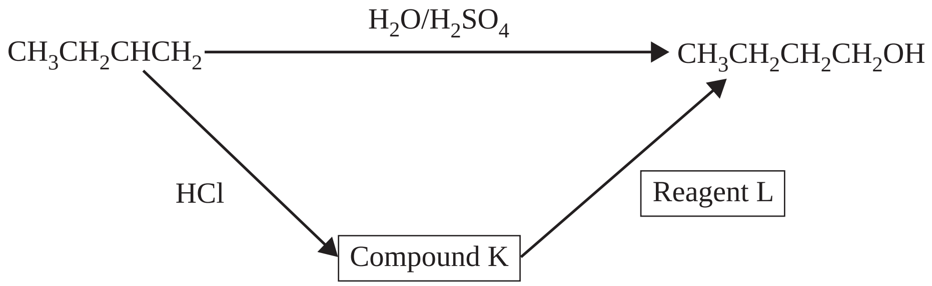
Question 22



Based on the pathways shown above, which of the following correctly identifies Compound K and Reagent L when $CH_3CH_2CH_2CH_2OH$ is produced?

	Compound K	Reagent L
A.	2-chlorobutane	H_2O
B.	2-chlorobutane	MnO_4^-
C.	1-chlorobutane	H_2O
D.	1-chlorobutane	MnO_4^-

Question 23

0.50 g of ethane, C_2H_6, undergoes complete combustion in a bomb calorimeter containing 200 mL of water. The water temperature rises from 22.0 °C to 48.5 °C.

The thermochemical equation for the combustion of C_2H_6 using this information is

A. $C_2H_6 + 5O_2 \rightarrow 2CO_2 + 3H_2O$ $\Delta H = -1330$ kJ mol^{-1}

B. $2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$ $\Delta H = -3120$ kJ mol^{-1}

C. $C_2H_6 + 5O_2 \rightarrow 2CO_2 + 3H_2O$ $\Delta H = -1560$ kJ mol^{-1}

D. $2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$ $\Delta H = -2660$ kJ mol^{-1}

Question 24

A particular HPLC instrument was used to separate mixtures of two chemicals. Each separation was done under similar conditions. The mobile phase used was either water or hexane and the same stationary phase was used for each separation.

For the mobile phase given in the first column, which one of the following options gives the two chemicals expected to have the largest difference in retention time?

	Mobile phase	Chemicals in the mixtures
A.	hexane	butanoic acid, butane
B.	water	acetic acid, ethanol
C.	hexane	ethanol, methanol
D.	water	butane, octane

SECTION A – continued

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Question 25

A student aims to calculate the theoretical amount of energy available to the body from cellular respiration using the oxygen gas, O_2, retained by the body in a normal breath.

In this calculation, the student assumes that:

- the energy released at normal body temperature is the same as that released at standard laboratory conditions (SLC)
- 19.6 mL of O_2 is retained by the body in a normal breath.

A balanced thermochemical equation for cellular respiration, with glucose as the primary reactant, is shown below.

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O \qquad \Delta H = -2816 \text{ kJ mol}^{-1}$$

The theoretical amount of energy produced through cellular respiration from the O_2 retained by the body in a normal breath would be

A. 2.2 kJ

B. 3.7×10^{-1} kJ

C. 7.9×10^{-2} kJ

D. 7.9×10^{-4} kJ

Question 26

An electrolysis cell is made up of a 500 mL solution of a metal salt with two inert electrodes. A current of 3.0 A is applied for one hour and 1.9 g of metal is deposited on the cathode.

The 500 mL solution used in this electrolysis cell is

A. 1 M $CuSO_4$

B. 0.3 M $CuSO_4$

C. 0.8 M Ag_2SO_4

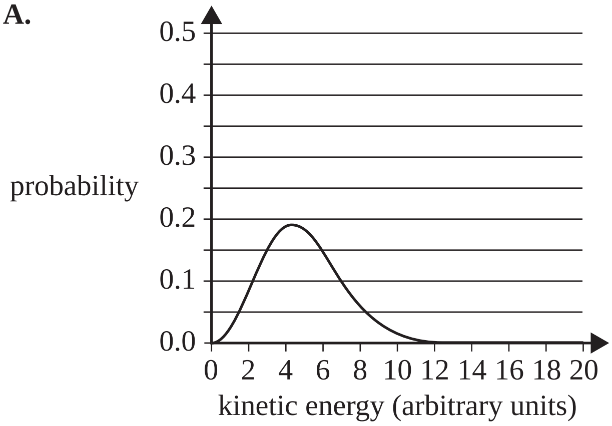
D. 0.5 M $Cr_2(SO_4)_3$

Question 27

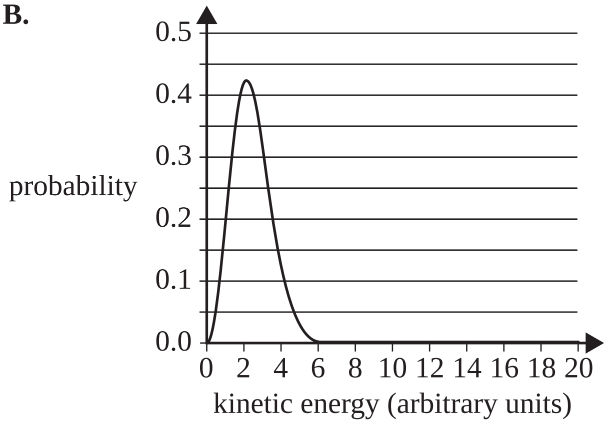
The Maxwell-Boltzmann distribution curves below represent the kinetic energies of molecules in a reaction with an activation energy, E_a, of 7 arbitrary units.

Which one of the following shows the distribution curve with the highest proportion of successful collisions?

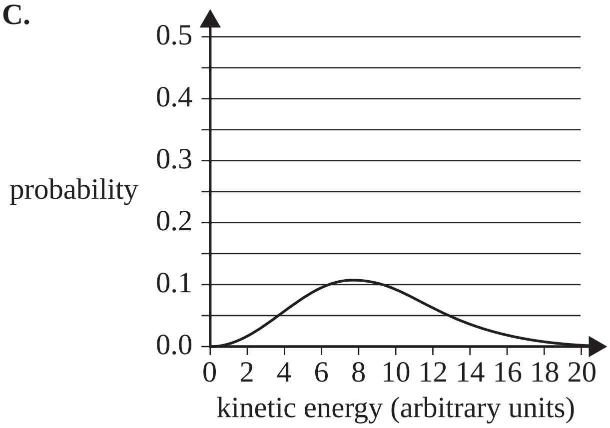
A.



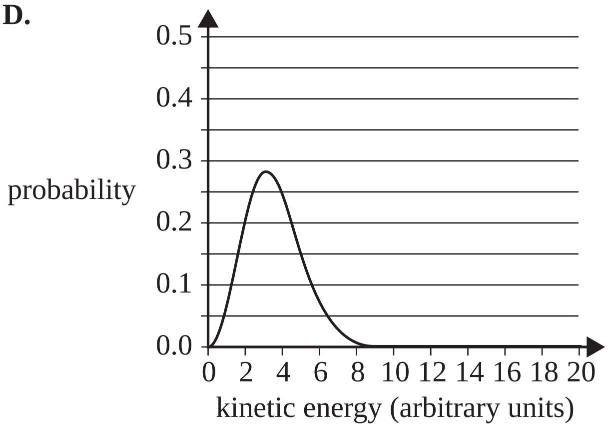
B.



C.



D.



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Question 28

A student's breakfast consists of mashed avocado, fetta cheese and a poached egg on a slice of rye bread.

The nutrition information for each component of the breakfast is shown in the tables below.

Avocado

Serving size ½ avocado (68 g)

Nutrient	Mass per serve
protein	1.34 g
fat	10.5 g
carbohydrate	5.9 g

Egg

Serving size 1 egg (52 g)

Nutrient	Mass per serve
protein	12.7 g
fat	10.3 g
carbohydrate	1.4 g

Fetta cheese

Serving size 20 g

Nutrient	Mass per serve
protein	3.0 g
fat	3.6 g
carbohydrate	< 1.0 g

Rye bread

Serving size 1 slice

Nutrient	Mass per serve
protein	2.7 g
fat	1.1 g
carbohydrate	13.1 g

The component of this breakfast that provides the largest amount of energy per serve is the

A. avocado.

B. egg.

C. fetta cheese.

D. rye bread.

Question 29

Some scientists are exploring batteries that utilise the metals potassium, K, or calcium, Ca, as anode components.

If all other aspects of the cell are the same, a cell using Ca would produce more current because

A. Ca produces more electrons per mole than K.

B. K produces more electrons per mole than Ca.

C. K produces a higher voltage than Ca.

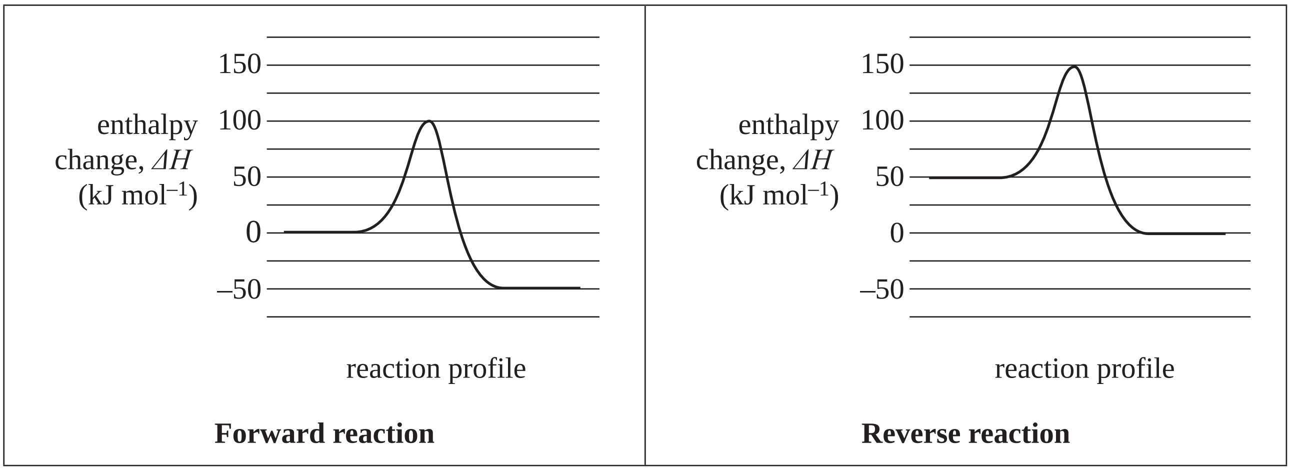
D. Ca has a higher molar mass than K.

Question 30

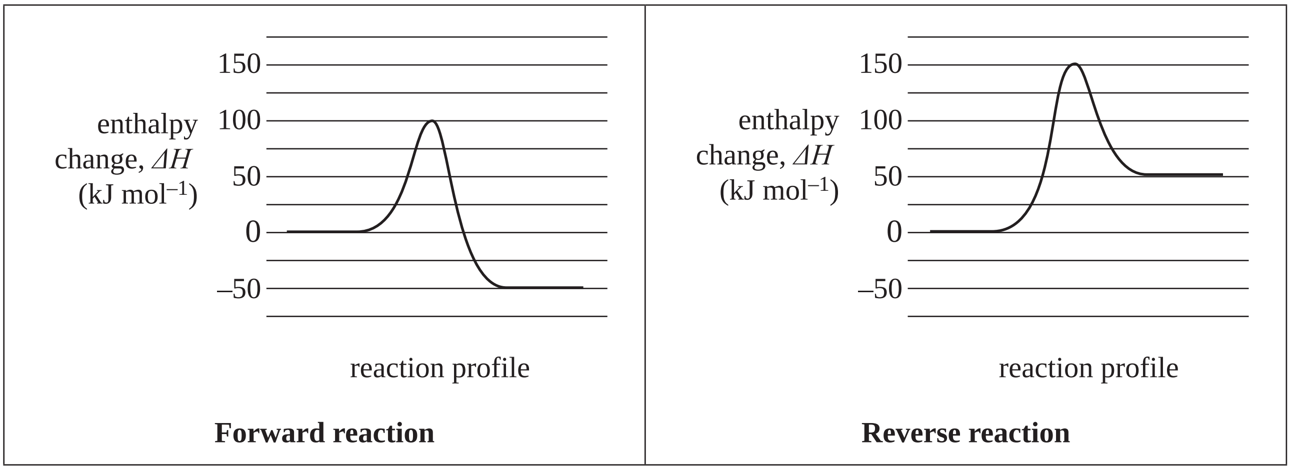
A reversible reaction has an enthalpy change, *ΔH*, of –50 kJ mol^{-1} for the forward reaction.

Which one of the following pairs of energy profile diagrams, one for the forward reaction and one for the reverse reaction, represents this reaction?

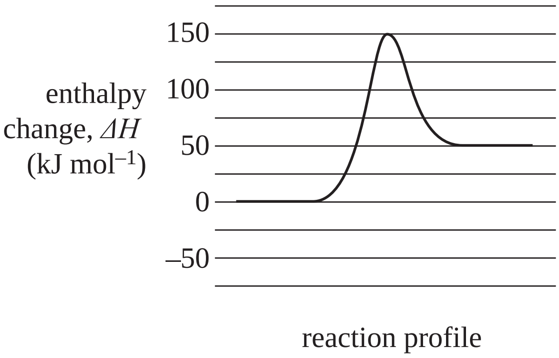
A.



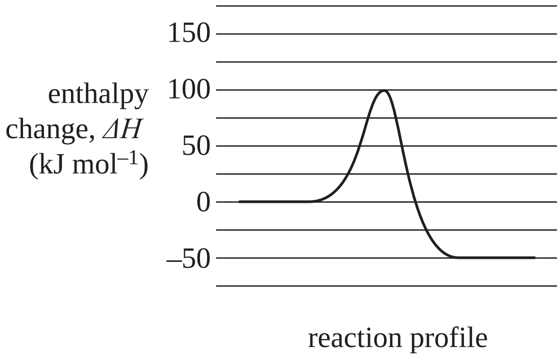
B.



C.

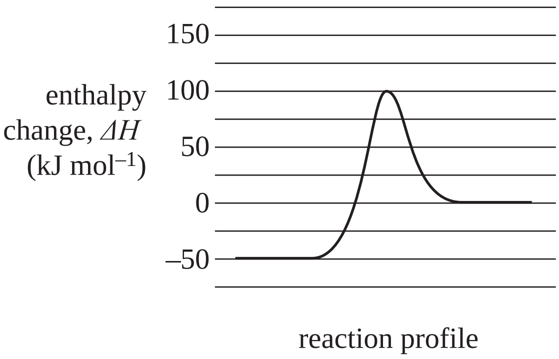


Forward reaction

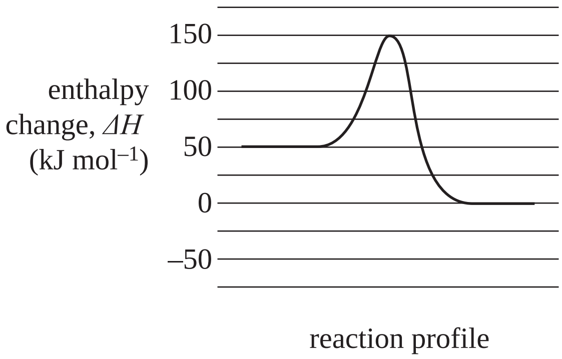


Reverse reaction

D.



Forward reaction



Reverse reaction

SECTION B

Instructions for Section B

Answer **all** questions in the spaces provided. Write using blue or black pen.

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 (10 marks)

Different types of fuels can be used in vehicles with combustion engines. These fuels can be produced from either fossil fuels or from renewable sources.

Liquefied petroleum gas (LPG), a fossil fuel used in cars, is mainly made up of propane, C_3H_8.

a. Write a balanced thermochemical equation for the complete combustion of C_3H_8 in air at standard laboratory conditions (SLC). 3 marks

b. How much energy, in kilojoules, would be produced from the complete combustion of 290 g of C_3H_8 at SLC? 1 mark

c. What volume of air (21.0% oxygen, O_2, by volume), measured at SLC, would be required to fully combust 68.5 g of C_3H_8? 3 marks

Biodiesel is a renewable fuel produced from a reaction between an alcohol and a triglyceride. The nature of both the fatty acids in the triglyceride and the alcohol involved affects the viscosity of the fuel produced.

A scientist produces a variety of alkyl esters from different combinations of fatty acids and alcohols that can be used as fuels.

The viscosity of these fuels is measured at 40 °C, in arbitrary units, and listed in Table 1 below. When measured in these arbitrary units, the larger the value the greater the viscosity.

Table 1. Viscosity of alkyl ester fuels at 40 °C (arbitrary units)

Fatty acid	**Alcohol**		
	Methanol	**Ethanol**	**Butanol**
lauric acid	2.43	2.63	3.39
oleic acid	4.51	4.78	5.69
linoleic acid	3.65	4.25	4.39

d. According to the data provided, which combination of alcohol and lauric acid produces a biodiesel that flows the slowest through a fuel line at 40 °C? 1 mark

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e. Oleic acid and linoleic acid contain the same number of carbon atoms. The viscosities of the esters of linoleic acid are consistently lower than the viscosities of the corresponding esters of oleic acid, as shown in Table 1.

What feature of linoleic acid contributes to its lower viscosity? Justify your answer. 2 marks

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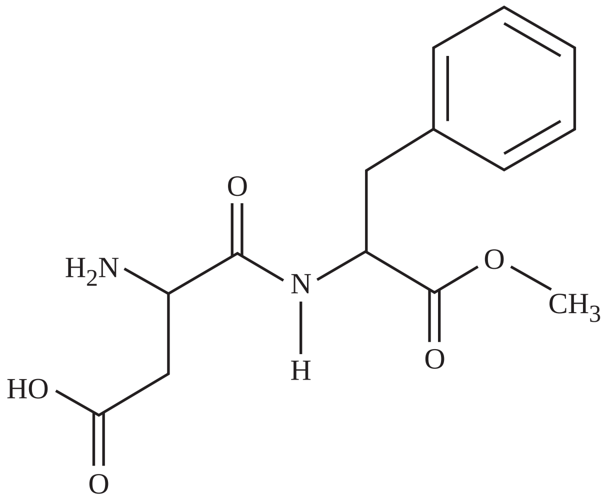
Question 2 (8 marks)

Glucose, fructose and sucrose are naturally occurring sugars that, along with aspartame, an artificial sweetener, are used in processed foods and diet soft drinks.

a. The diagram below shows an aspartame molecule that can be formed by condensation reactions.

Circle **two** functional groups of the aspartame molecule that can be formed by condensation reactions and label each group with its name. 2 marks



b. When aspartame is metabolised in the body, methanol, CH_3OH, and two amino acids are produced.

Name the two amino acids produced. 2 marks

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c. Glucose, fructose, sucrose and aspartame all contain approximately the same number of kilojoules per gram. Aspartame tastes around 180 times sweeter than the natural sugars.

In terms of energy content, why is aspartame used instead of natural sugars in diet soft drinks? 1 mark

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d. Fructose, $C_6H_{12}O_6$, is a sugar commonly found in fruit and corn syrup.

Below is the thermochemical equation for the combustion of $C_6H_{12}O_6$ in excess oxygen, O_2, under standard conditions.

$$C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l) \qquad \Delta H = -2810 \text{ kJ mol}^{-1}$$

When 1.00 g of solid $C_6H_{12}O_6$ is burnt in excess O_2 in a bomb calorimeter, the temperature of the water in the calorimeter increases by 1.60 °C.

Calculate the calibration factor for this particular bomb calorimeter.

$M(C_6H_{12}O_6) = 180 \text{ g mol}^{-1}$ 3 marks

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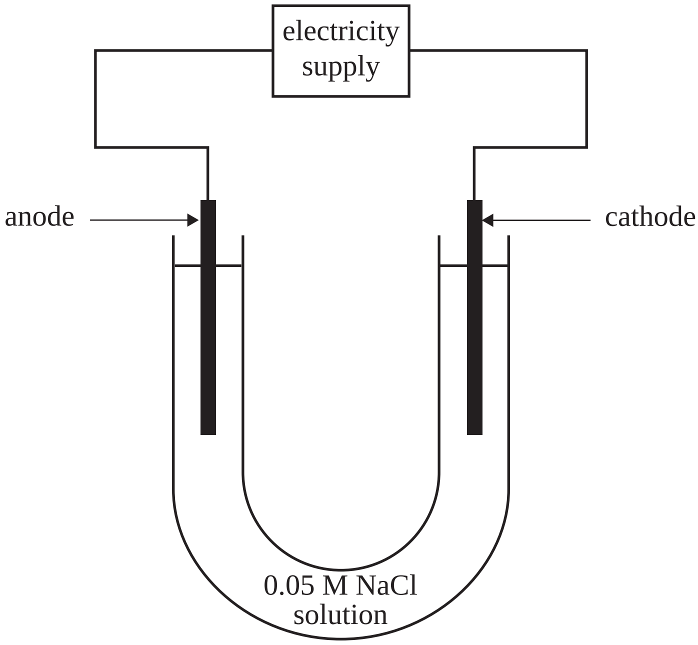
Question 3 (9 marks)

A student electrolysed a 0.05 M sodium chloride, NaCl, solution using graphite electrodes, as shown in the set-up below.



Several drops of phenol red were added to the solution next to each electrode.

The following observations were made as the reactions proceeded.

Polarity of electrode	Observation	Colour of phenol red
positive	Bubbles formed at the electrode.	yellow
negative	Bubbles formed at the electrode.	red

a. What colour was observed at the cathode as the electrolysis proceeded? 1 mark

____

b. Use the electrochemical series to predict the gas expected to be formed at each electrode. 2 marks

At the anode ______________________________

At the cathode ______________________________

c. Molten NaCl can be electrolysed commercially. The melting point of NaCl is 801 °C.

i. Write the overall equation for this electrolysis. 1 mark

ii. Give **two** reasons why it would be difficult to carry out this electrolysis in a school laboratory. 2 marks

d. The student constructs the summary table below to compare the processes that take place in galvanic cells and electrolytic cells.

Complete the table by writing 'true' or 'false' in each space provided. 3 marks

Process	Galvanic cells	Electrolytic cells
Oxidation occurs at the cathode.		
Chemical energy is converted to electrical energy.		
Spontaneous reactions take place.		

Question 4 (12 marks)

Hydrolysis reactions in the human body break down large biomolecules to produce smaller molecules. These large biomolecules include proteins, fats and oils, and starch.

a. The hydrolysis of starch proceeds through several stages. A significant intermediate in the breakdown of starch is maltose, $C_{12}H_{22}O_{11}$.

Complete the following equation for the hydrolysis of maltose using molecular formulas. 2 marks

$$C_{12}H_{22}O_{11} + \boxed{} \rightarrow \boxed{}$$

b. **i.** Name **one** of the products of the hydrolysis of a fat or an oil in the body. 1 mark

____

ii. What is the name of the linkage broken during the hydrolysis of fats and oils? 1 mark

____

c. Pepsin is an enzyme in the stomach that hydrolyses proteins during digestion.

Explain what happens when an enzyme catalyses the hydrolysis of a protein. 3 marks

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d. Describe the difference between the hydrolysis of a protein and the denaturation of a protein in terms of the primary, secondary and tertiary structures of the protein. 2 marks

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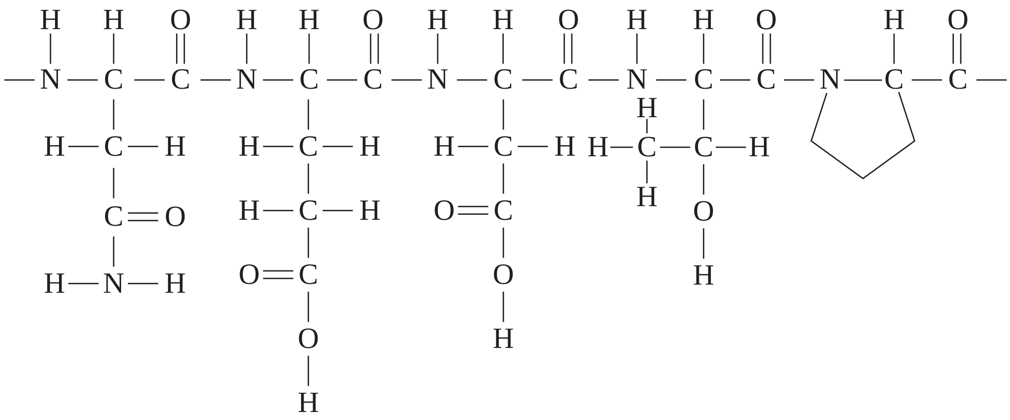
DO NOT WRITE IN THIS AREA

A section of glycinin, a protein found in soy beans, has the following amino acid sequence.



e. On the diagram above, circle **one** of the linkages that is broken during hydrolysis. 1 mark

f. One of the amino acids in the sequence has an amide side chain.

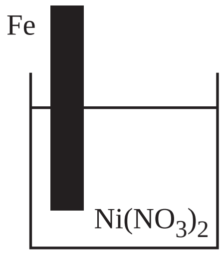
Draw the structural formula of the zwitterion of this amino acid in the space provided below. 2 marks

Question 5 (11 marks)

Energy can be produced in a variety of ways, including from galvanic cells, fuel cells and gas-fired power stations. Each of these methods suits particular applications.

Galvanic cells and fuel cells are methods of energy production that are based on redox reactions, similar to the reaction that would occur in Set-up A shown below. Set-up A consists of a beaker with a strip of iron, Fe, in a solution of nickel(II) nitrate, $Ni(NO_3)_2$.

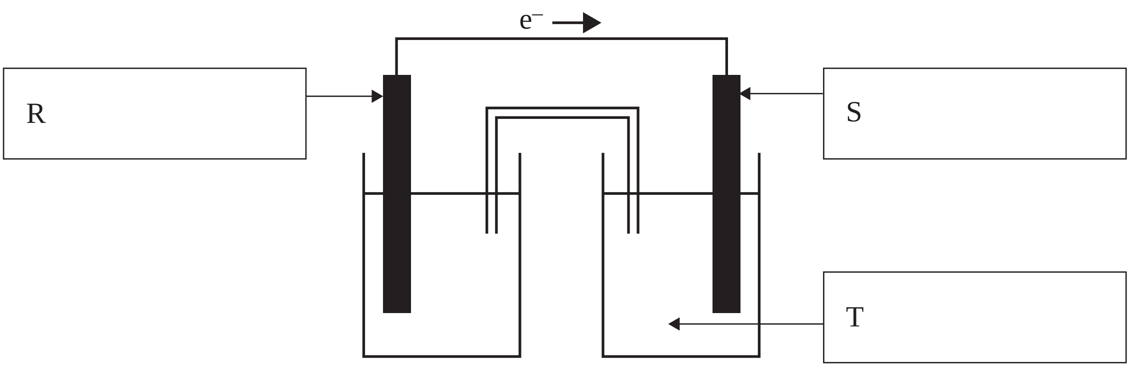
Set-up A



a. Identify the reducing agent for the reaction that would occur in Set-up A. 1 mark

Batteries made up of primary galvanic cells, such as the one in Set-up B shown below, have traditionally been used in small electrical devices. Set-up B consists of a galvanic cell based on the redox reaction in Set-up A.

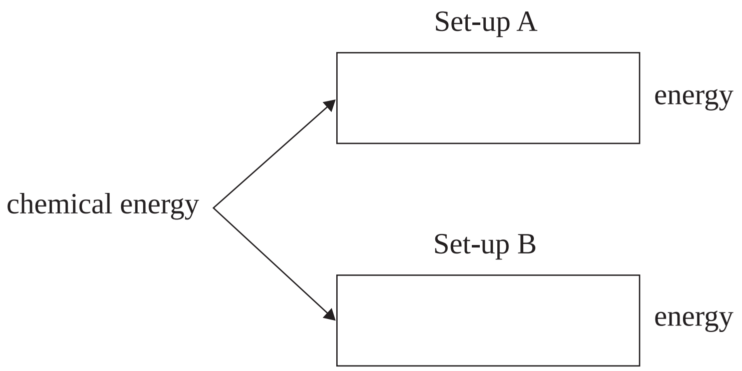
Set-up B



b. **i.** Identify an appropriate electrode material for each half-cell by writing the respective formula in boxes R and S in Set-up B. 2 marks

ii. Write the formula of an appropriate solution for the half-cell in box T in Set-up B. 1 mark

c. Complete the flow chart below to summarise the energy conversions that would occur in Set-up A and Set-up B. 2 marks

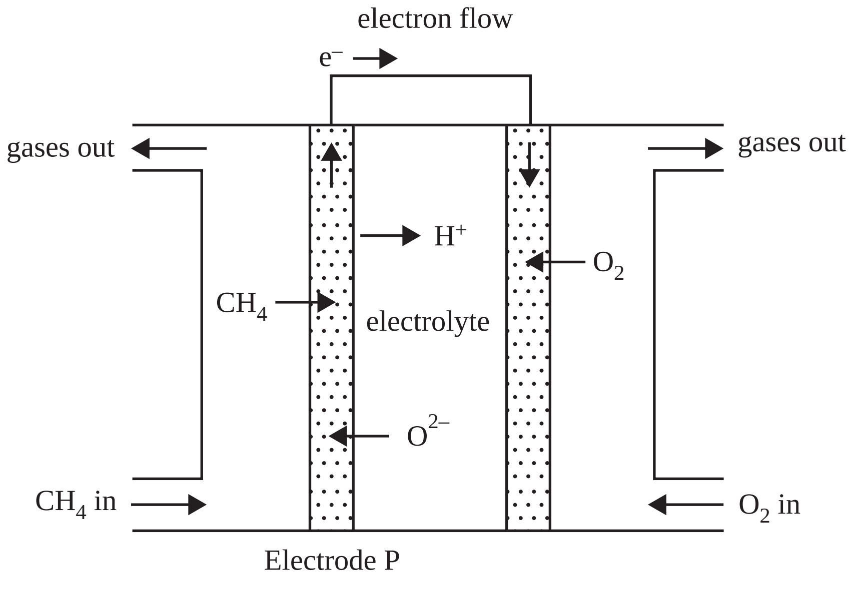


In solid oxide fuel cells (SOFC), redox reactions can be utilised to produce electrical energy for use in homes and businesses.

The diagram below represents an SOFC where the two supplied reactants are methane, CH_4, and oxygen, O_2.

The overall equation for this cell is

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$$



d. Identify Electrode P as either the anode or the cathode. 1 mark

____

e. For the SOFC shown above, write the half-equation occurring at the cathode. States are not required. 1 mark

____

____

f. In a conventional gas-fired power station, CH_4 undergoes complete combustion. The heat generated by this reaction is ultimately used to generate electrical energy.

For a given amount of energy produced, compare the amount of greenhouse gases produced by an SOFC and a gas-fired power station based on their relative efficiencies. 3 marks

DO NOT WRITE IN THIS AREA

Question 6 (13 marks)

A Year 11 Chemistry class performed an experiment to check the accuracy of laboratory glassware for measuring volumes of liquid.

A student chose a clean 25 mL pipette with a stated delivery volume of 25 ± 0.03 mL at 20.0 °C and a clean 25 mL measuring cylinder with a stated delivery volume of 25 ± 0.25 mL at 20.0 °C.

The following procedure was used for each piece of equipment:

1. Fill with distilled water up to the mark.
2. Transfer the distilled water into a dry, pre-weighed beaker.
3. Immediately weigh the beaker on an accurate balance (± 0.01 g).
4. Determine the mass of water in the beaker.
5. Repeat the steps above five times.

The glassware and water were at the laboratory temperature of 22.5 °C.

The results obtained by the student are shown in Table 1 below.

Table 1. The student's results

Experiment no.	Pipette (mass of water, g)	Measuring cylinder (mass of water, g)
1	24.97	24.79
2	24.97	24.73
3	24.95	24.67
4	24.94	24.69
5	24.95	24.78
Average	**24.96**	**24.73**
Range	**0.03**	**0.12**

The range is a measure of spread and is calculated as the maximum value minus the minimum value.

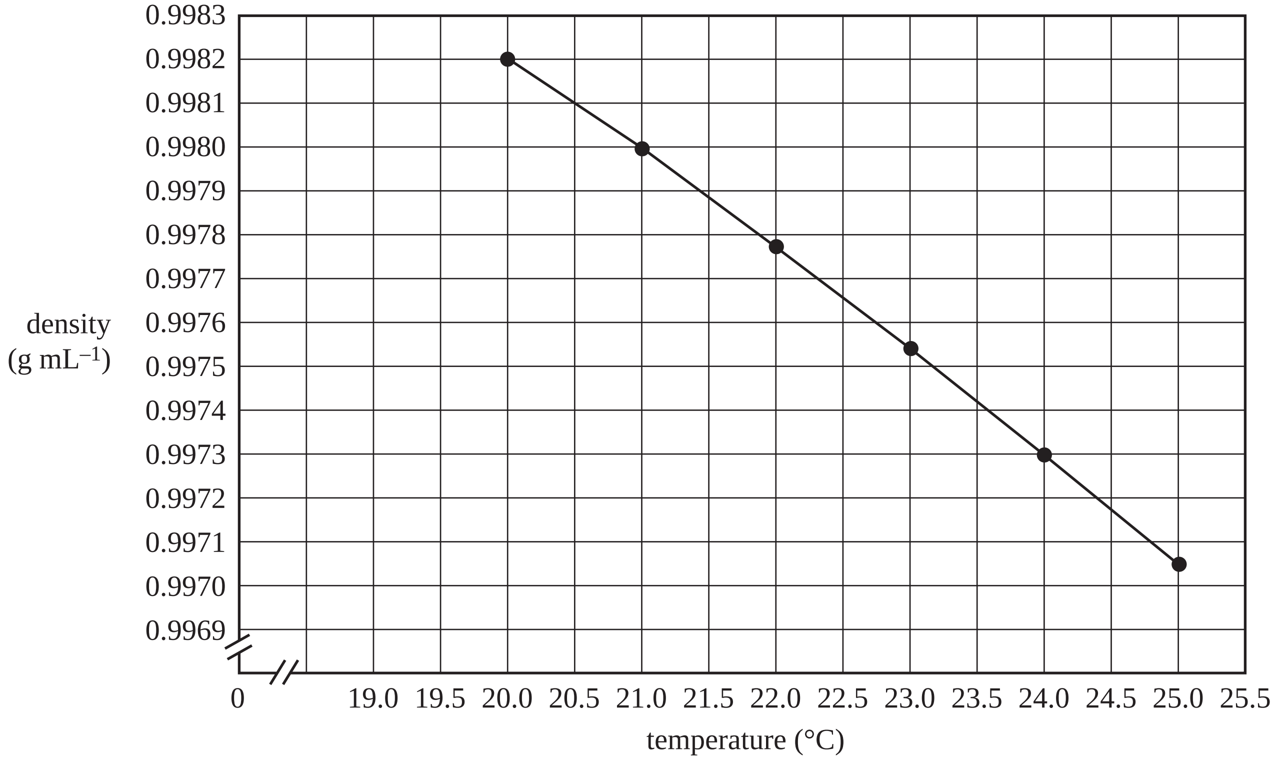
a. What type of error was the student trying to minimise by performing Step 5 of the procedure? Give an example of how this type of error could occur. 2 marks

b. The student decided to use the data from all of the experiments to determine the average mass of water measured by the pipette.

Explain why this was appropriate. 2 marks

c. The density of water varies with temperature, as shown in the graph below.

Density of water versus temperature



i. Use this graph to determine the density of water at the laboratory temperature of 22.5 °C. 1 mark

____

ii. Complete the table below using the information in Table 1 on page 27 and the density of water determined in **part c.i.** 2 marks

Equipment	Average volume delivered (mL)	Range (mL)
25 mL pipette		
25 mL measuring cylinder		

d. There is a difference between the temperature of 20.0 °C stated on the glassware and the temperature of 22.5 °C at which the experiment was conducted.

What effect would this have on the volumes calculated in **part c.ii.**? Justify your answer. 2 marks

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DO NOT WRITE IN THIS AREA

e. Compare the accuracy and reliability of the two pieces of glassware for the measurement of a known volume of water using evidence to support your response. 2 marks

f. The student wanted to accurately determine the concentration of sodium hydroxide, NaOH, in a sample by titration with standardised acetic acid, CH_3COOH, solution.

State, with a reason, whether the 25 mL measuring cylinder or the 25 mL pipette should be used to accurately measure out the volume of sample to be titrated. 2 marks

Question 7 (9 marks)

A change in the position of equilibrium can be demonstrated visually using two forms of cobalt(II) ions.

Solutions of the $[Co(H_2O)_6]^{2+}$ ion are pink and solutions of the $CoCl_4^{2-}$ ion are blue.

A solution made from 0.5 M $[Co(H_2O)_6]^{2+}$ ions and 5 M Cl^- ions reaches the following equilibrium.

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

At SLC the mixture is blue when this solution is at equilibrium.

a. Write the equilibrium expression, K_c, for the equation above. 2 marks

b. Two 20 mL samples of the solution above at equilibrium at SLC are placed in separate conical flasks for each of the following tests.

i. One 20 mL sample is diluted by adding 10 mL of deionised water, H_2O, at SLC. The solution immediately becomes a paler blue due to the dilution.

Use Le Chatelier's principle to explain the colour change expected from this paler blue colour until a new equilibrium is reached. 2 marks

DO NOT WRITE IN THIS AREA

ii. Silver nitrate, $AgNO_3$, is highly soluble and very readily dissolves in water. Silver ions, Ag^+, participate in the following precipitation reaction.

$$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$$

10 g of $AgNO_3$ crystals is mixed into the second 20 mL sample.

What effect will the addition of $AgNO_3$ crystals to the second solution have on the position of equilibrium? Explain your answer in terms of collision theory. 3 marks

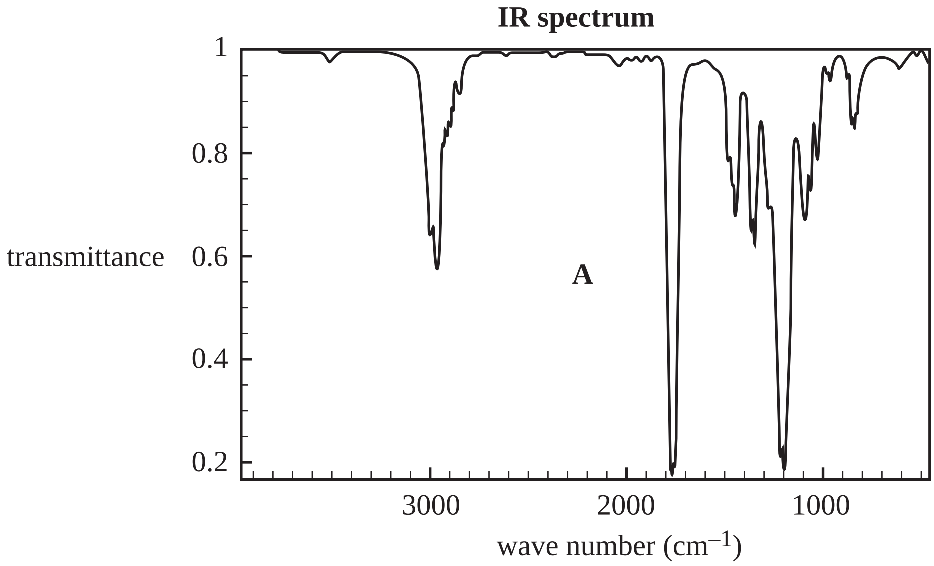
c. Samples of the original equilibrium solution are pink when refrigerated at 4 °C and blue when kept at 25 °C.

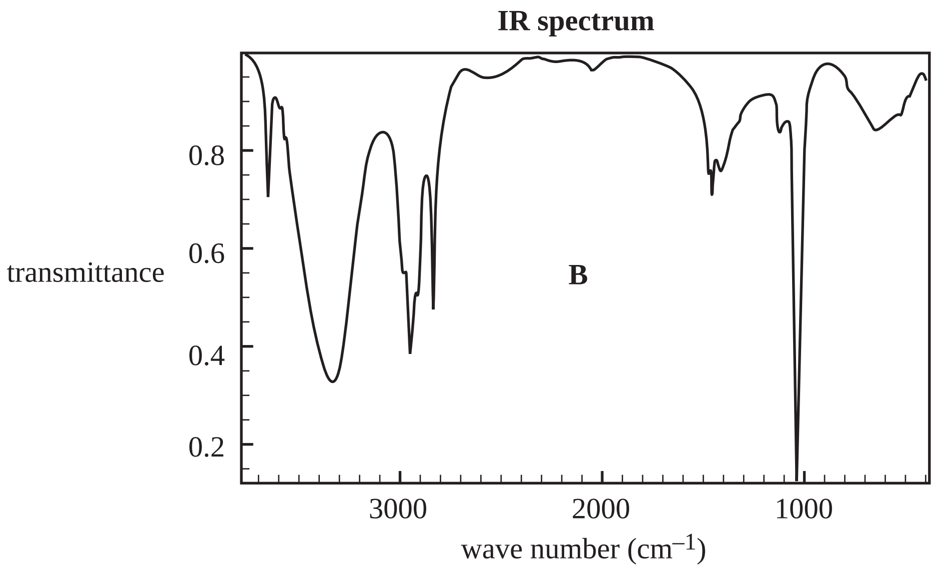
Is the reaction in the original equilibrium solution endothermic or exothermic? Explain your reasoning. 2 marks

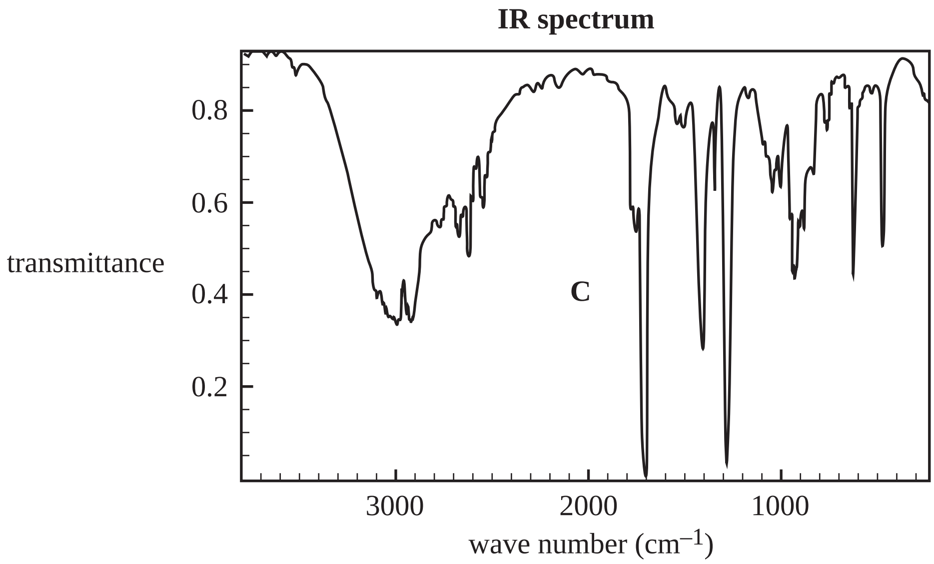
DO NOT WRITE IN THIS AREA

Question 8 (11 marks)

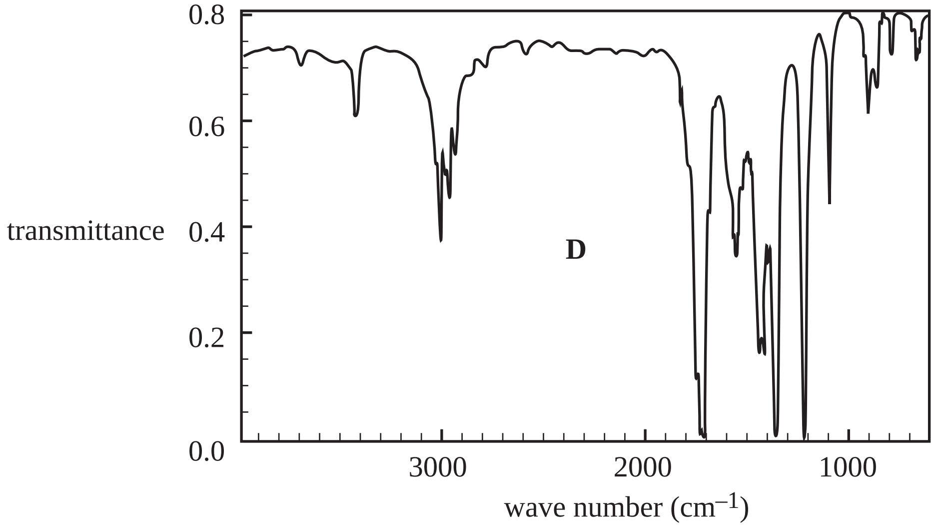
A student prepared the compound methyl propanoate in a school laboratory using two reactants. The infra-red (IR) spectra for the two reactants and two other related compounds are given on pages 32 and 33.







IR spectrum



Data (all spectra): National Institute of Standards and Technology, NIST Chemistry WebBook, <https://webbook.nist.gov/chemistry/>

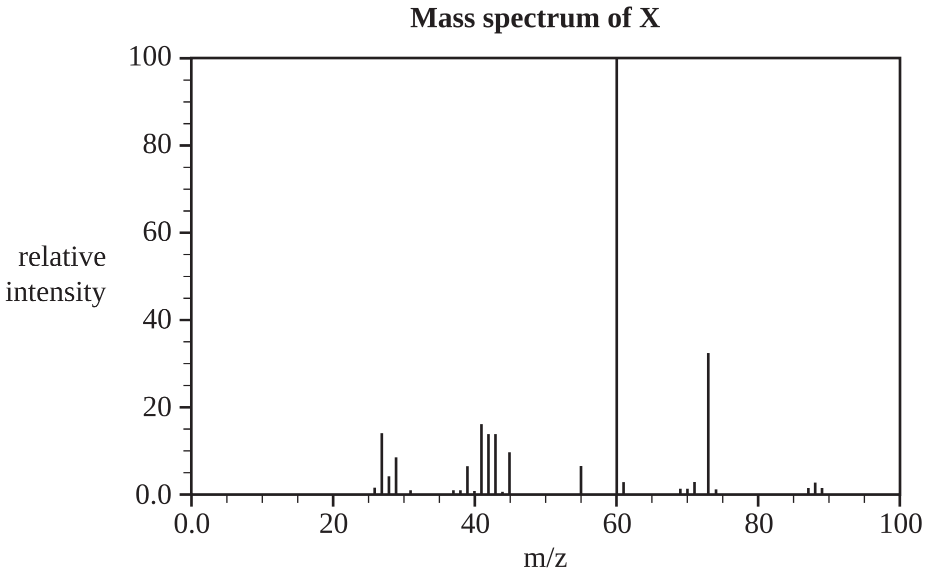
a. **i.** Name each of the reactants used to produce methyl propanoate. 2 marks

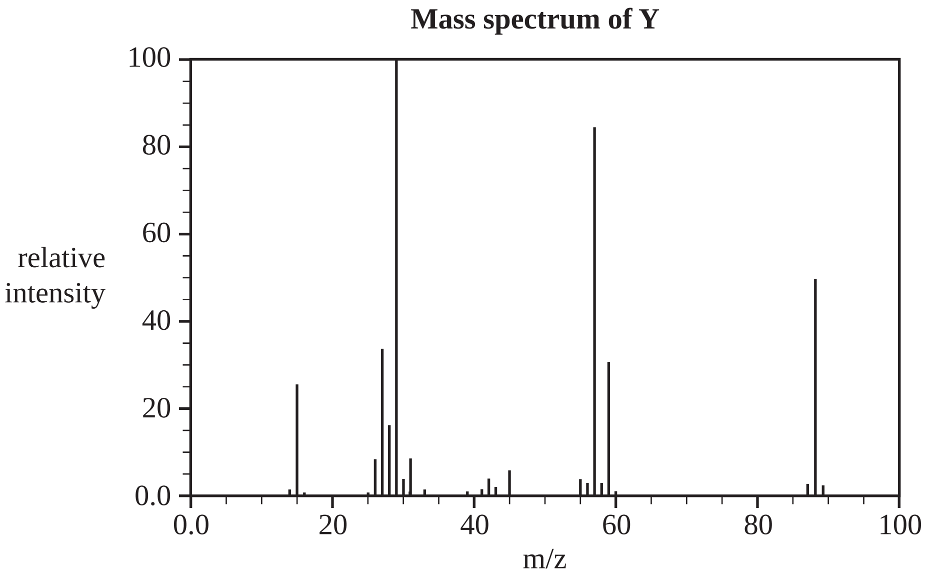
ii. For one of the reactants named in **part a.i.**, identify its corresponding IR spectrum from spectra A to D shown above and on page 32. Justify your answer using data from the spectrum. 2 marks

Reactant ______________________ Spectrum ______________________

b. Draw the structural formula of methyl propanoate in the space provided below. 2 marks

Two mass spectra, X and Y, are shown below.



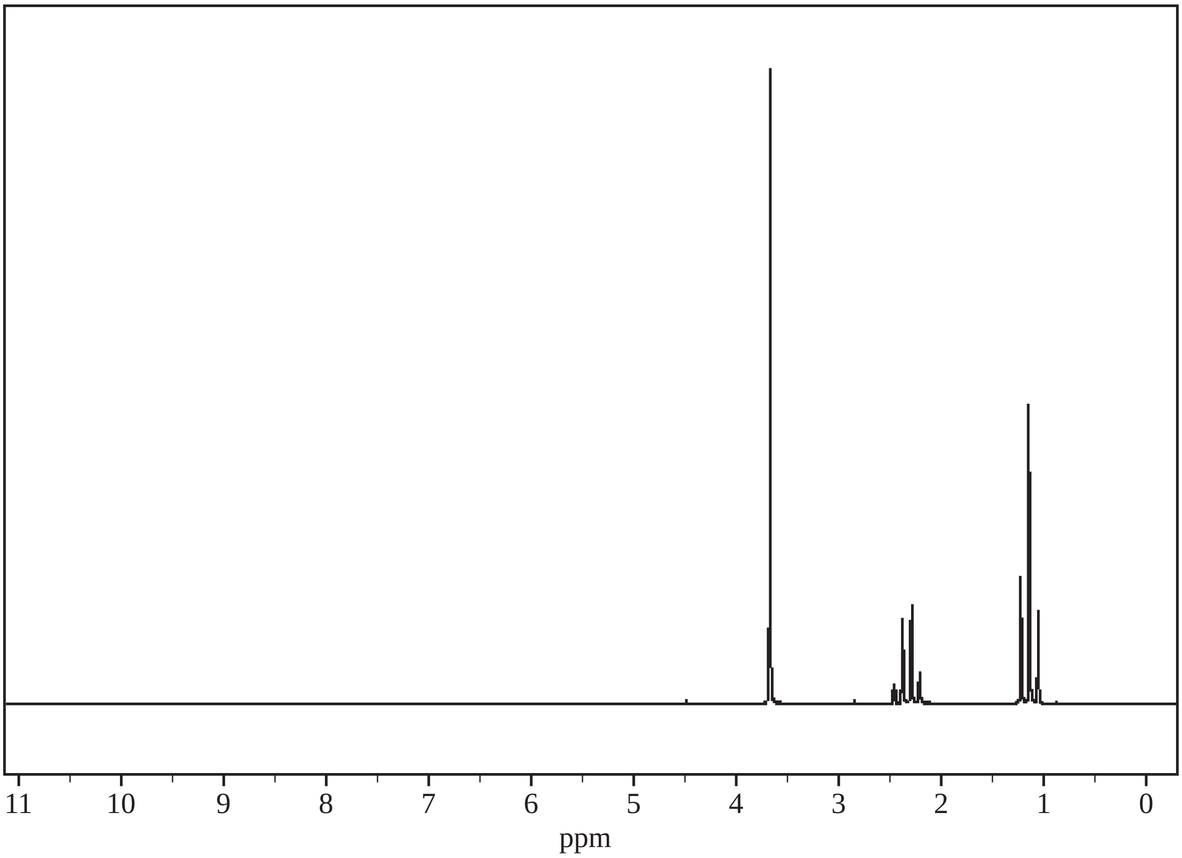


Data (both spectra): National Institute of Standards and Technology, NIST Chemistry WebBook, <https://webbook.nist.gov/chemistry/>

c. One of the spectra above is for a pure sample of methyl propanoate.

Identify which of these spectra is likely to be that of methyl propanoate. Explain how a fragment in the chosen spectrum is consistent with the structure of methyl propanoate. 2 marks

d. The high-resolution proton NMR spectrum, ^{1}H NMR, for methyl propanoate is shown below.



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

Describe **three** features of this spectrum that confirm it is for methyl propanoate. 3 marks

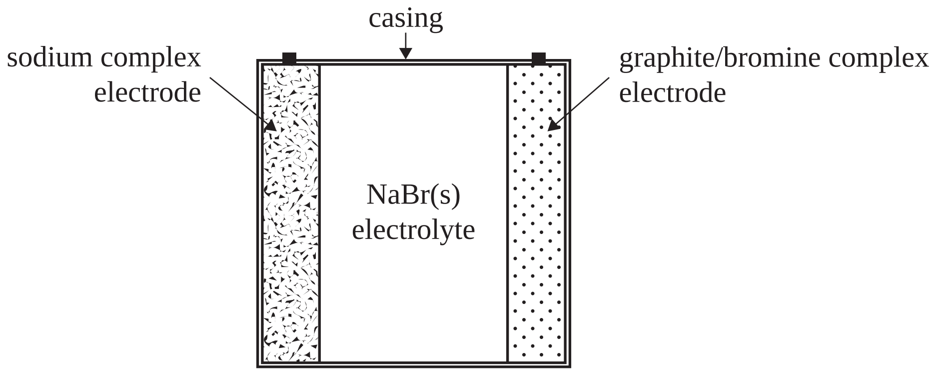
Question 9 (7 marks)

Lithium-ion rechargeable batteries are very convenient and are widely used in portable electronic devices. However, there are some issues with the ongoing use of these rechargeable batteries, such as the limited availability and the high cost of lithium metal. Another concern is the fires and burns that have resulted from malfunctions occurring during the recharging of some lithium-ion batteries.

Alternative materials to lithium for use in rechargeable batteries are currently being researched and developed. One renewable energy technology company conducted an online competition calling for new and innovative ideas for rechargeable batteries. The submissions required only a labelled diagram of the battery, including all of the essential components, as well as the equations for the reactions that would be expected to occur.

A start-up company submitted the following design for a rechargeable battery.

A hypothetical rechargeable battery (HRB)



Half-reactions for the HRB

$$Na \rightleftharpoons Na^+ + e^-$$
$$Br_2 + 2e^- \rightleftharpoons 2Br^-$$

MP(NaBr)	747 °C
MP(Na)	98 °C
BP(Br_2)	59 °C

a. Solid sodium bromide, NaBr, has been chosen as the electrolyte for the HRB.

Is this a suitable electrolyte? Justify your answer. In your response, refer to the essential requirements of an electrolyte. 3 marks

b. Discuss improvements that could be made to the HRB. Your response should be based on chemical principles rather than financial or environmental concerns. In your response:

- comment on what is required for a battery to be rechargeable
- suggest and justify a specific improvement to the HRB
- comment on a safety implication of the material(s) used in your improved version of the HRB.

4 marks

END OF QUESTION AND ANSWER BOOK

VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education 2019

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

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	$n(e^-) = \frac{Q}{F}$
% 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

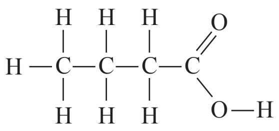
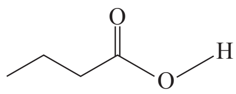
Metric (including SI) prefixes	Scientific notation	Multiplying factor
giga (G)	10^9	1 000 000 000
mega (M)	10^6	1 000 000
kilo (k)	10^3	1000
deci (d)	10^{-1}	0.1
centi (c)	10^{-2}	0.01
milli (m)	10^{-3}	0.001
micro (μ)	10^{-6}	0.000001
nano (n)	10^{-9}	0.000000001
pico (p)	10^{-12}	0.000000000001

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

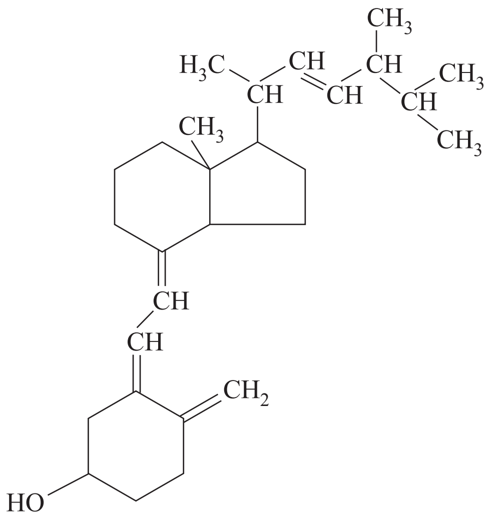
The following table shows different representations of organic molecules, using butanoic acid as an example.

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	

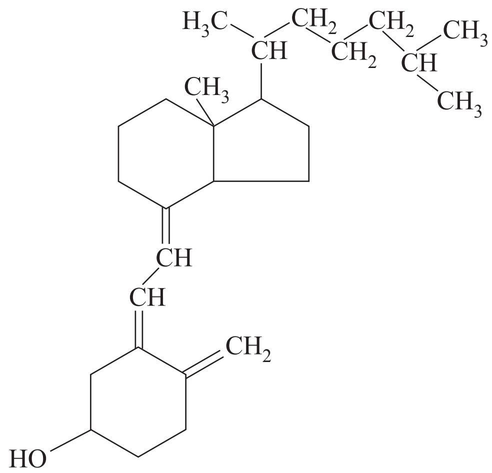
9. Formulas of some fatty acids

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

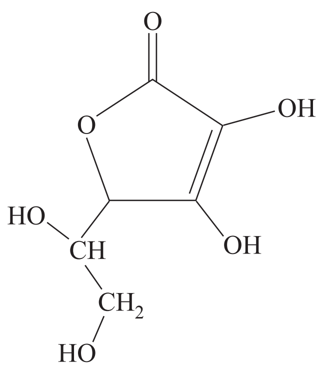
10. Formulas of some biomolecules



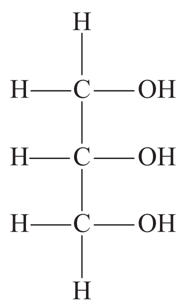
vitamin D_2 (ergocalciferol)



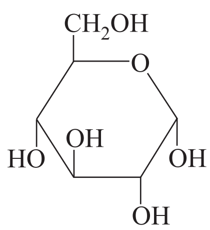
vitamin D_3 (cholecalciferol)



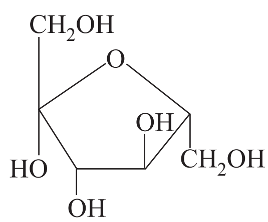
vitamin C (ascorbic acid)



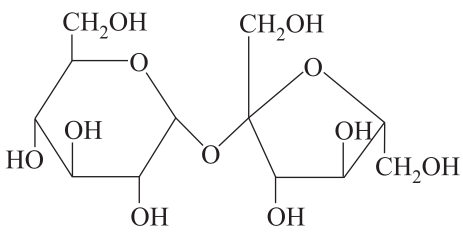
glycerol



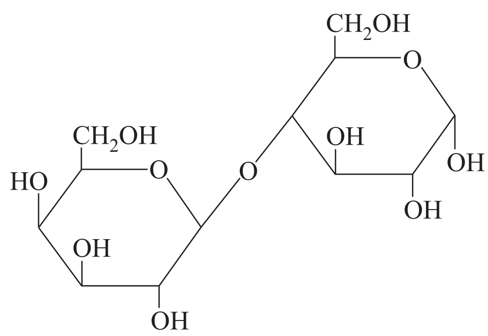
α-glucose



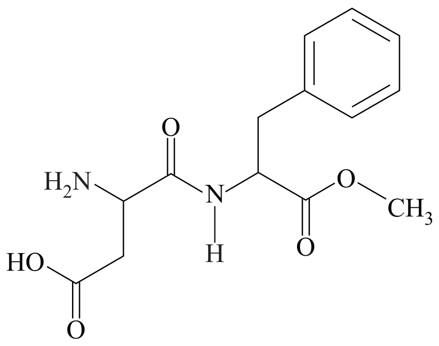
β-fructose



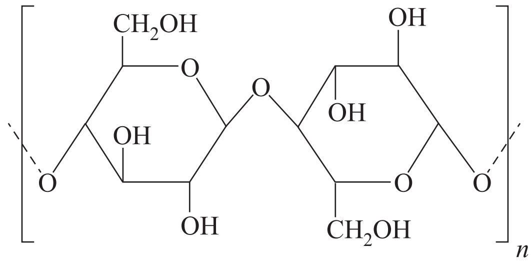
sucrose



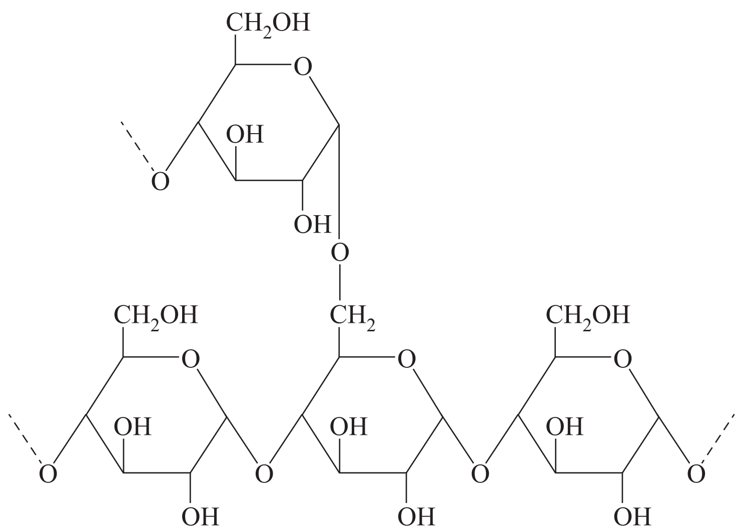
α-lactose



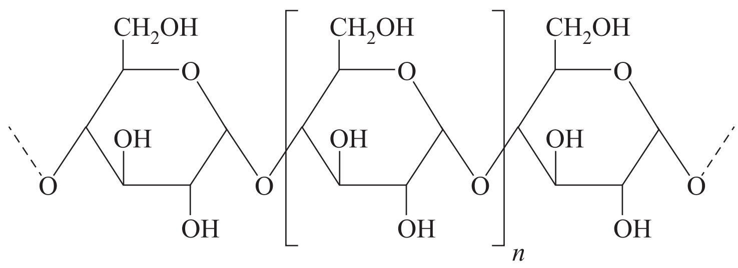
aspartame



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

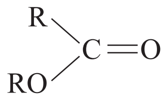
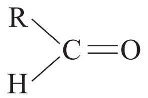
14. Characteristic ranges for infra-red absorption

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

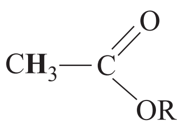
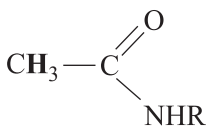
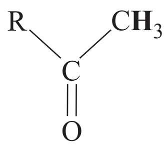
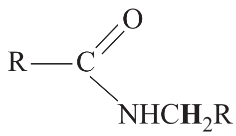
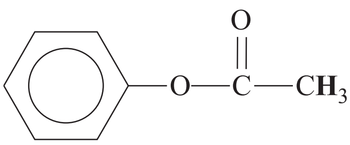
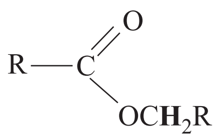
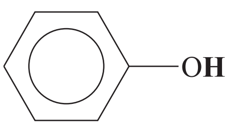
These can differ slightly in different solvents.

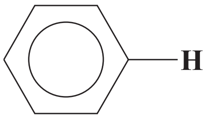
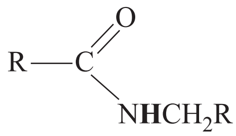
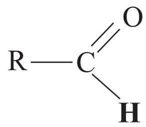
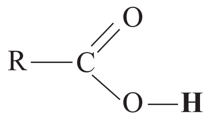
Type of carbon	Chemical shift (ppm)
$R–CH_3$	8–25
$R–CH_2–R$	20–45
$R_3–CH$	40–60
$R_4–C$	36–45
$R–CH_2–X$	15–80
$R_3C–NH_2$, $R_3C–NR$	35–70
$R–CH_2–OH$	50–90
RC≡CR	75–95
$R_2C=CR_2$	110–150
RCOOH	160–185
	165–175
	190–200
$R_2C=O$	205–220

16. ^{1}H NMR data

Typical proton shift values relative to TMS = 0

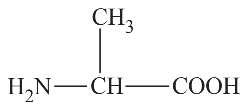
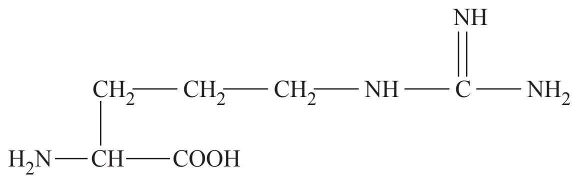
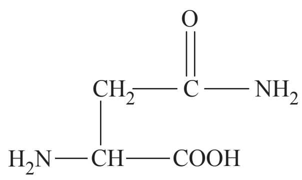
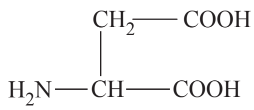
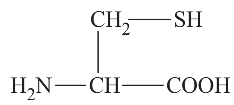
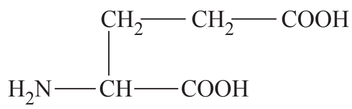
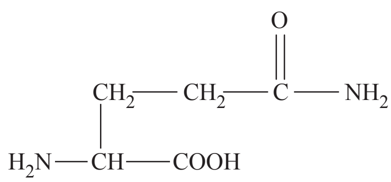
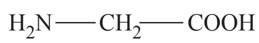
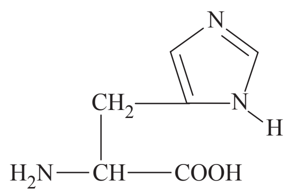
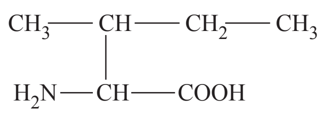
These can differ slightly in different solvents. The shift refers to the proton environment that is indicated in bold letters in the formula.

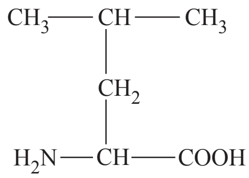
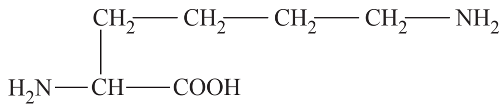
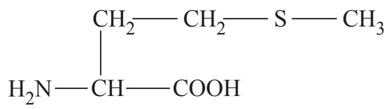
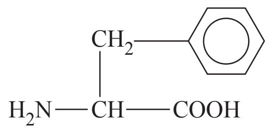
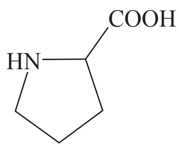
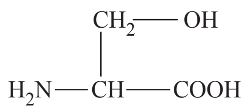
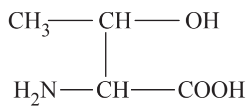
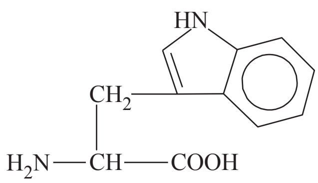
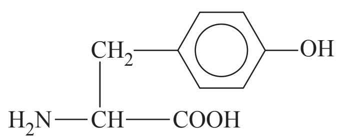
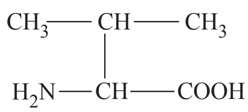
Type of proton	Chemical shift (ppm)
$R–C\mathbf{H}_3$	0.9–1.0
$R–C\mathbf{H}_2–R$	1.3–1.4
$RCH{=}CH–C\mathbf{H}_3$	1.6–1.9
$R_3–C\mathbf{H}$	1.5
 or 	2.0
	2.1–2.7
$R–C\mathbf{H}_2–X$ (X = F, Cl, Br or I)	3.0–4.5
$R–C\mathbf{H}_2–OH$, $R_2–C\mathbf{H}–OH$	3.3–4.5
	3.2
$R—O—C\mathbf{H}_3$ or $R—O—C\mathbf{H}_2R$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

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