VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

Victorian Certificate of Education 2018

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

CHEMISTRY

Written examination

Tuesday 13 November 2018

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 41 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 statements is the **most** accurate?

A. All fuel cells are galvanic cells.
B. All galvanic cells are primary cells.
C. All secondary cells have porous electrodes.
D. All fuel cells are more efficient than all secondary cells.

Question 2

Aspartame is a widely used sweetener.

Aspartame

A. contains a glycosidic link.
B. is a naturally occurring sugar.
C. has an energy content similar to that of sucrose.
D. contains two amino groups in its chemical structure.

Question 3

Which one of the following statements about fuels is correct?

A. Petroleum gas is a form of renewable energy.
B. Electricity can only be generated by burning coal.
C. Carbon dioxide is not produced when biogas is burnt.
D. Biodiesel can be derived from both plant and animal material.

Question 4

At the molecular level, Protein P is shaped like a coil. When a solution of Protein P is mixed with citric acid, solid lumps form.

The change in the structure of Protein P is due to

A. hydrolysis.
B. denaturation.
C. polymerisation.
D. the formation of peptide bonds.

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Question 5

Coal seam gas is used to generate electricity.

Which one of the following statements applies to coal seam gas?

A. Coal seam gas is mostly methane and is found naturally in commercial quantities near some coal deposits.

B. Burning coal produces less greenhouse emissions, by mass, than burning coal seam gas.

C. Water released during the extraction of coal seam gas is used to irrigate farms.

D. Coal seam gas is extracted from decomposing plant and animal material.

Question 6

Ethoxyethane, $C_2H_5OC_2H_5$, is commonly used as a solvent in the purification of compounds. The boiling point of $C_2H_5OC_2H_5$ is 36 °C.

The safety data sheet for $C_2H_5OC_2H_5$ states: 'Extremely flammable. Keep away from sources of ignition.'

During the purification process, a compound is dissolved in $C_2H_5OC_2H_5$ by heating it for an extended period of time. This is done using glassware that is open to the atmosphere.

This step in the purification process should be carried out using a

A. water bath in a fume cupboard.

B. water bath on a laboratory bench.

C. Bunsen burner in a fume cupboard.

D. Bunsen burner on a laboratory bench.

Question 7

Vitamins are required by the human body.

Which one of the following statements about vitamins is correct?

A. Vitamin D_2 and vitamin D_3 are structural isomers.

B. Vitamin D can be stored in the fatty tissues of the body.

C. Vitamin D is water-soluble due to the presence of the hydroxyl group.

D. Vitamin D is essential in the human diet as it cannot be manufactured by the body.

Question 8

Which one of the following fatty acids is an omega-3 fatty acid?

A. arachidonic

B. palmitoleic

C. linolenic

D. linoleic

Question 9

When molten sodium chloride, NaCl, is electrolysed, the product formed at the cathode is

A. sodium liquid, Na.

B. hydrogen gas, H_2.

C. chlorine gas, Cl_2.

D. oxygen gas, O_2.

Question 10

Bioethanol, C_2H_5OH, is produced by the fermentation of glucose, $C_6H_{12}O_6$, according to the following equation.

$$C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(aq) + 2CO_2(g)$$

The mass of C_2H_5OH obtained when 5.68 g of carbon dioxide, CO_2, is produced is

A. 0.168 g

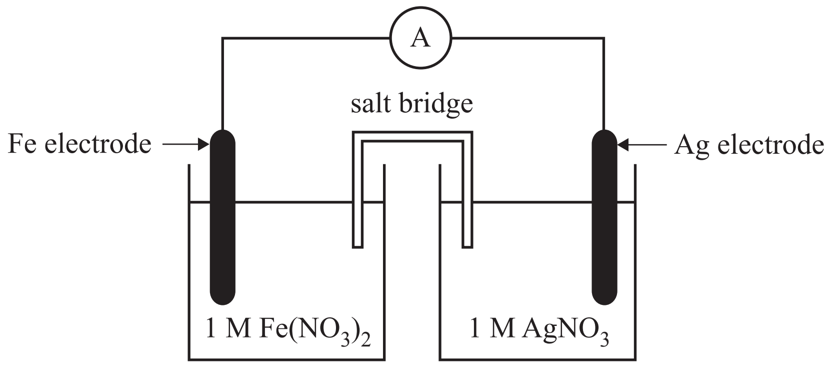
B. 0.337 g

C. 2.97 g

D. 5.94 g

Question 11

A galvanic cell is set up as shown in the diagram below.



When this cell is operating

A. a gas forms at the Ag electrode.

B. the mass of the Ag electrode increases.

C. Ag^+ ions move towards the Fe electrode.

D. electrons move from the Ag electrode to the Fe electrode.

Question 12

The overall reaction for an acidic fuel cell is shown below.

$$2H_2 + O_2 \rightarrow 2H_2O$$

Porous electrodes are often used in acidic fuel cells because they

A. are highly reactive.

B. are cheap to produce and readily available.

C. are more efficient than solid electrodes at moving charges and reactants.

D. provide a surface for the hydrogen and oxygen to directly react together.

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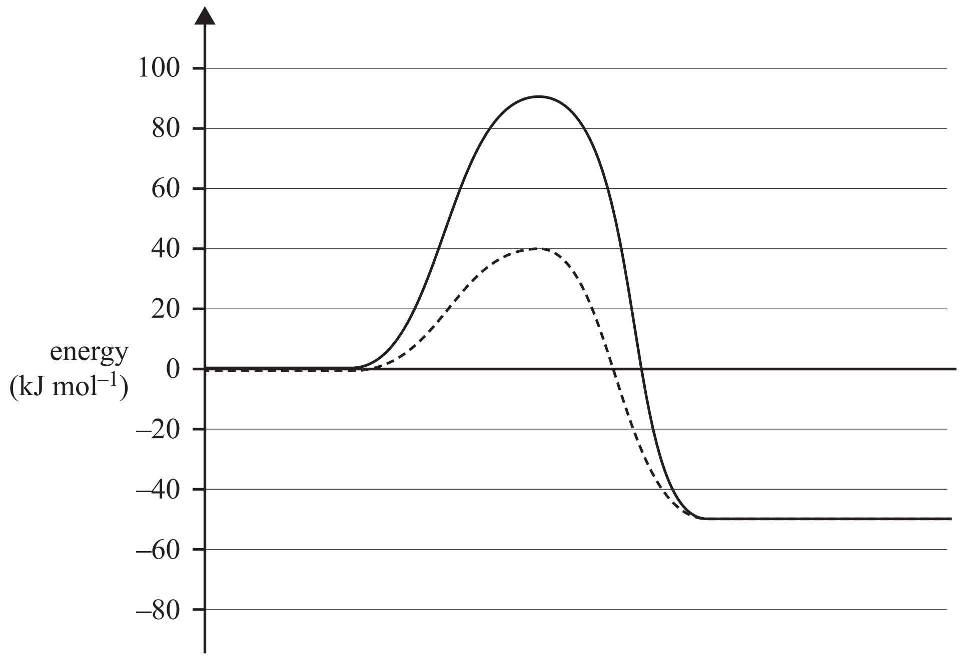
Question 13

The energy profile diagram below represents a particular reaction. One graph represents the uncatalysed reaction and the other graph represents the catalysed reaction.



Which of the following **best** matches the energy profile diagram?

	E_a **uncatalysed reaction (kJ mol^{-1})**	ΔH **catalysed reaction (kJ mol^{-1})**
A.	40	–140
B.	90	–140
C.	40	–50
D.	90	–50

Question 14

An equation for the complete combustion of methanol is

$$2CH_3OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(g)$$

ΔH for this equation would be

A. +726 kJ mol^{-1}

B. –726 kJ mol^{-1}

C. +1452 kJ mol^{-1}

D. –1452 kJ mol^{-1}

Question 15

The following table contains the percentage composition by mass of the nutritional value of some common foods.

Food	% Carbohydrates	% Fats and oils	% Protein
fish	0	8	29
bread	50	4	8
cheese	1	34	25
milk	5	4	3

Which one of the following servings has the highest energy content?

A. 100 g of fish
B. 80 g of bread
C. 40 g of cheese
D. 258 g (250 mL) of milk

Question 16

The silver oxide-zinc battery is rechargeable and utilises sodium hydroxide, NaOH, solution as the electrolyte. The battery is used as a backup in spacecraft, if the primary energy supply fails.

The overall reaction during discharge is

$$Zn + Ag_2O \rightarrow ZnO + 2Ag$$

When the silver oxide-zinc battery is being **recharged**, the reaction at the anode is

A. $2Ag + 2OH^- \rightarrow Ag_2O + H_2O + 2e^-$
B. $Ag_2O + H_2O + 2e^- \rightarrow 2Ag + 2OH^-$
C. $ZnO + H_2O + 2e^- \rightarrow Zn + 2OH^-$
D. $Zn + 2OH^- \rightarrow ZnO + H_2O + 2e^-$

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Use the following information to answer Questions 17 and 18.

A clear, colourless liquid extract of the rhubarb plant was analysed for the concentration of oxalic acid, $H_2C_2O_4$, by direct titration with a recently standardised and acidified potassium permanganate solution, $KMnO_4(aq)$.

The balanced equation for this titration is shown below.

$$2MnO_4^-(aq) + 5C_2O_4^{2-}(aq) + 16H^+(aq) \rightarrow 2Mn^{2+}(aq) + 10CO_2(g) + 8H_2O(l)$$

purple colourless colourless

The steps in the titration were as follows:

Step 1 – A 20.00 mL aliquot of the rhubarb extract was placed in a 200 mL conical flask.

Step 2 – The burette was filled with acidified 0.0200 M $KMnO_4$ solution.

Step 3 – The acidified 0.0200 M $KMnO_4$ solution was titrated into the rhubarb extract in the conical flask. The titration was considered to have reached the end point when the solution in the conical flask showed a permanent change in colour to pink. The volume of the titre was recorded.

Step 4 – The titration was repeated until three concordant results were obtained. The average of the concordant titres was 21.7 mL.

Question 17

The concentration of $H_2C_2O_4$ in the rhubarb extract is closest to

A. 5.43×10^{-2} M

B. 5.00×10^{-2} M

C. 2.17×10^{-2} M

D. 7.40×10^{-4} M

Question 18

Which of the following rinses is **least** likely to affect the accuracy of the results?

	Item	Rinse solution
A.	burette	distilled water
B.	burette	rhubarb extract
C.	pipette	$KMnO_4(aq)$
D.	conical flask	distilled water

Question 19

Which one of the following molecules contains a chiral carbon?

A. $CH_2CHCH_2CH_3$

B. $CH_2FCH_2CH_2Cl$

C. $CH_3CHOHCH_2CH_3$

D. $CH_3CH_2CFClCH_2CH_3$

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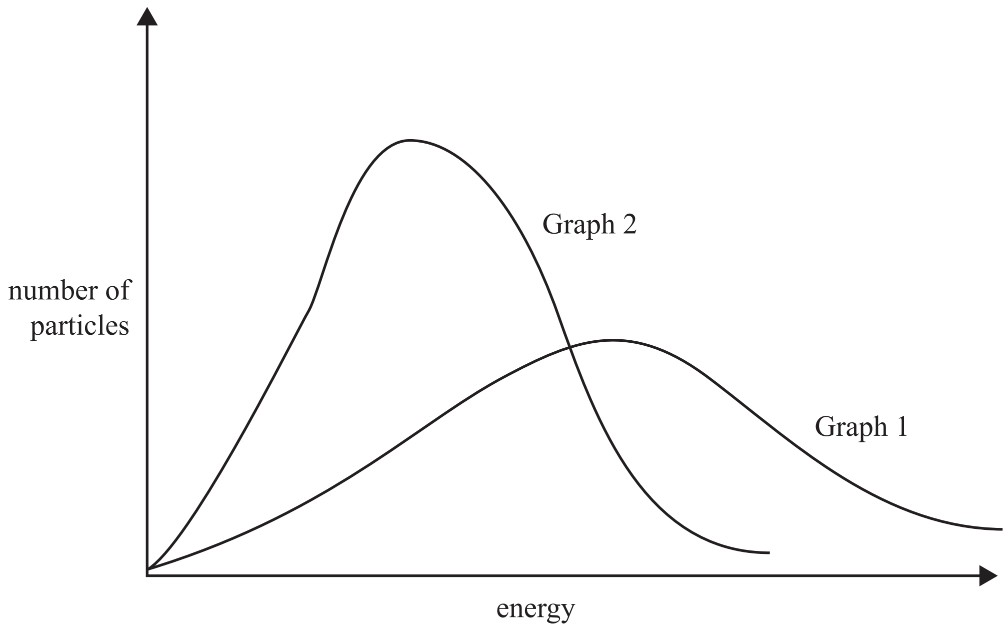
Question 20

The kinetic energy of a sample of gas in a container of fixed volume is represented by the distribution curve shown in Graph 1 below.

One change was made to the sample and the resulting distribution curve of kinetic energy is shown in Graph 2.



Which one of the following statements explains the change from Graph 1 to Graph 2?

A. The average kinetic energy of the gas molecules decreased.

B. More gas, at the same temperature, was added to the container.

C. More collisions occurred between gas particles.

D. The temperature of the gas was increased.

Question 21

A student wants to use a physical property to distinguish between two alcohols, octan-1-ol and propan-1-ol. Both alcohols are colourless liquids at standard laboratory conditions (SLC).

The student should use

A. density because propan-1-ol has a much higher density than octan-1-ol.

B. boiling point because octan-1-ol has a higher boiling point than propan-1-ol.

C. electrical conductivity because octan-1-ol has a higher conductivity than propan-1-ol.

D. spectroscopy because it is not possible to distinguish between the alcohols using their physical properties.

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Question 22

Four fuels undergo complete combustion in excess oxygen, O_2, and the energy released is used to heat 1000 g of water.

Assuming there is no energy lost to the environment, which one of these fuels will increase the temperature of the water from 25.0 °C to 85.0 °C?

A. 0.889 g of hydrogen, H_2

B. 3.95 g of propane, C_3H_8

C. 0.282 mol of methane, CH_4

D. 0.301 mol of methanol, CH_3OH

Question 23

A student is asked to research and then recommend either petrodiesel or biodiesel as the preferred fuel for a small Victorian transport company. The company stores some of its fuel supplies in tanks situated in remote locations for occasional use. The air temperature in these remote locations can range between 0 °C and 40 °C.

Based on this information, the student would recommend petrodiesel rather than biodiesel because petrodiesel is

A. more hygroscopic, more viscous and less likely to biodegrade when stored.

B. more hygroscopic, less viscous and more likely to biodegrade when stored.

C. less hygroscopic, more viscous and more likely to biodegrade when stored.

D. less hygroscopic, less viscous and less likely to biodegrade when stored.

Question 24

The four equations below represent different equilibrium systems.

Equation 1	$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$	$\Delta H = -180$ kJ mol^{-1}
Equation 2	$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$	$\Delta H = -46$ kJ mol^{-1}
Equation 3	$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$	$\Delta H = 93$ kJ mol^{-1}
Equation 4	$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$	$\Delta H = 205$ kJ mol^{-1}

After equilibrium was established in each system, the temperature was decreased and the pressure was increased.

In which equilibrium system would both changes result in an increase in yield?

A. Equation 1

B. Equation 2

C. Equation 3

D. Equation 4

Question 25

The molar heat of combustion of pentan-1-ol, $C_5H_{11}OH$, is 3329 kJ mol^{-1}.

$M(C_5H_{11}OH) = 88.0$ g mol^{-1}

The mass of $C_5H_{11}OH$, in tonnes, required to produce 10 800 MJ of energy is closest to

A. 0.0286

B. 0.286

C. 2.86

D. 286

Question 26

Organic acids, including vitamin C (ascorbic acid), are present in lemon juice. Since organic acids and vitamin C are weak acids, they will undergo acid-base reactions. Only vitamin C, not the organic acids, will undergo a redox reaction with iodine, I_2.

Which one of the following methods would be most appropriate to determine the concentrations of the organic acids and the vitamin C in a sample of lemon juice?

A. an acid-base titration with sodium hydroxide and phenolphthalein indicator

B. an acid-base titration with ammonia and phenol red indicator, and a redox titration with iodine and permanganate ion indicator

C. an acid-base titration with sodium hydroxide and methyl orange indicator, and a redox titration with iodine and a starch indicator

D. an acid-base titration with potassium hydroxide and phenolphthalein indicator, and a redox titration with iodine and a starch indicator

Question 27

$$Br_2(g) + I_2(g) \rightleftharpoons 2IBr(g) \qquad K_c = 1.2 \times 10^2 \text{ at } 150\ °C$$

Given the information above, what is K_c for the reaction $4IBr(g) \rightleftharpoons 2Br_2(g) + 2I_2(g)$ at 150 °C?

A. 1.6×10^{-2}

B. 4.1×10^{-3}

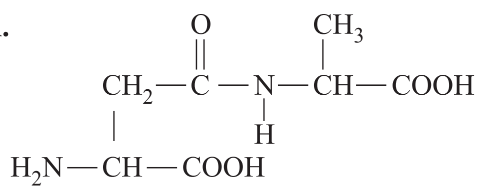
C. 6.9×10^{-5}

D. 8.03×10^{-5}

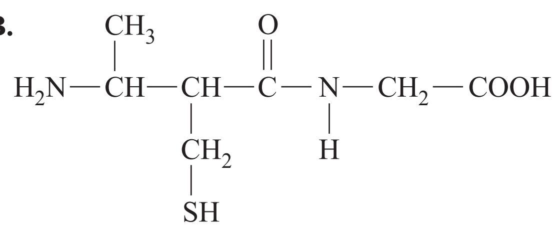
Question 28

Which one of the following is a dipeptide made from *α*-amino acids?

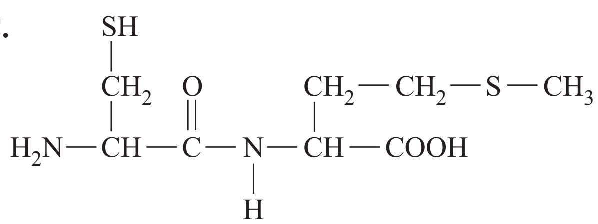
A.



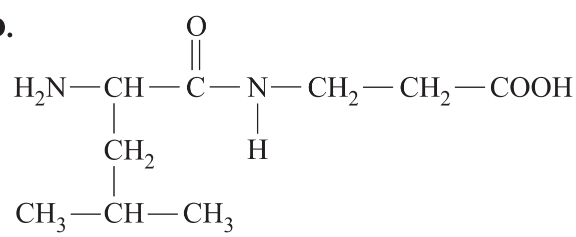
B.



C.



D.



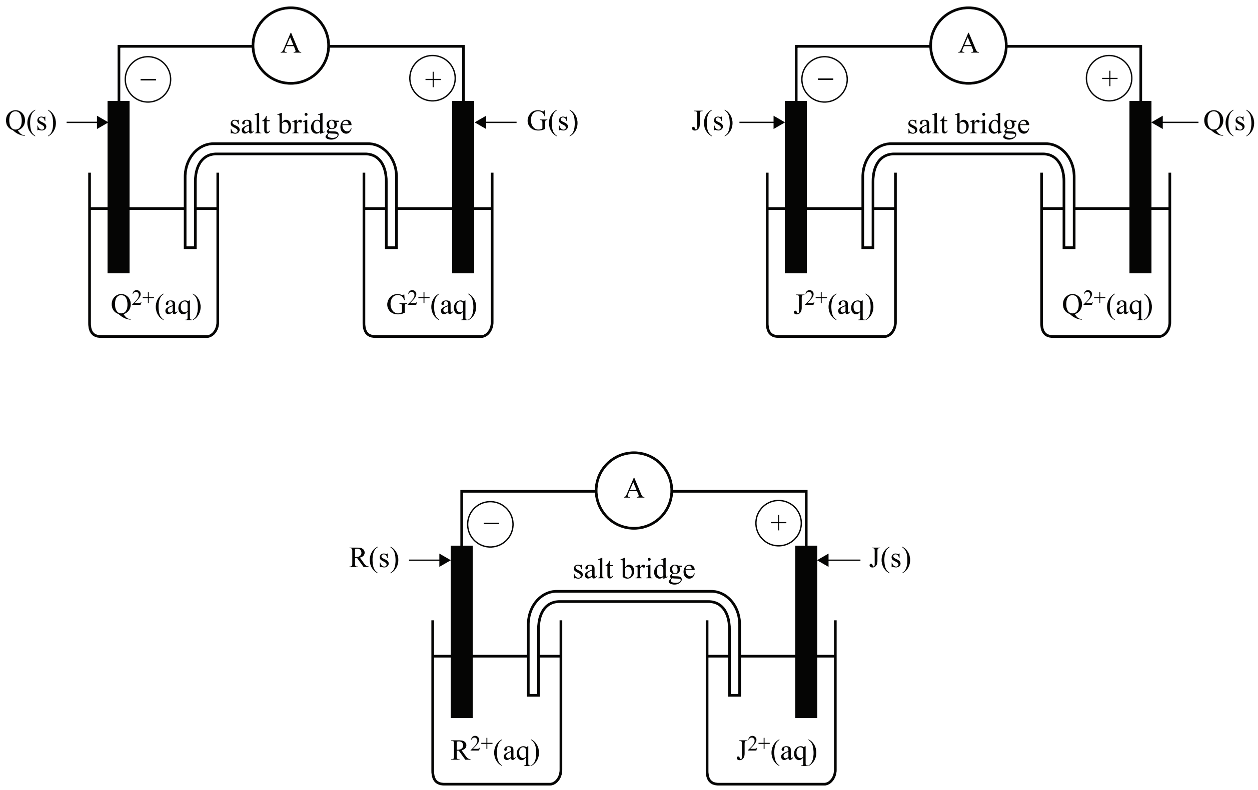
Question 29

The following diagrams represent combinations of four galvanic half-cells (G/G^{2+}, J/J^{2+}, Q/Q^{2+} and R/R^{2+}) that were investigated under standard conditions.

Each half-cell consisted of a metal electrode placed in a 1.0 M nitrate solution of the respective metal ion.

The diagrams show the polarity of the electrodes in each half-cell, as determined using an ammeter.

The results were then used to determine the order of the E^0 values of the half-reactions.



Which of the following indicates the order of the half-cell reactions, from the lowest E^0 value to the highest?

A. J/J^{2+}, R/R^{2+}, G/G^{2+}, Q/Q^{2+}

B. Q/Q^{2+}, G/G^{2+}, R/R^{2+}, J/J^{2+}

C. R/R^{2+}, J/J^{2+}, Q/Q^{2+}, G/G^{2+}

D. G/G^{2+}, Q/Q^{2+}, J/J^{2+}, R/R^{2+}

Question 30

In the human body, not all energy available from the metabolism of food is dissipated as heat energy. A student carried out further research on this and found that some of the energy is used in the production of adenine triphosphate, ATP^{3-}, from adenine diphosphate, ADP^{2-}, and inorganic phosphate, PO_4^{3-}, according to the following equation.

$$ADP^{2-} + PO_4^{3-} + 2H^+ \rightarrow ATP^{3-} + H_2O$$

The student also learnt that the overall equation for aerobic respiration can be represented as shown below.

$$C_6H_{12}O_6 + 6O_2 + 32ADP^{2-} + 32PO_4^{3-} + 64H^+ \rightarrow 6CO_2 + 32ATP^{3-} + 38H_2O$$

It is reasonable to deduce that in aerobic respiration

A. the formation of ATP^{3-} is a hydrolysis reaction.

B. for 3.3 g of CO_2 to be produced, 0.40 mol of ADP^{2-} is needed [$M(CO_2) = 44$ g mol^{-1}].

C. the production of ATP^{3-} from ADP^{2-} and PO_4^{3-} is an exothermic reaction.

D. 9.5 g of $C_6H_{12}O_6$ will produce 2.0 mol of ATP^{3-} [$M(C_6H_{12}O_6) = 180$ g mol^{-1}].

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END OF SECTION A

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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).

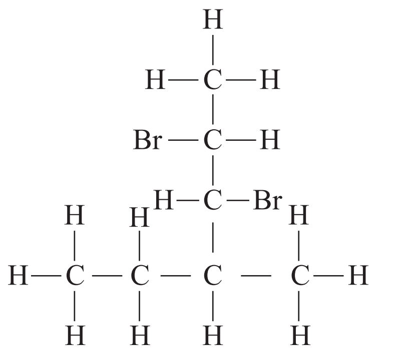
Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

Question 1 (6 marks)

Organic compounds are numerous and diverse due to the nature of the carbon atom. There are international conventions for the naming and representation of organic compounds.

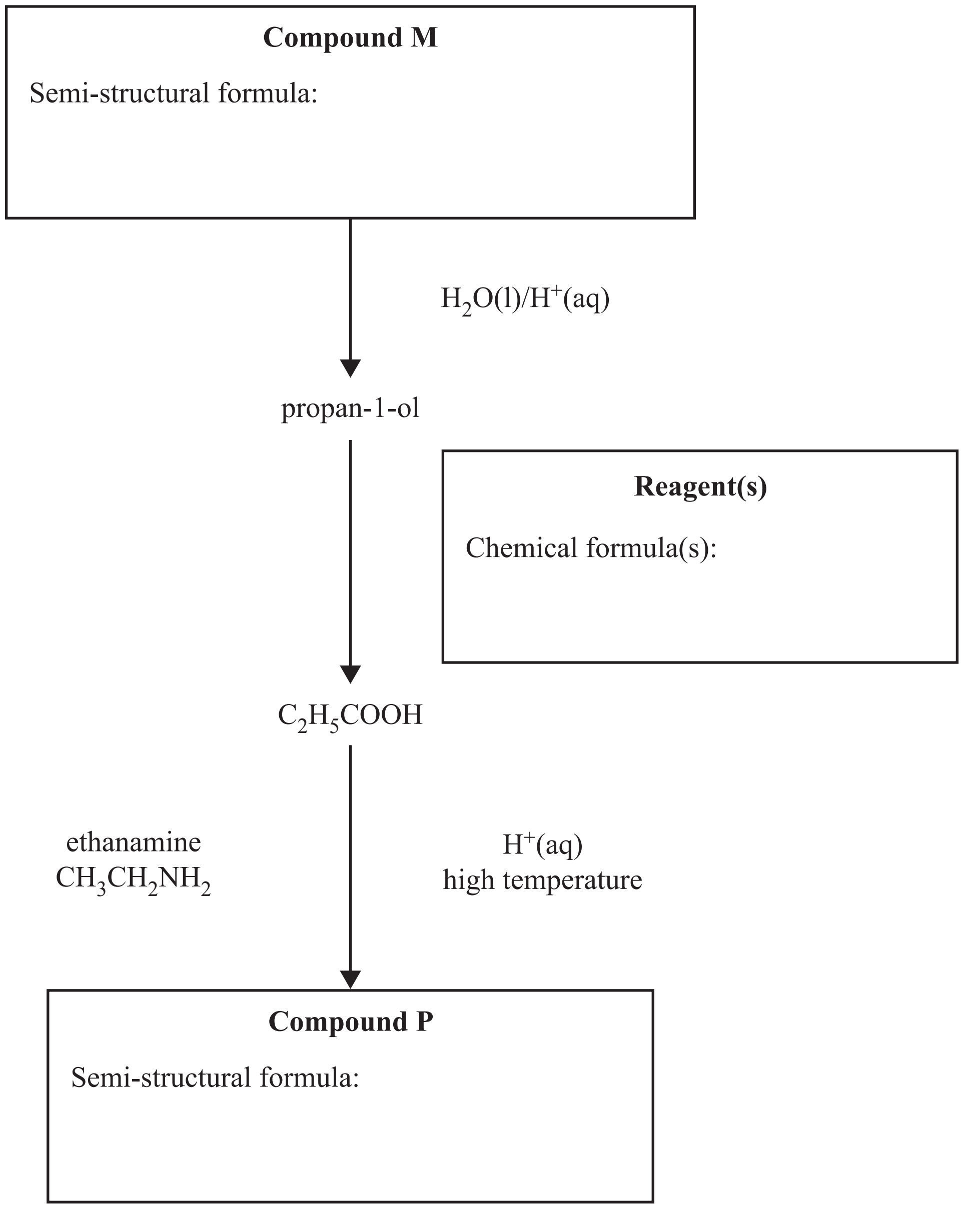
a. **i.** Draw the structural formula of 2-methyl-propan-2-ol. 1 mark

ii. Give the molecular formula of but-2-yne. 1 mark



iii. Give the IUPAC name of the compound that has the structural formula shown above. 1 mark

b. The following diagram represents a reaction pathway for the synthesis of Compound P.



i. Identify the starting substance, Compound M, by writing its semi-structural formula in the box provided. 1 mark

ii. Identify the reagent(s) needed to convert propan-1-ol to propanoic acid, C_2H_5COOH, by writing the chemical formula(s) of the reagent(s) in the box provided. 1 mark

iii. When C_2H_5COOH is mixed with ethanamine, $CH_3CH_2NH_2$, in an acidified high-temperature environment, Compound P is formed.

Write the semi-structural formula of Compound P in the box provided. 1 mark

Question 2 (9 marks)

Hydrogen peroxide, H_2O_2, in aqueous solution at room temperature decomposes slowly and irreversibly to form water, H_2O, and oxygen, O_2, according to the following equation.

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g) \qquad \Delta H < 0$$

a. What effect will increasing the temperature have on the rate of O_2 production? Use collision theory to explain your answer. 3 marks

b. When a small lump of manganese(IV) dioxide, MnO_2, is added to the H_2O_2 solution, the rate of O_2 production increases, but when powdered MnO_2 is added instead, the rate of O_2 production is **greatly** increased. The MnO_2 is recovered at the end of the reaction.

State the function of MnO_2 in this reaction. 1 mark

c. A solution of H_2O_2 is labelled '10 volume' because 1.00 L of this solution produces 10.0 L of O_2 measured at standard laboratory conditions (SLC) when the H_2O_2 in the solution is fully decomposed.

Calculate the concentration of H_2O_2 in the '10 volume' solution, in grams per litre, when this solution is first prepared. 2 marks

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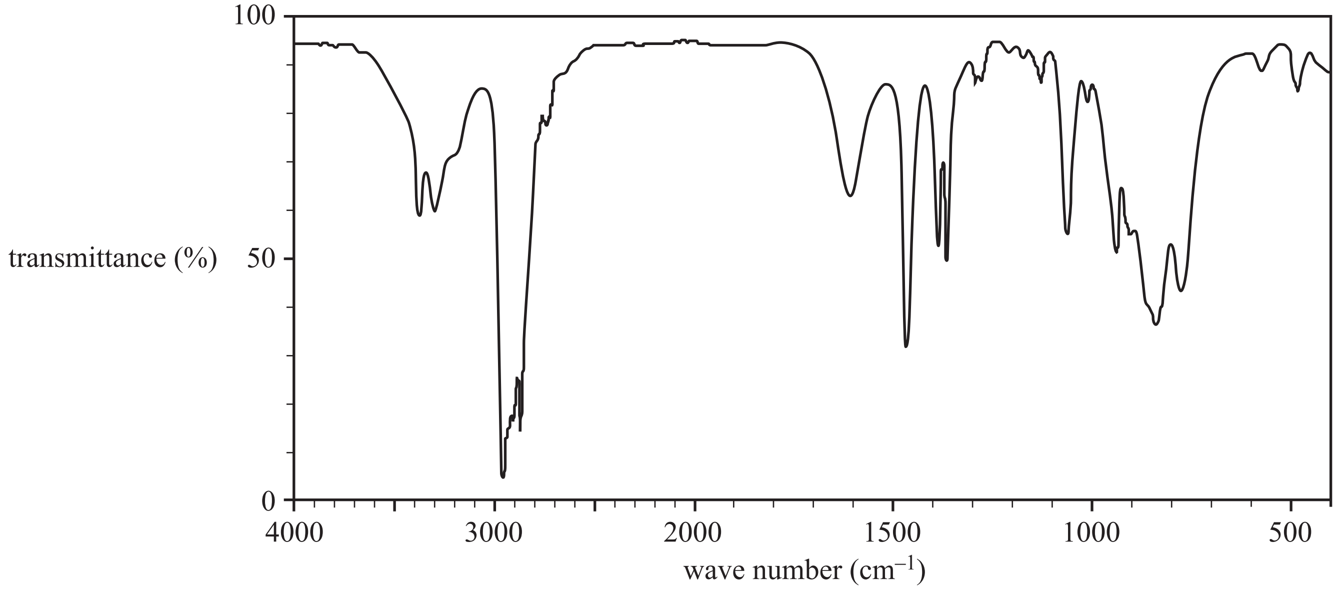
d. Propose a method to determine how quickly a solution of H_2O_2 decomposes when stored at a particular temperature. 3 marks

Question 3 (10 marks)

A chemical that contains carbon, C, nitrogen, N, and hydrogen, H, in the ratio 4:1:11 is analysed using spectroscopy.

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



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

In the table below, write the bond responsible for the wave numbers given. 1 mark

Wave number (cm^{-1})	Bond
2956	
3376	

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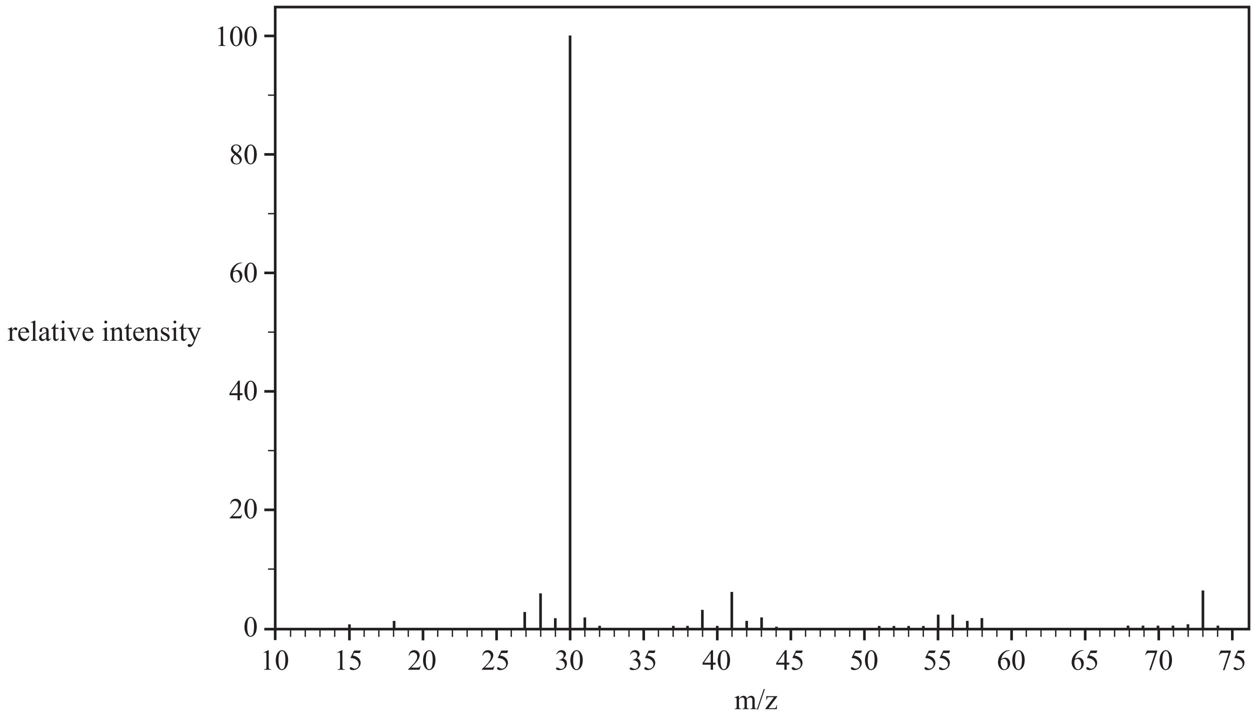
b. The mass spectrum of the chemical is shown below.



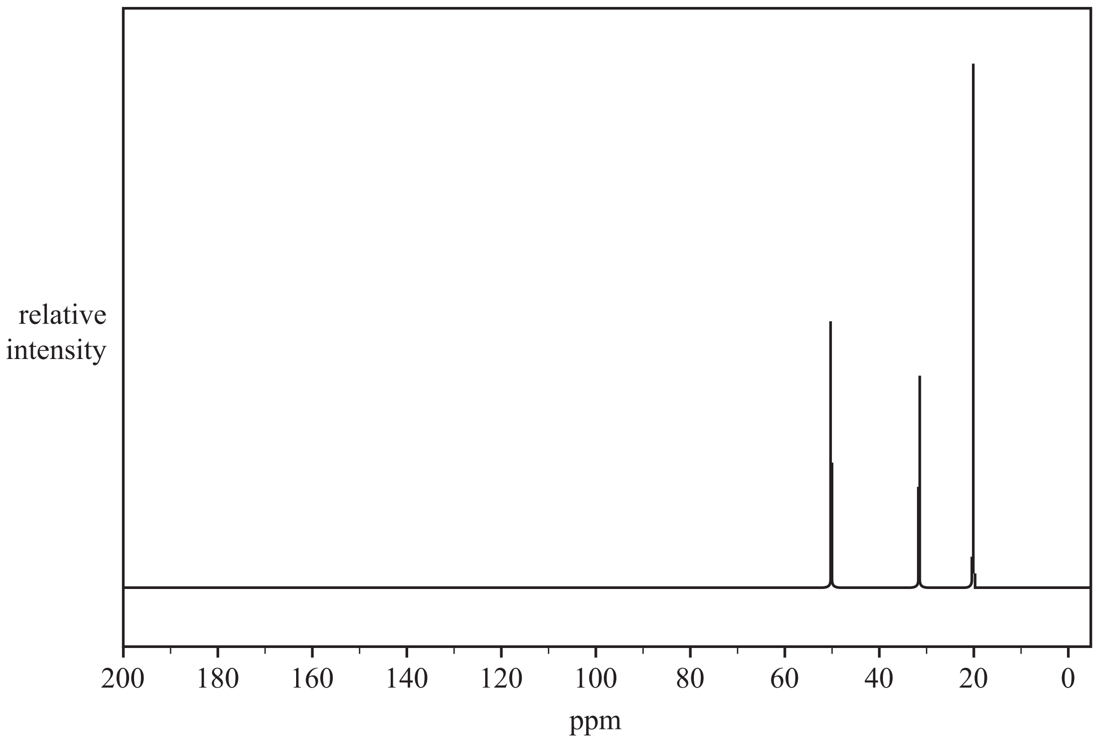
Data: SDBS Web, <http://sdbs.db.aist.go.jp>,
National Institute of Advanced Industrial Science and Technology

i. What is the molecular formula for the parent molecule? Justify your answer using information from the mass spectrum. 2 marks

ii. Identify the fragment that produces the base peak. 1 mark

iii. Draw the structural formulas for **two** possible structural isomers of the chemical, which are consistent with the mass spectrum and the IR spectrum. 2 marks

c. The ^{13}C NMR spectrum of the chemical is shown below.



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

i. Complete the following table using the ^{13}C NMR spectrum. 2 marks

Chemical shift	Type of carbon
20.0	
50.2	

ii. Draw the skeletal formula for the chemical, which is consistent with the IR spectrum, mass spectrum and ^{13}C NMR spectrum. 2 marks

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Question 4 (9 marks)

There are four optical isomers of ascorbic acid. Only one of these, L-ascorbic acid (vitamin C), is active in the human body.

Vitamin C is essential in the human diet and has many functions. One of its functions is as a coenzyme in the production of the protein collagen. During the synthesis of collagen, vitamin C acts as an electron donor. Collagen is important in the body. A lack of collagen results in a condition called scurvy.

a. The second most common amino acid in collagen is proline.

Draw the zwitterion of proline. 1 mark

b. Describe the role of vitamin C as a coenzyme in collagen synthesis. Use the physical and chemical interactions of vitamin C with the enzyme to explain how the enzyme is able to catalyse the production of collagen. 3 marks

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c. **i.** What is meant by the term ‘optical isomer’? 1 mark

ii. Explain why L-ascorbic acid, as vitamin C, is active as a coenzyme in the human body while the other optical isomers are not. 2 marks

d. Vitamin C can also act as an antioxidant and is often added to food.

Explain why foods that contain a high proportion of unsaturated fats would require more vitamin C to preserve them than foods that contain a high proportion of saturated fats. 2 marks

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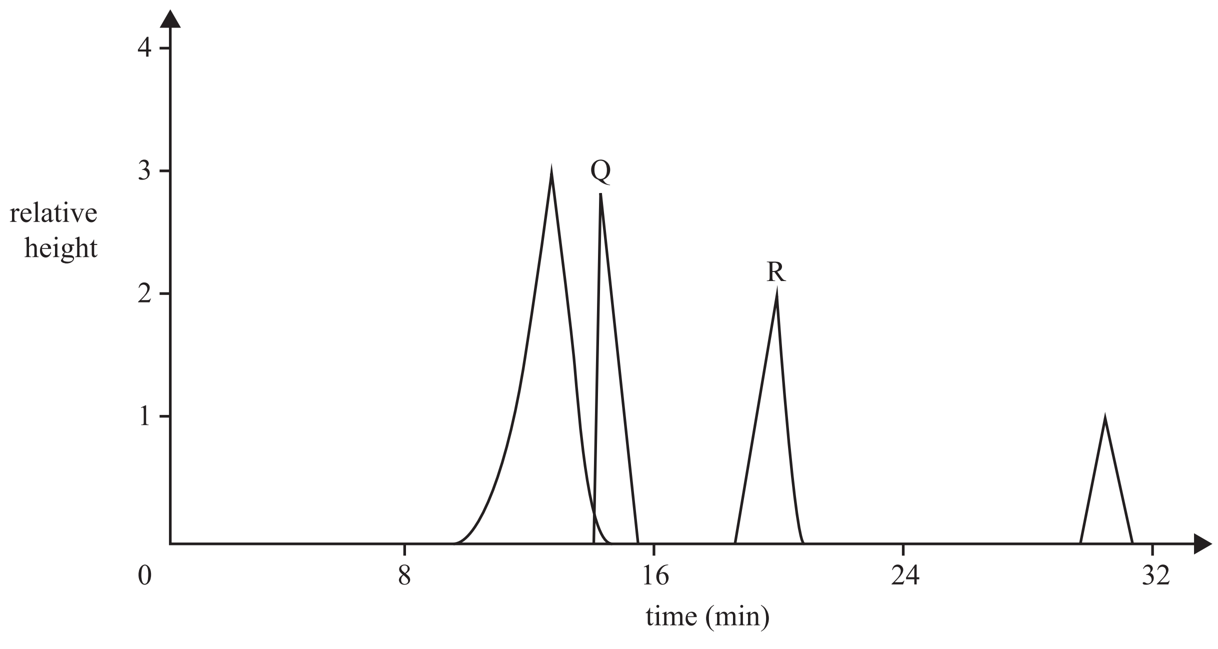
Question 5 (11 marks)

Researchers have developed a technique that allows high-performance liquid chromatography (HPLC) to simultaneously determine the concentration of sugar, organic acids and alcohols in fermentation products and food samples. The table below shows the retention times for some common organic molecules using this technique.

Retention times for some organic molecules

Organic molecule	Retention time (min)
maltose	12.50
lactose	12.70
glucose	14.45
galactose	15.35
succinic acid	18.25
glycerol	20.33
ethanol	30.63

Below is a chromatogram of four organic molecules.



a. Identify the substances responsible for each of the peaks Q and R. 2 marks

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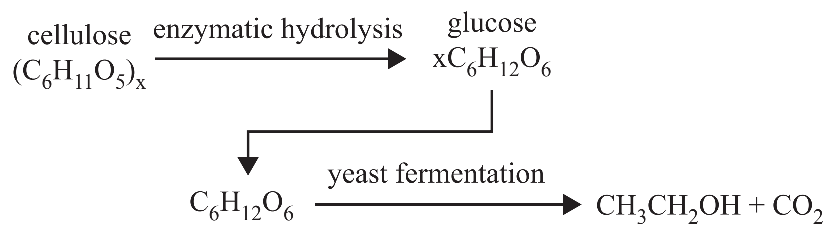
b. Two substances have different retention times under identical conditions using the same HPLC equipment.

Explain this difference in retention times. 3 marks

c. *Miscanthus floridulus* is a type of grass that is approximately 37% cellulose by mass. *M. floridulus* is being researched as a feedstock for bioethanol, CH_3CH_2OH, production. The cellulose in this grass can be used to produce CH_3CH_2OH, as summarised in the flow chart below. In each step of this process, there is incomplete conversion and waste products are formed.



HPLC can be used to determine the concentration of fermentation products at different points in the process.

i. Researchers use percentage by mass of CH_3CH_2OH produced to make comparisons between different grasses as feedstocks. Using HPLC, a researcher determined that 144 L of CH_3CH_2OH was produced from 1000 kg of *M. floridulus*.

Calculate the percentage by mass of CH_3CH_2OH produced from the mass of cellulose in *M. floridulus*, assuming the density of CH_3CH_2OH is 0.79 g mL^{-1}. 3 marks

ii. Calculate the amount of energy, in kilojoules, that would be produced if complete combustion of 144 L of CH_3CH_2OH occurred. 1 mark

d. CH_3CH_2OH can be added to petrol to make E10, a type of fuel containing 10% CH_3CH_2OH.

Explain why E10 is more viscous than regular petrol under the same conditions. 2 marks

DO NOT WRITE IN THIS AREA

Question 6 (10 marks)

Redox reactions occur in the human body as well as in electrochemical cells.

a. Nicotinamide adenine dinucleotide (NAD) is a vital coenzyme for energy production in the human body. It exists in two forms: an oxidised form, NAD^+, and a reduced form, NADH.

NAD is involved in the conversion of ethanol, CH_3CH_2OH, to ethanal, CH_3CHO, in the human body.

The overall equation for this redox reaction is

$$CH_3CH_2OH + NAD^+ \rightarrow CH_3CHO + NADH + H^+$$

i. Write the two half-equations for this redox reaction. States are not required. 2 marks

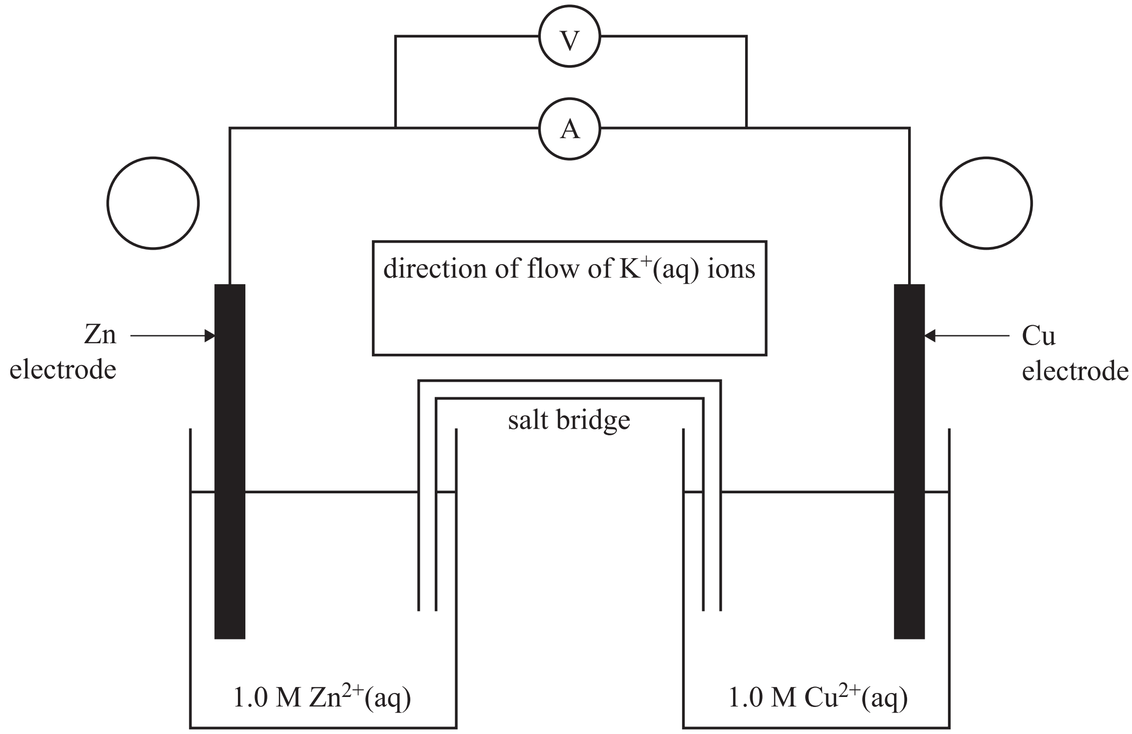
Oxidation half-equation ______________________________

Reduction half-equation ______________________________

ii. Identify the reducing agent in this redox reaction. 1 mark

____

b. The Daniell cell, a type of galvanic cell, was first constructed in the mid-1800s and this type of cell is still in use today. A diagram of the Daniell cell is shown below.



i. Label the polarity of the electrodes by placing a positive (+) or negative (–) sign in each of the circles next to the electrodes on the diagram above. 1 mark

DO NOT WRITE IN THIS AREA

ii. Use the electrochemical series to determine the theoretical voltage of this cell. 1 mark

iii. The electrolyte in the salt bridge is a potassium nitrate solution, $KNO_3(aq)$.

In the box above the salt bridge, use an arrow to indicate the direction of flow of $K^+(aq)$ ions. 1 mark

iv. List **two** visible changes that are likely to be observed when the Daniell cell has been operating for some time. 2 marks

c. What design features of the Daniell cell structure would allow it to produce electrical energy? 2 marks

Question 7 (8 marks)

A student is investigating the following reaction system.

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad \Delta H < 0$$

brown colourless

a. The reaction system can be observed in a sealed test tube, which allows the student to investigate the impact of temperature on the equilibrium position of the reaction.

State the colour change expected when the student places the sealed test tube of the gas mixture in a beaker of hot water. Explain why this colour change occurs. 3 marks

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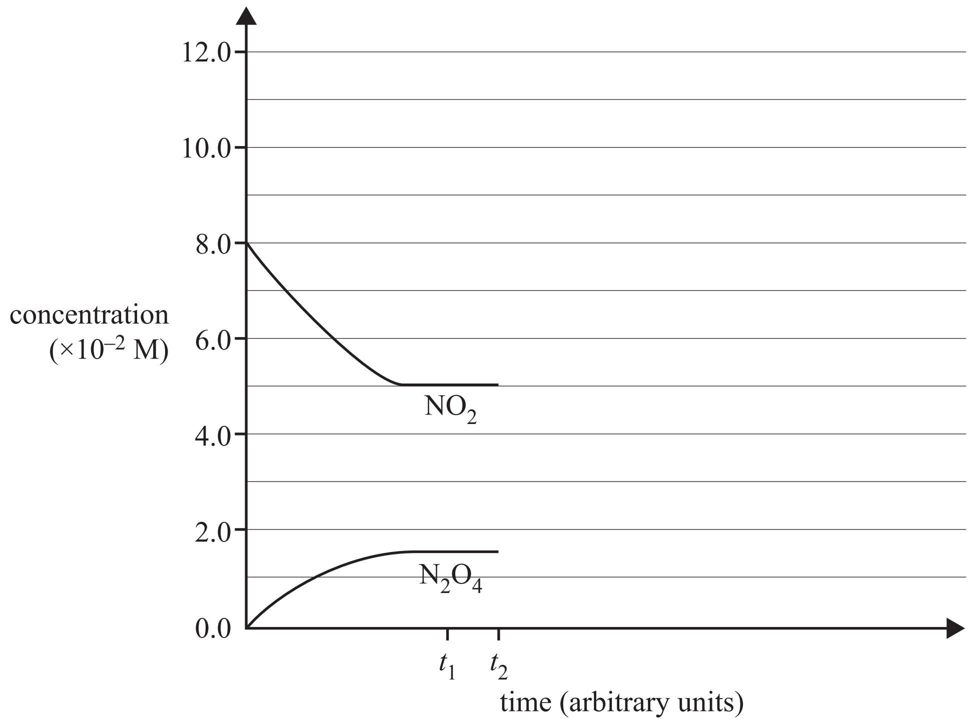
DO NOT WRITE IN THIS AREA

b. Below is the concentration versus time graph for the reaction system. The graph was produced using secondary data at a temperature of 22 °C.



i. Time t_1 is shown on the graph above.

Calculate the equilibrium constant at time t_1. 2 marks

---

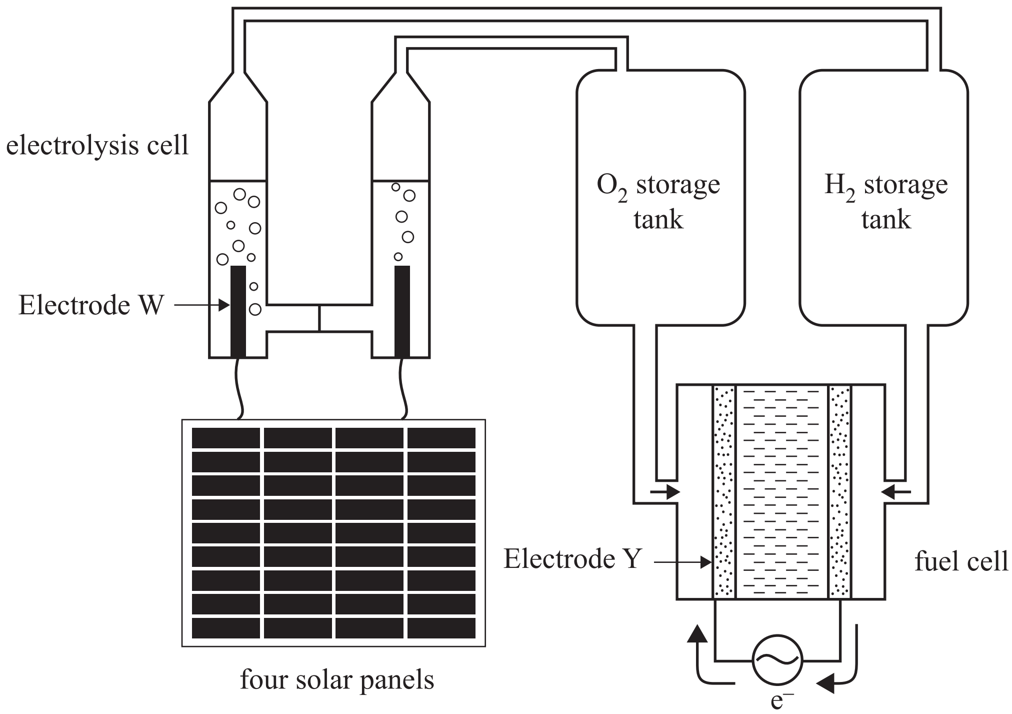
ii. At time t_2 the volume of the system was halved, keeping the temperature at 22 °C.

Continue the graph to show how this change would affect the reaction system and how the system would respond to this change until equilibrium is restored. 3 marks

Question 8 (11 marks)

An energy company investigates the feasibility of supplying energy while reducing greenhouse gas emissions. Solar panels collect energy from the sun during daylight hours and this energy is used to electrolyse water, H_2O, to produce oxygen gas, O_2, and hydrogen gas, H_2. These gases are stored separately and then used in a fuel cell to produce energy when required.

The diagram below shows a simplified representation of the set-up used.



a. **i.** State the polarity of Electrode W in the electrolysis cell. 1 mark

___

ii. The fuel cell operates in an alkaline environment.

Write the half-equation for the reaction that takes place at Electrode Y. 1 mark

___

DO NOT WRITE IN THIS AREA

b. Each of the four solar panels produces an average current of 5.20 A and operates over an eight-hour period. The electrical energy generated is used by the electrolysis cell to produce O_2 and H_2.

i. Calculate the amount, in moles, of H_2 produced by the electrolysis cell. 3 marks

ii. Determine the pressure this amount of H_2 gas would exert at SLC in a 10.0 L H_2 tank. 1 mark

c. The fuel cell produces 3553 kJ when 20 mol of H_2 is consumed. Another possible energy source is a generator using petrodiesel as a fuel. The generator operates with an efficiency of 35%. A particular petrodiesel containing a range of hydrocarbons has been found to have a heat content of 45 kJ g^{-1}. The formula for this petrodiesel can be represented by $C_{12}H_{24}$ (M = 168 g mol^{-1}).

i. Calculate the mass of petrodiesel required to produce 3553 kJ. 2 marks

ii. Calculate the mass of CO_2(g) released when 3553 kJ of energy is produced from petrodiesel. 2 marks

iii. How would the mass of CO_2 produced from the combustion of this petrodiesel compare with the mass of CO_2 produced by the fuel cell? 1 mark

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Question 9 (9 marks)

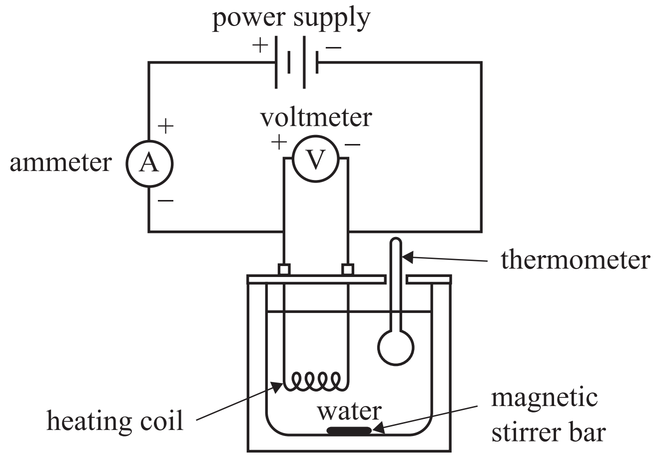
A Chemistry class conducted a practical investigation to determine the calibration factor of a calorimeter using two different methods: electrical and chemical. Each student compared the results from the two different methods and presented the investigation as a scientific poster.

The materials, set-up and methods used by the students are shown below.

Materials

calorimeter	ammeter
DC power supply	voltmeter
5 × wire leads	3 g of potassium nitrate (KNO_3)
thermometer	electronic balance
stopwatch	measuring cylinder

Calorimeter set-up



Methods

Electrical method for collecting calibration data

1. Add 100 mL of water to the calorimeter. Stir the water and record its temperature every 30 seconds for several minutes.
2. Apply a voltage of 6 V for three minutes. Stir throughout and record the temperature every 30 seconds.
3. Record the voltage and the current while the water is heating.
4. Once the power is turned off, continue to stir the water and record the temperature every 30 seconds for a further three minutes.

Chemical method for collecting calibration data

1. Measure 3.0 g of KNO_3 accurately.
2. After completing the electrical calibration, add the KNO_3 to the calorimeter.
3. Stir and record the temperature every 30 seconds.

Student A wrote the following aim.

> **Student A**
>
> **Aim**
>
> To compare the calibration factors obtained from two different methods
>
> The calibration factors were found by recording the temperature change of a solution resulting from the addition of a measured electrical input and from potassium nitrate dissolving in water.

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a. The dependent variable in this investigation is the calibration factor.

Identify the independent variable from Student A's aim. 1 mark

b. Identify **one** systematic error that applies **only** to the electrical method of calibration. 1 mark

c. Identify **one** limitation of the chemical method of calibration, as given on page 36. Explain how it could affect the reliability of the results. 2 marks

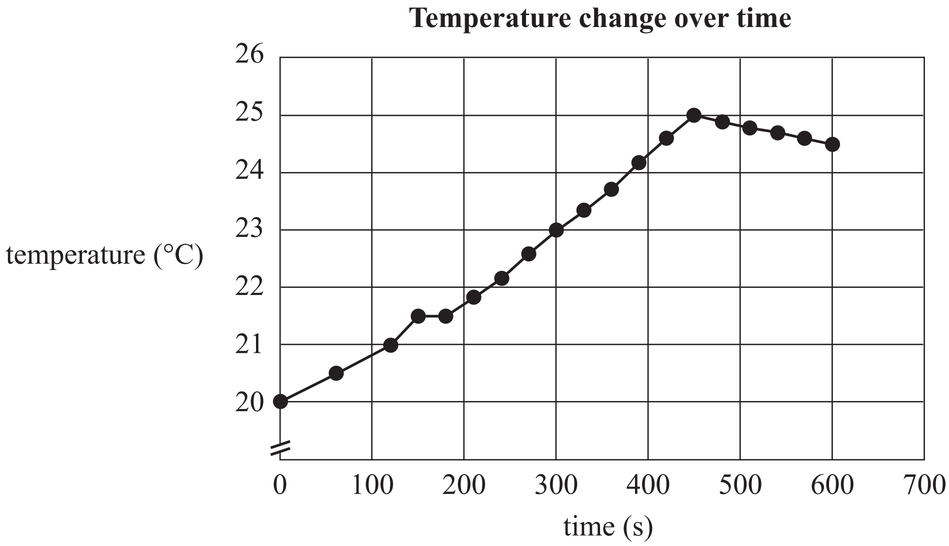
d. Examine the graphs below prepared by Student A and Student B for the temperature change during electrical calibration.

Student A

Results – Electrical method of calibration

voltage = 5.8 V

current = 1.6 A

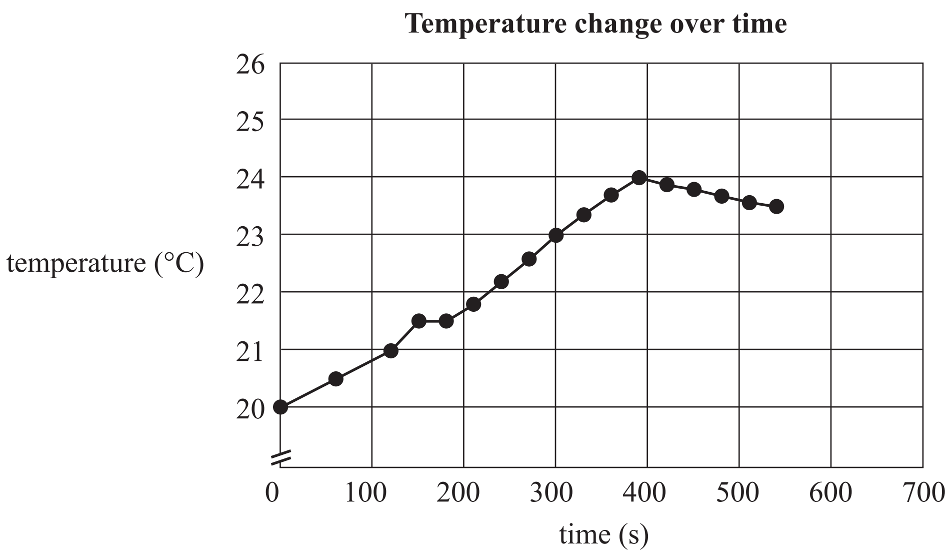


Student B

Results – Electrical method of calibration

voltage = 5.8 V

current = 1.6 A



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Identify **one** difference in the results between the students' graphs and suggest what variation in the students' experiments might account for this difference. 2 marks

e. Student B's data for the chemical method of calibration is shown in the graph below.

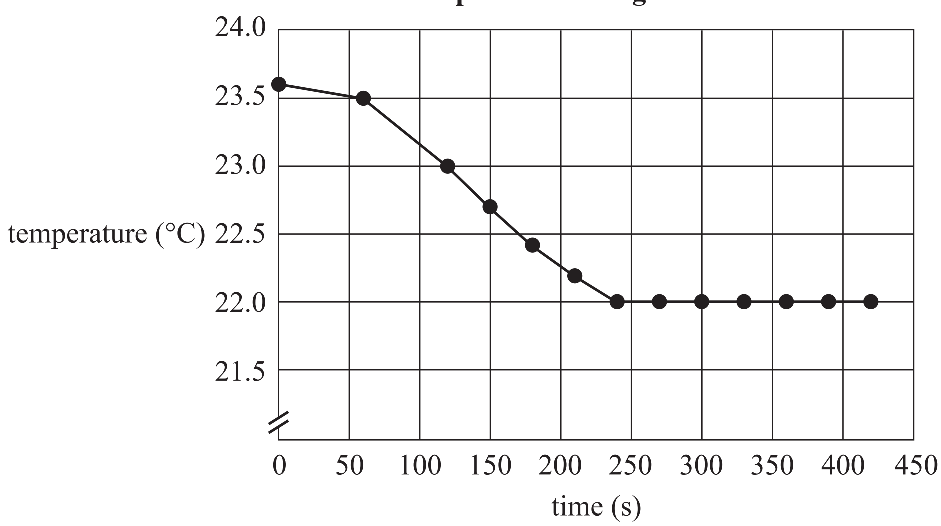
Student B

Results – Chemical method of calibration

Below is the chemical equation and enthalpy used to calculate the calibration factor for the chemical method.

$$KNO_3(s) \xrightarrow{H_2O} K^+(aq) + NO_3^-(aq) \qquad \Delta H = 35 \text{ kJ mol}^{-1}$$

Temperature change over time



Use this data to calculate the calibration factor, in J °C^{-1}, for the chemical method of calibration. 3 marks

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Question 10 (7 marks)

A group of travellers is exploring the equatorial regions of the world. During their journey they arrive at an island where there is an abundant supply of coconuts. Coconuts can make up a significant portion of the standard diet of some people living near the equator.

a. Coconut oil is a source of triglycerides.

Demonstrate your understanding of the chemistry of the metabolism of fats and oils in the human body. In your answer:

- show the structure of triglycerides
- identify the types of reactions involved. 4 marks

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b. Coconuts contain about 15% carbohydrates by weight. A coconut is cut in half. One half is cut into large pieces. The other half is shredded into thin, small pieces.

Compare the glycaemic index (GI) of the large pieces of coconut and the shredded pieces of coconut. Identify which of these two forms of coconut has the lower GI value and explain why. 3 marks

END OF QUESTION AND ANSWER BOOK

VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education
2018

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	$n(e^-) = \frac{Q}{F}$
% atom economy	$\frac{\text{molar mass of desired product}}{\text{molar mass of all reactants}} \times \frac{100}{1}$
% yield	$\frac{\text{actual yield}}{\text{theoretical yield}} \times \frac{100}{1}$

4. Physical constants and standard values

Name	Symbol	Value
Avogadro constant	N_A or L	6.02×10^{23} mol^{-1}
charge on one electron (elementary charge)	e	-1.60×10^{-19} C
Faraday constant	F	96 500 C mol^{-1}
molar gas constant	R	8.31 J mol^{-1} K^{-1}
molar volume of an ideal gas at SLC (25 °C and 100 kPa)	V_m	24.8 L mol^{-1}
specific heat capacity of water	c	4.18 kJ kg^{-1} K^{-1} or 4.18 J g^{-1} K^{-1}
density of water at 25 °C	d	997 kg m^{-3} or 0.997 g mL^{-1}

5. Unit conversions

Measured value	Conversion
0 °C	273 K
100 kPa	750 mm Hg or 0.987 atm
1 litre (L)	1 dm^3 or 1 × 10^{-3} m^3 or 1 × 10^3 cm^3 or 1 × 10^3 mL

6. Metric (including SI) prefixes

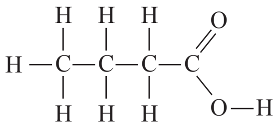
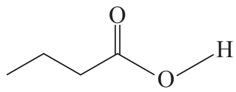
Metric (including SI) prefixes	Scientific notation	Multiplying factor
giga (G)	10^9	1 000 000 000
mega (M)	10^6	1 000 000
kilo (k)	10^3	1000
deci (d)	10^{-1}	0.1
centi (c)	10^{-2}	0.01
milli (m)	10^{-3}	0.001
micro (μ)	10^{-6}	0.000001
nano (n)	10^{-9}	0.000000001
pico (p)	10^{-12}	0.000000000001

7. Acid-base indicators

Name	pH range	Colour change from lower pH to higher pH in range
thymol blue (1st change)	1.2–2.8	red → yellow
methyl orange	3.1–4.4	red → yellow
bromophenol blue	3.0–4.6	yellow → blue
methyl red	4.4–6.2	red → yellow
bromothymol blue	6.0–7.6	yellow → blue
phenol red	6.8–8.4	yellow → red
thymol blue (2nd change)	8.0–9.6	yellow → blue
phenolphthalein	8.3–10.0	colourless → pink

8. Representations of organic molecules

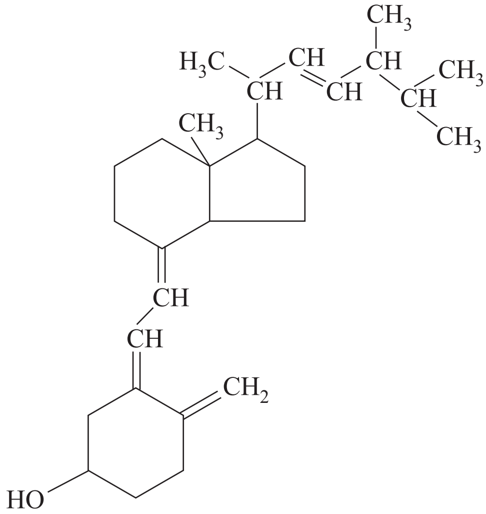
The following table shows different representations of organic molecules, using butanoic acid as an example.

Formula	Representation
molecular formula	$C_4H_8O_2$
structural formula	
semi-structural (condensed) formula	$CH_3CH_2CH_2COOH$ or $CH_3(CH_2)_2COOH$
skeletal structure	

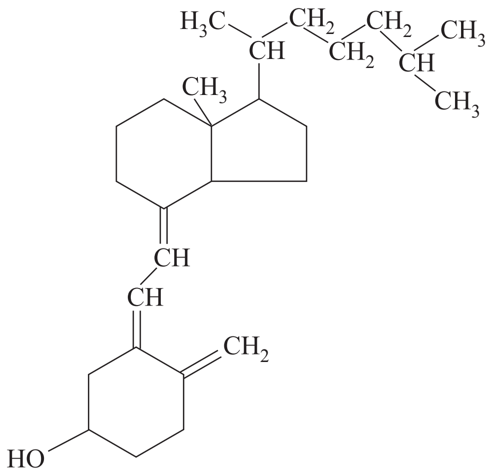
9. Formulas of some fatty acids

Name	Formula	Semi-structural formula
lauric	$C_{11}H_{23}COOH$	$CH_3(CH_2)_{10}COOH$
myristic	$C_{13}H_{27}COOH$	$CH_3(CH_2)_{12}COOH$
palmitic	$C_{15}H_{31}COOH$	$CH_3(CH_2)_{14}COOH$
palmitoleic	$C_{15}H_{29}COOH$	$CH_3(CH_2)_4CH_2CH{=}CHCH_2\ (CH_2)_5CH_2COOH$
stearic	$C_{17}H_{35}COOH$	$CH_3(CH_2)_{16}COOH$
oleic	$C_{17}H_{33}COOH$	$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$
linoleic	$C_{17}H_{31}COOH$	$CH_3(CH_2)_4(CH{=}CHCH_2)_2(CH_2)_6COOH$
linolenic	$C_{17}H_{29}COOH$	$CH_3CH_2(CH{=}CHCH_2)_3(CH_2)_6COOH$
arachidic	$C_{19}H_{39}COOH$	$CH_3(CH_2)_{17}CH_2COOH$
arachidonic	$C_{19}H_{31}COOH$	$CH_3(CH_2)_4(CH{=}CHCH_2)_3CH{=}CH(CH_2)_3COOH$

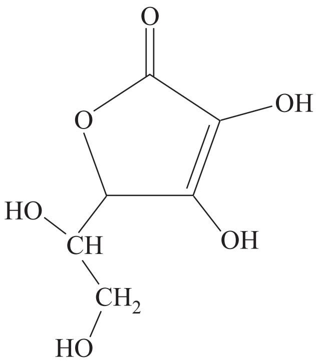
10. Formulas of some biomolecules



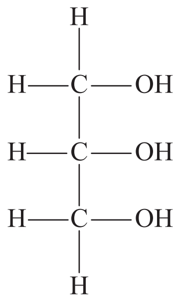
vitamin D_2 (ergocalciferol)



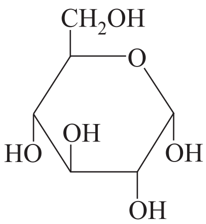
vitamin D_3 (cholecalciferol)



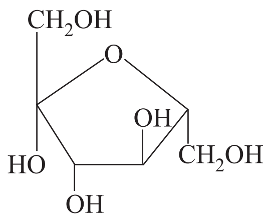
vitamin C (ascorbic acid)



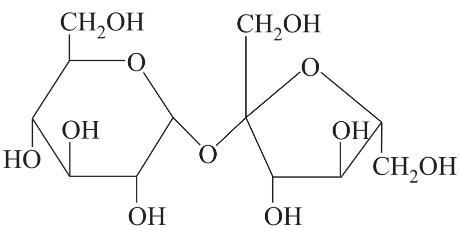
glycerol



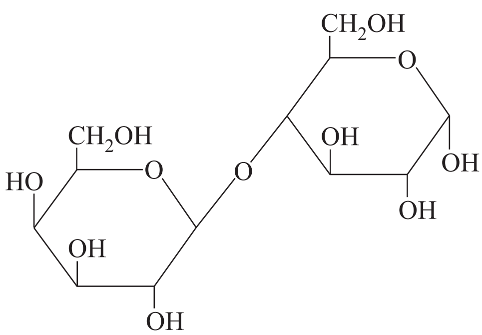
α-glucose



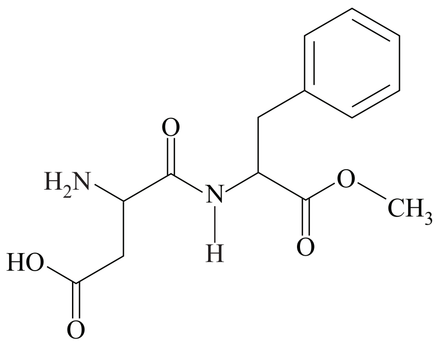
β-fructose



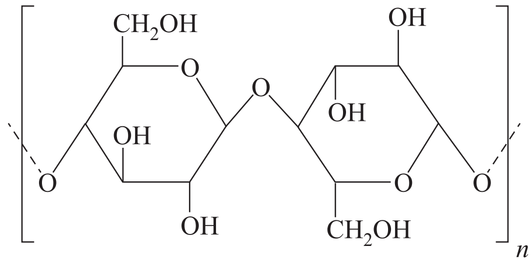
sucrose



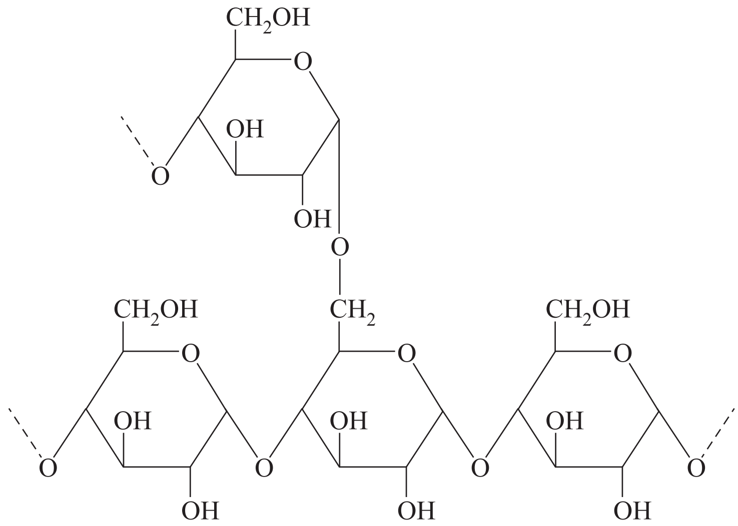
α-lactose



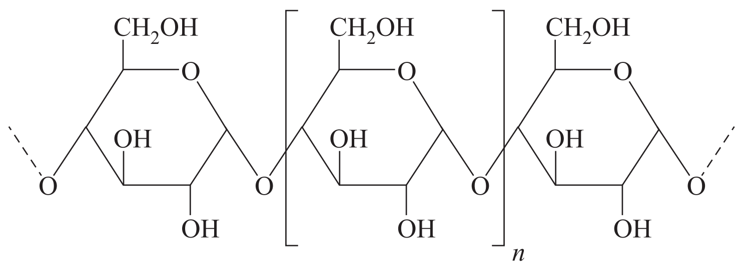
aspartame



cellulose



amylopectin (starch)



amylose (starch)

11. Heats of combustion of common fuels

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

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

12. Heats of combustion of common blended fuels

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

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

13. Energy content of food groups

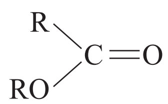
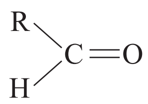
Food	Heat of combustion (kJ g^{-1})
fats and oils	37
protein	17
carbohydrate	16

14. Characteristic ranges for infra-red absorption

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

15. ^{13}C NMR data

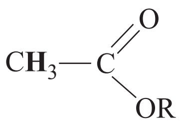
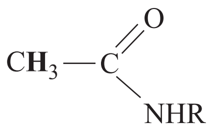
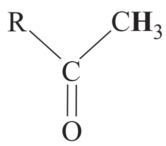
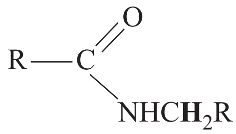
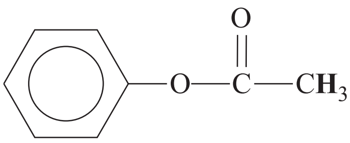
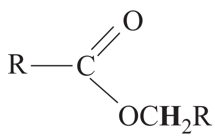
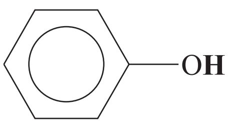
Typical ^{13}C shift values relative to TMS = 0
These can differ slightly in different solvents.

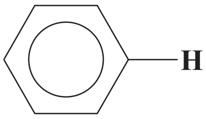
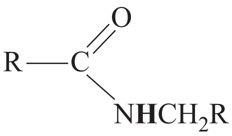
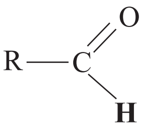
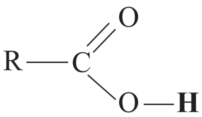
Type of carbon	Chemical shift (ppm)
$R–CH_3$	8–25
$R–CH_2–R$	20–45
$R_3–CH$	40–60
$R_4–C$	36–45
$R–CH_2–X$	15–80
$R_3C–NH_2$, $R_3C–NR$	35–70
$R–CH_2–OH$	50–90
RC≡CR	75–95
$R_2C=CR_2$	110–150
RCOOH	160–185
	165–175
	190–200
$R_2C=O$	205–220

16. ^{1}H NMR data

Typical proton shift values relative to TMS = 0

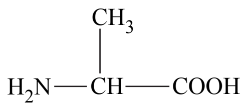
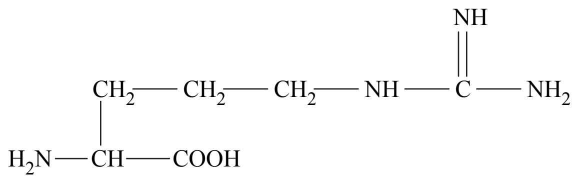
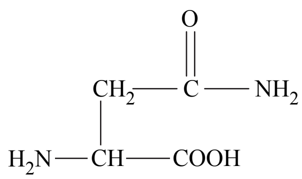
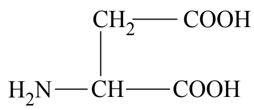
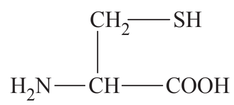
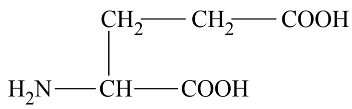
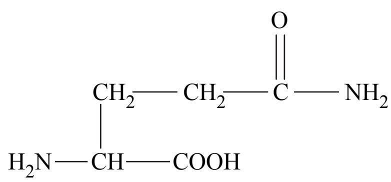
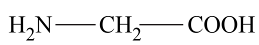
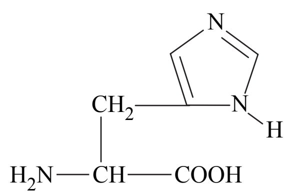
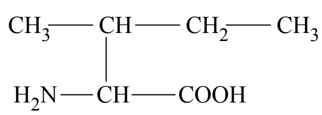
These can differ slightly in different solvents. The shift refers to the proton environment that is indicated in bold letters in the formula.

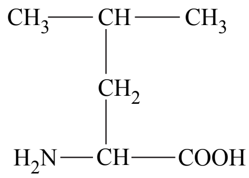
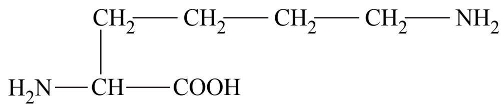
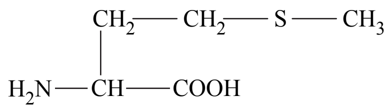
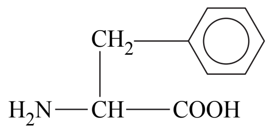
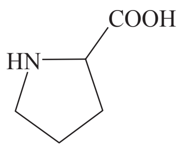
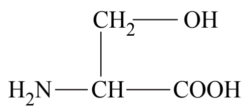
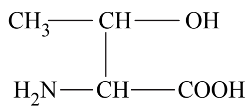
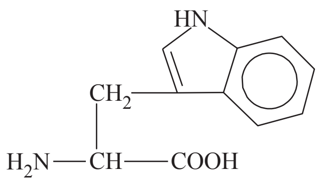
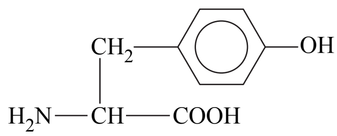
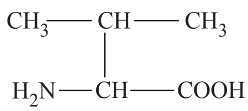
Type of proton	Chemical shift (ppm)
R–C**H**$_3$	0.9–1.0
R–C**H**$_2$–R	1.3–1.4
RCH=CH–C**H**$_3$	1.6–1.9
R$_3$–C**H**	1.5
 or 	2.0
	2.1–2.7
R–C**H**$_2$–X (X = F, Cl, Br or I)	3.0–4.5
R–C**H**$_2$–OH, R$_2$–C**H**–OH	3.3–4.5
	3.2
R—O—C**H**$_3$ or R—O—C**H**$_2$R	3.3–3.7
	2.3
	3.7–4.8
R–O–**H**	1–6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

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

17. 2-amino acids (*α*-amino acids)

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

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

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

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