# Higher Chemistry Past Papers 2021-23 

## September 2023

## 1. About this study aid...

This document has been designed to make revision and self-marking easy for students studying Higher chemistry in Scotland.

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## 2. How to use...

The following two pages contain tables which cross-reference the course topics with SQA question numbers for the years 2021-23.

The first table is for multiple choice questions; the second accesses Section 2 questions. Each question number is hyperlinked to the SQA question and clicking it will take you there. The question pages have further hyperlinks taking you either back to the topic grid (top) or to the SQA marking instructions (bottom).

Of course, you can always just treat it as a succession of question papers with marking instructions. This will be useful for end-of-course timed revision.

Updated to 2021-2023 by Mr Shepherd, St. Ambrose High School

Full credit goes to Mr Sinclair, Vale of Leven Academy for making the original 2015-2019 hyper-linked question paper



Duration - 40 minutes

Total marks - 25
Attempt ALL questions.
You may use a calculator.
Instructions for the completion of Paper 1 are given on page 02 of your answer booklet X813/76/02.

Record your answers on the answer grid on page 03 of your answer booklet.
You may refer to the Chemistry Data Booklet for Higher and Advanced Higher.
Space for rough work is provided at the end of this booklet.
Before leaving the examination room you must give your answer booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

## Total marks - 25

## Attempt ALL questions

1. Aluminium carbonate can be produced by the following reaction.

$$
2 \mathrm{AlCl}_{3}(\mathrm{aq})+3 \mathrm{~K}_{2} \mathrm{CO}_{3}(\mathrm{aq}) \rightarrow \mathrm{Al}_{2}\left(\mathrm{CO}_{3}\right)_{3}(\mathrm{~s})+6 \mathrm{KCl}(\mathrm{aq})
$$

The most suitable method for separating the aluminium carbonate from the mixture is

A filtration
B distillation
C evaporation
D collection over water.
2. The difference in the size of sodium and chlorine atoms is mainly due to the difference in the

A mass of each atom
B number of electrons
C number of neutrons
D number of protons.
3. Solid carbon dioxide is known as 'dry ice'. It changes directly to a gas when it is heated.

$$
\mathrm{CO}_{2}(\mathrm{~s}) \quad \rightarrow \quad \mathrm{CO}_{2}(\mathrm{~g})
$$

The strongest bonds broken in this process are
A polar covalent bonds
B London dispersion forces
C non-polar covalent bonds
D permanent dipole-permanent dipole interactions.
4. Which of the following statements is correct?

A Elements with high electronegativities tend to be reduced
B Elements with high electronegativities tend to act as reducing agents
C Elements with low electronegativities tend to gain electrons
D Elements with low electronegativities tend to act as oxidising agents
5. The viscosities of two liquids, $X$ and $Y$, were investigated by dropping a metal ball into a tube of each liquid.
The diagram shows the position of the metal balls after 10 seconds.


Which line in the table correctly describes the viscosity and relative strengths of the van der Waals forces in liquids $\mathbf{X}$ and Y ?

|  | X | $\mathbf{Y}$ |
| :---: | :---: | :---: |
| A | most viscous | strongest van der Waals forces |
| B | least viscous | weakest van der Waals forces |
| C | least viscous | strongest van der Waals forces |
| D | most viscous | weakest van der Waals forces |

6. What is the enthalpy change, in $\mathrm{kJ} \mathrm{mol}^{-1}$, for the following reaction?

$$
\mathrm{Be}(\mathrm{~g}) \rightarrow \mathrm{Be}^{2+}(\mathrm{g})+2 \mathrm{e}^{-}
$$

A 900
B 1757
C 2657
D 3514
7. Which of the following is an isomer of pentanoic acid?

A 2-methylpropanoic acid
B propyl methanoate
C 2-ethylbutanoic acid
D ethyl propanoate
8. The structures of two common painkillers are shown below.



Which of the following is true?
A Both painkillers are ketones
B Aspirin contains a carboxyl group and an ester link
C Paracetamol contains a hydroxyl group and a carboxyl group
D Neither painkiller contains an amide link
9. Which two isomers would each produce an acid when warmed with acidified potassium dichromate solution?
1

2

3

4


A 1 and 2
B 1 and 4
C 2 and 3
D 3 and 4
10. When an aldehyde is converted into the corresponding alcohol a reduction reaction takes place.

Reduction of 2-methylbutanal $(G F M=86)$ produces a compound with a $G F M$ of
A 70
B 84
C 88
D 102 .
11. Which of the following compounds would react with sodium hydroxide solution to form the salt sodium propanoate?

A $\mathrm{HCOOC}_{2} \mathrm{H}_{5}$
B $\mathrm{CH}_{3} \mathrm{COOCH}_{3}$
C $\mathrm{C}_{2} \mathrm{H}_{5} \mathrm{COOH}$
D $\mathrm{C}_{3} \mathrm{H}_{7} \mathrm{COOH}$
12. When a protein is denatured

A it is broken into amino acids
B hydrogen bonds are broken
C peptide links are hydrolysed
D water molecules are eliminated.
13. Compared with oils, fats are

A less saturated and have higher melting points
B less saturated and have lower melting points
C more saturated and have higher melting points
D more saturated and have lower melting points.
14. Vitamin C is an antioxidant used to preserve food and lengthen shelf-life.

Which of the following does not describe an antioxidant?
A Electron donor
B Oxidising agent
C Reducing agent
D Free-radical scavenger
15. On exposure to UV light, methane and chlorine undergo a chain reaction.

Which of the following is a propagation step in this reaction?
$\mathrm{A} \cdot \mathrm{CH}_{3}+\mathrm{Cl} \cdot \rightarrow \mathrm{CH}_{3} \mathrm{Cl}$
B $\mathrm{Cl}_{2} \rightarrow 2 \mathrm{Cl} \cdot$
$\mathrm{C} \mathrm{H} \cdot \mathrm{Cl} \cdot \rightarrow \mathrm{HCl}$
D $\mathrm{CH}_{4}+\mathrm{Cl} \cdot \rightarrow \cdot \mathrm{CH}_{3}+\mathrm{HCl}$
16. A reaction was carried out at four different temperatures. The table shows the times taken for the reaction to occur.

| Temperature $\left({ }^{\circ} \mathrm{C}\right)$ | 20 | 30 | 40 | 50 |
| :--- | :---: | :---: | :---: | :---: |
| Time (s) | 60 | 30 | 14 | 5 |

The results show that
A a small rise in temperature results in a large increase in the rate of the reaction

B the activation energy increases with increasing temperature
C doubling the temperature of the reaction doubles the rate of the reaction
D the reaction is slowing down with increasing temperature.
17. The graph shows the effect of increasing the concentration of potassium iodide solution on reaction rate.


What was the concentration, in $\mathrm{moll}^{-1}$, of the potassium iodide solution used in a reaction that took 5 s to complete?

A 0.04
B $\quad 0.20$
C 0.24
D 0.96
18. Which of the following diagrams represents an exothermic reaction that is more likely to take place at room temperature?

A


B


C


D

19. Which of the following will result in the volume of the products being half the volume of the reactants?
$\mathrm{A} \quad 2 \mathrm{SO}_{2}(\mathrm{~g})+\mathrm{O}_{2}(\mathrm{~g}) \quad \rightarrow \quad 2 \mathrm{SO}_{3}(\mathrm{~g})$
$\mathrm{B} \quad \mathrm{C}(\mathrm{s})+\mathrm{O}_{2}(\mathrm{~g}) \quad \rightarrow \quad \mathrm{CO}_{2}(\mathrm{~g})$
$\mathrm{C} \mathrm{C}_{2} \mathrm{H}_{4}(\mathrm{~g})+3 \mathrm{O}_{2}(\mathrm{~g}) \rightarrow 2 \mathrm{CO}_{2}(\mathrm{~g})+2 \mathrm{H}_{2} \mathrm{O}(\ell)$
$\mathrm{D} \mathrm{C}(\mathrm{s})+\mathrm{H}_{2} \mathrm{O}(\mathrm{g}) \quad \rightarrow \quad \mathrm{H}_{2}(\mathrm{~g})+\mathrm{CO}(\mathrm{g})$
20. The ester ethyl ethanoate is produced by the following reaction.

$$
\mathrm{CH}_{3} \mathrm{COOH}+\mathrm{C}_{2} \mathrm{H}_{5} \mathrm{OH} \rightleftharpoons \mathrm{CH}_{3} \mathrm{COOC}_{2} \mathrm{H}_{5}+\mathrm{H}_{2} \mathrm{O}
$$

Which of the following mixtures would produce 0.8 moles of ester if the yield was 80\%?

|  | moles of $\mathrm{CH}_{3} \mathrm{COOH}$ | moles of $\mathrm{C}_{2} \mathrm{H}_{5} \mathrm{OH}$ |
| :---: | :---: | :---: |
| A | 0.4 | 0.4 |
| $B$ | 0.5 | 0.5 |
| $C$ | 0.8 | 0.8 |
| D | 1.0 | 1.0 |

21. The graph shows how the yield of product in a reversible reaction varies with pressure at two different temperatures.


From this information it can be concluded that
A the reaction is exothermic
B all reactants are converted to products at $250^{\circ} \mathrm{C}$ and 300 atmospheres
C increasing the temperature increases the yield
D increasing the pressure above 200 atmospheres has no effect on yield.
22.

$$
2 \mathrm{KOH}(\mathrm{aq})+\mathrm{H}_{2} \mathrm{SO}_{4}(\mathrm{aq}) \rightarrow \mathrm{K}_{2} \mathrm{SO}_{4}(\mathrm{aq})+2 \mathrm{H}_{2} \mathrm{O}(\ell)
$$

How many moles of potassium hydroxide, KOH , neutralise $50 \mathrm{~cm}^{3}$ of $0.2 \mathrm{moll}^{-1}$ sulfuric acid, $\mathrm{H}_{2} \mathrm{SO}_{4}$ ?

A 0.01
B 0.02
C 0.10
D 0.40
23. Four amino acids, P, Q, R and S were analysed by chromatography. Larger molecules travel a shorter distance from the base line. Less polar molecules travel a greater distance from the base line.


Which of the following statements is correct?
A $P$ is less polar than $S$
B $\quad \mathrm{Q}$ is a larger molecule than P
C $R$ is more polar than $P$
D S is a smaller molecule than Q
24. A student produced the following results for a redox titration.

| Sample | Volume of solution added $\left(\mathrm{cm}^{3}\right)$ |
| :---: | :---: |
| 1 | $21 \cdot 0$ |
| 2 | 20.3 |
| 3 | 20.7 |
| 4 | 20.4 |

The volume of solution, in $\mathrm{cm}^{3}$, that should be used in the titration calculation is
A 20.35
B 20.50
C 20.55
D $20 \cdot 60$
25. An equilibrium mixture of $\mathrm{NO}_{2}$ and $\mathrm{N}_{2} \mathrm{O}_{4}$ in a sealed gas syringe has a pale brown colour.

$$
2 \mathrm{NO}_{2}(\mathrm{~g}) \rightleftharpoons \mathrm{N}_{2} \mathrm{O}_{4}(\mathrm{~g})
$$

Increasing the pressure causes the mixture to become paler.
Increasing the temperature causes the mixture to become darker.
Which line in the table correctly identifies the colour of $\mathrm{NO}_{2}$ and the enthalpy change for the forward reaction?

|  | Colour of $\mathrm{NO}_{2}$ | Enthalpy change for <br> the forward reaction |
| :---: | :---: | :---: |
| A | brown | exothermic |
| B | brown | endothermic |
| C | colourless | exothermic |
| D | colourless | endothermic |

[END OF QUESTION PAPER]

|  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- |

Duration - 2 hours 20 minutes

Fill in these boxes and read what is printed below.

Full name of centre

$\square$


## Forename(s)

Surname
Number of seat


Date of birth


## Total marks - 95

Attempt ALL questions.

## You may use a calculator.

You may refer to the Chemistry Data Booklet for Higher and Advanced Higher.
Write your answers clearly in the spaces provided in this booklet. Additional space for answers and rough work is provided at the end of this booklet. If you use this space you must clearly identify the question number you are attempting. Any rough work must be written in this booklet. Score through your rough work when you have written your final copy.
Use blue or black ink.
Before leaving the examination room you must give this booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

1. Electronegativity is a measure of the attraction an atom involved in a bond has for the electrons of the bond.

The graph shows the trend in electronegativity for the first 20 elements.

(a) (i) State the trend in electronegativity as you go across period 2 from lithium to fluorine.
(ii) No electronegativity values are shown for the elements with atomic numbers 2, 10 and 18.
Suggest why no values are provided for these elements.

1. (a) (continued)
(iii) On descending Group 7 from fluorine to iodine, the electronegativity of the elements decreases.

Explain why the electronegativity of the elements decreases as you go down the group.

1. (continued)
(b) Electronegativity values can be used to predict the type of bonding present in substances.

The type of bonding between two elements can be predicted using the diagram below.

(i) Using the information in the diagram, state the highest average electronegativity found in ionic compounds.

## 1. (b) (continued)

(ii) The electronegativity values of magnesium and nitrogen are shown.

Electronegativity of magnesium $=1 \cdot 2$
Electronegativity of nitrogen $\quad=3.0$
Draw an X on the diagram on page 04 to show the position of magnesium nitride.

Show your calculations clearly.
(An additional diagram, if required, can be found on page 38.)
(iii) Compounds with a difference in electronegativities of 1.5 can have ionic or covalent properties.
(A) The electronegativity difference between the elements in lithium sulfide is 1.5 .

Write an ionic formula for lithium sulfide.
(B) A compound contains two non-metal elements with an electronegativity difference of $1 \cdot 5$.

Suggest names for the two non-metal elements.
(c) Fluorine has a greater attraction for bonding electrons than hydrogen. State the term used to describe the type of covalent bond in hydrogen fluoride.
2. Carbon and its compounds are important in the chemical industry.
(a) Carbon can exist in multiple forms. Two of these are fullerenes and diamond.
(i) Name another form of carbon.
(ii) Both diamond and the fullerene, $\mathrm{C}_{60}$, can change directly from a solid to a gas. This is called sublimation. For diamond this occurs at $3825^{\circ} \mathrm{C}$. The fullerene changes from a solid to a gas at approximately $550^{\circ} \mathrm{C}$. Complete the table below to show the strongest type of attraction broken when diamond and the fullerene sublime.

| Form of carbon | Strongest attraction broken |
| :---: | :---: |
| diamond |  |
| fullerene |  |

(iii) The fullerene, $\mathrm{C}_{60}$, reacts with bromine solution in an addition reaction to produce the bromofullerene, $\mathrm{C}_{60} \mathrm{Br}_{24}$.
Determine the number of double bonds present in a molecule of $\mathrm{C}_{60}$.
(b) Carbon can combine with oxygen to make carbon monoxide, CO.

Carbon monoxide is used in the production of iron from iron(III) oxide.

$$
\begin{gathered}
\mathrm{Fe}_{2} \mathrm{O}_{3}(\mathrm{~s})+\begin{array}{c}
3 \mathrm{CO}(\mathrm{~g}) \\
G F M=159.6 \mathrm{~g} \\
G F M=28.0 \mathrm{~g}
\end{array} \begin{array}{c}
\ln (\mathrm{l})
\end{array}+\begin{array}{c}
3 \mathrm{CO}_{2}(\mathrm{~g}) \\
G F M=55.8 \mathrm{~g}
\end{array} \quad G F M=44.0 \mathrm{~g}
\end{gathered}
$$

Calculate the atom economy for the production of iron.
2. (continued)
(c) Carbon monoxide can be produced by the reaction of methane and steam.

$$
\begin{aligned}
& \mathrm{CH}_{4}(\mathrm{~g})+\mathrm{H}_{2} \mathrm{O}(\mathrm{~g}) \rightarrow \mathrm{CO}(\mathrm{~g})+3 \mathrm{H}_{2}(\mathrm{~g}) \\
& \mathrm{CO}(\mathrm{~g})+\frac{1}{2} \mathrm{O}_{2}(\mathrm{~g}) \rightarrow \mathrm{CO}_{2}(\mathrm{~g}) \quad \Delta H=-283 \mathrm{~kJ} \mathrm{~mol}^{-1} \\
& \mathrm{H}_{2}(\mathrm{~g})+\frac{1}{2} \mathrm{O}_{2}(\mathrm{~g}) \rightarrow \mathrm{H}_{2} \mathrm{O}(\mathrm{~g}) \quad \Delta H=-286 \mathrm{~kJ} \mathrm{~mol}^{-1} \\
& \mathrm{CH}_{4}(\mathrm{~g})+2 \mathrm{O}_{2}(\mathrm{~g}) \rightarrow \mathrm{CO}_{2}(\mathrm{~g})+2 \mathrm{H}_{2} \mathrm{O}(\mathrm{~g}) \quad \Delta H=-891 \mathrm{~kJ} \mathrm{~mol}^{-1}
\end{aligned}
$$

Calculate the enthalpy change, in $\mathrm{kJ} \mathrm{mol}^{-1}$, for this reaction.
3. A teacher told a class that collisions were the key to chemical reactions.

Using your knowledge of chemistry, discuss this statement.
4. Nitrogen is a stable element and only reacts with a few other elements.
(a) Explain, using bond enthalpy values, why the element nitrogen is so unreactive.
(b) A laboratory preparation of nitrogen gas involves separating nitrogen from all of the other gases in the air and then collecting it.
Air is bubbled through potassium hydroxide solution to remove carbon dioxide. The remaining gases are passed over heated copper to remove oxygen before the remaining nitrogen is collected.


Complete a labelled diagram for the preparation of a sample of nitrogen by drawing suitable apparatus for carrying out this preparation.
(An additional diagram, if required, can be found on page 38.)

## 4. (continued)

(c) Nitrogen can react with lithium at room temperature to form the compound lithium nitride, $\mathrm{Li}_{3} \mathrm{~N}$.
(i) A scientist prepared a sample of lithium nitride by reacting 0.9 litres of nitrogen gas with 0.5 g of lithium.

$$
\begin{aligned}
& \begin{array}{l}
6 \mathrm{Li}(\mathrm{~s})+\mathrm{N}_{2}(\mathrm{~g}) \rightarrow 2 \mathrm{Li}_{3} \mathrm{~N}(\mathrm{~s}) \\
G F M=6.9 \mathrm{~g}
\end{array}
\end{aligned}
$$

Determine, by calculation, which of the reactants was in excess.
Take the volume of 1 mole of nitrogen gas to be 24 litres.
(Clearly show your working for the calculation.)
(ii) Lithium nitride reduces copper(I) ions to copper atoms.

Write the ion-electron equation to show the reduction of copper(I) ions.
(iii) Lithium nitride is ionic.

State the term used to describe the structure of solid ionic compounds like lithium nitride.

## 4. (continued)

(d) During thunderstorms, nitrogen can react with oxygen to form different compounds.

Nitrogen and oxygen can react to form the free radical molecule nitrogen monoxide, $\cdot \mathrm{N}=\mathrm{O}$.
(i) State what is meant by the term free radical.
(ii) The equation for this reaction is


The enthalpy change, $\Delta H$, for this reaction is $+91 \mathrm{~kJ} \mathrm{~mol}^{-1}$.
Use this data and the bond enthalpy values shown in the data booklet to calculate the bond enthalpy, in $\mathrm{kJ} \mathrm{mol}^{-1}$, of the nitrogen to oxygen double bond in nitrogen monoxide.
(iii) Nitrogen monoxide free radicals can react with hydroxyl free radicals to form a molecule of nitrous acid, $\mathrm{HNO}_{2}$.
(A) Name the type of reaction that occurs when two free radicals join together.
(B) Draw a possible structure for the $\mathrm{HNO}_{2}$ molecule.

## 4. (continued)

(e) Nitrogen can also react with hydrogen in the Haber process to form ammonia.
(i) The equation to produce ammonia is shown.

$$
\mathrm{N}_{2}(\mathrm{~g})+3 \mathrm{H}_{2}(\mathrm{~g}) \rightleftharpoons 2 \mathrm{NH}_{3}(\mathrm{~g}) \quad \Delta H=-92 \mathrm{~kJ} \mathrm{~mol}^{-1}
$$

Explain fully the effect of decreasing the reaction temperature on the yield of ammonia.
(ii) Ammonia can be reacted to produce the explosive nitroglycerin. A small shock or physical bump can make the nitroglycerin explode. The reaction that takes place is shown.

$$
\mathrm{C}_{3} \mathrm{H}_{5} \mathrm{~N}_{3} \mathrm{O}_{9} \rightarrow \mathrm{CO}_{2}+\mathrm{H}_{2} \mathrm{O}+\mathrm{N}_{2}+\mathrm{O}_{2}
$$

(A) Balance this equation.
(B) Suggest why a small shock or bump can cause nitroglycerin to react.
5. A bomb calorimeter is used in the food industry to determine the energy released by foods when they are burned.

(a) Identify a feature of the bomb calorimeter and explain how this allows the accurate determination of the energy released by burning foods.
[Turn over
5. (continued)
(b) Fats and oils release a large amount of energy when they are burned.
(i) A 1.00 g sample of the oil, triolein $(G F M=884 \mathrm{~g})$ was burned in a bomb calorimeter.
The temperature rise in the $775 \mathrm{~cm}^{3}$ of water was $11.9^{\circ} \mathrm{C}$.
Calculate the enthalpy of combustion, in $\mathrm{kJ} \mathrm{mol}^{-1}$, of triolein.
(ii) Foods with a lower respiratory quotient are better for people who find it difficult to obtain energy from food.
The respiratory quotient, RQ , is the ratio of carbon dioxide, $\mathrm{CO}_{2}$, produced to the oxygen, $\mathrm{O}_{2}$, consumed when a food is burned in the body.

$$
\text { Respiratory quotient }=\frac{\mathrm{CO}_{2} \text { produced }}{\mathrm{O}_{2} \text { consumed }}
$$

The equation for the combustion of triolein, $\mathrm{C}_{57} \mathrm{H}_{104} \mathrm{O}_{6}$, is shown.

$$
\mathrm{C}_{57} \mathrm{H}_{104} \mathrm{O}_{6}(\ell)+80 \mathrm{O}_{2}(\mathrm{~g}) \rightarrow 57 \mathrm{CO}_{2}(\mathrm{~g})+52 \mathrm{H}_{2} \mathrm{O}(\ell)
$$

Determine the respiratory quotient for triolein.
5. (continued)
(c) Tristearin, $\mathrm{C}_{57} \mathrm{H}_{110} \mathrm{O}_{6}$, is a saturated fat.

The table shows the viscosity of different saturated fats at $70^{\circ} \mathrm{C}$.

| Fat | Molecular formula | Viscosity at $70{ }^{\circ} \mathrm{C}$ (units) |
| :--- | :---: | :---: |
| Tributyrin | $\mathrm{C}_{15} \mathrm{H}_{26} \mathrm{O}_{6}$ | 3.0 |
| Tricaproin | $\mathrm{C}_{21} \mathrm{H}_{38} \mathrm{O}_{6}$ | 5.9 |
| Tricaprylin | $\mathrm{C}_{27} \mathrm{H}_{50} \mathrm{O}_{6}$ | 8.8 |
| Tricaprin | $\mathrm{C}_{33} \mathrm{H}_{62} \mathrm{O}_{6}$ | 11.7 |
| Trilaurin | $\mathrm{C}_{39} \mathrm{H}_{74} \mathrm{O}_{6}$ | 14.6 |

(i) Predict the viscosity of tristearin at $70^{\circ} \mathrm{C}$.
(ii) Edible fats and oils are molecules that contain three ester links.

Explain why glycerol is able to form fats and oils.
[Turn over
6. Seaweed can contain high levels of iodine.
(a) One type of seaweed contains 0.133 g of iodine per kilogram of seaweed. The World Health Organisation recommends a daily intake of iodine of 0.15 mg .

Calculate the mass of seaweed that would provide the recommended daily intake.
(b) An experiment was carried out to determine the quantity of iodine in a sample of dried seaweed.
(i) The first step in this process involves burning an accurately known mass of dried seaweed to ash.

Describe the steps involved in measuring the mass of the seaweed by difference.
(ii) The seaweed ash contains iodide ions. These react with hydrogen peroxide in acid conditions.

$$
\mathrm{H}_{2} \mathrm{O}_{2}(\mathrm{aq})+2 \mathrm{I}^{-}(\mathrm{aq})+2 \mathrm{H}^{+}(\mathrm{aq}) \rightarrow 2 \mathrm{H}_{2} \mathrm{O}(\ell)+\mathrm{I}_{2}(\mathrm{aq})
$$

Identify the reducing agent in this reaction.
6. (b) (continued)
(iii) The released iodine reacts with sodium thiosulfate, $\mathrm{Na}_{2} \mathrm{~S}_{2} \mathrm{O}_{3}$.

A standard solution of sodium thiosulfate, $\mathrm{Na}_{2} \mathrm{~S}_{2} \mathrm{O}_{3}$, is required to react with the released iodine.
State what is meant by a standard solution.
(iv) For this sample of seaweed, 0.00026 moles of sodium thiosulfate were required to fully react with the released iodine, $\mathrm{I}_{2}$.
$\mathrm{I}_{2}(\mathrm{aq})+2 \mathrm{Na}_{2} \mathrm{~S}_{2} \mathrm{O}_{3}(\mathrm{aq}) \rightarrow 2 \mathrm{Nal}(\mathrm{aq})+\mathrm{Na}_{2} \mathrm{~S}_{4} \mathrm{O}_{6}(\mathrm{aq})$
(A) Calculate the number of moles of iodine required to react with 0.00026 moles of sodium thiosulfate.
(B) Using your answer to part (A), calculate the mass, in g, of iodine in the seaweed sample.
6. (continued)
(c) Seaweed is a major component of the diet of sheep living on the island of North Ronaldsay.

Sheep wool is made mainly of a protein. This protein contains the essential amino acids methionine and histidine.

methionine

histidine
(i) State what is meant by an essential amino acid.
(ii) When two amino acids are joined together by a peptide link, a dipeptide is formed.

Draw a structural formula for the dipeptide formed from methionine and histidine.
7. Sulfuric acid is an important chemical with many uses in industry. The main process used to make sulfuric acid is the Contact Process.
(a) The Contact Process starts when sulfur is burned in a furnace with excess air. This forms a gas mixture that contains sulfur dioxide and oxygen. The gas mixture is cooled and then passed into the reactor which contains a catalyst. Sulfur trioxide is formed and then passed into absorbers where it is absorbed into concentrated sulfuric acid to form a product called oleum. The oleum is diluted with water to give sulfuric acid. Unreacted sulfur dioxide is not absorbed and is recycled back into the reactor.

Use the information above to complete the flow diagram for the Contact Process.
(An additional diagram, if required, can be found on page 39.)

7. (continued)
(b) The reactions involved in the Contact Process are highly exothermic.

State a disadvantage of industrial processes that involve reactions that are highly exothermic.
(c) Sulfur and oxygen contain London dispersion forces.
(i) Explain how London dispersion forces arise.
(ii) Explain fully why the London dispersion forces in sulfur are stronger than those in oxygen.
7. (continued)
(d) The reaction that occurs in the reactor of the Contact Process is

$$
2 \mathrm{SO}_{2}(\mathrm{~g})+\mathrm{O}_{2}(\mathrm{~g}) \rightleftharpoons 2 \mathrm{SO}_{3}(\mathrm{~g}) \quad \Delta H=-192 \mathrm{~kJ} \mathrm{~mol}^{-1}
$$

Circle the correct statement in each column of the table to show the effect of using a catalyst in the reaction.

| Effect of catalyst on <br> enthalpy change | Effect of catalyst on <br> activation energy |
| :---: | :---: |
| increase <br> stay the same <br> decrease | increase <br> stay the same <br> decrease |

(e) One use of sulfuric acid is in the production of soapless detergents.
(i) State the advantage that soapless detergents have over soap when used with hard water.
(ii) Describe the key structural features of a soapless detergent molecule.
8. Sweets contain a wide variety of chemicals.
(a) Many sweets contain esters.
(i) The structure of an ester used to produce a pear flavour in some sweets is


Name this ester.
(ii) Name the type of reaction used to form esters.
(b) Fizzy sweets can contain citric acid, $\mathrm{C}_{6} \mathrm{H}_{8} \mathrm{O}_{7}$, and sodium bicarbonate, $\mathrm{NaHCO}_{3}$.
When the sweets dissolve, the citric acid and sodium bicarbonate react together to make carbon dioxide gas.
(i) To calculate the mass of citric acid in a sweet, 5 sweets were dissolved in water and the resulting carbon dioxide was collected and measured.
Suggest why carbon dioxide can be collected over water.
8. (b) (continued)
(ii) In one experiment, 5 sweets were dissolved, and $55 \mathrm{~cm}^{3}$ of carbon dioxide gas was produced.
$\mathrm{C}_{6} \mathrm{H}_{8} \mathrm{O}_{7}(\mathrm{aq})+3 \mathrm{NaHCO}_{3}(\mathrm{aq}) \rightarrow 3 \mathrm{CO}_{2}(\mathrm{~g})+3 \mathrm{H}_{2} \mathrm{O}(\ell)+\mathrm{C}_{6} \mathrm{H}_{5} \mathrm{O}_{7} \mathrm{Na}_{3}(\mathrm{aq})$ $G F M=192 \mathrm{~g}$

Calculate the mass of citric acid, in g, in one sweet.
Take the volume of 1 mole of carbon dioxide to be 24 litres.

* X 813760123 *

8. (continued)
(c) The distinctive smell of some sweets is due to molecules such as limonene, carvone and vanillin.



limonene
carvone vanillin
(i) Vanillin is an aldehyde and carvone is a ketone.
(A) State the colour change that would be observed when aldehydes react with acidified potassium dichromate.
(B) Suggest a different chemical that could be used to distinguish aldehydes from ketones.
(ii) Limonene is a terpene consisting of joined isoprene units.

State the number of isoprene units in a limonene molecule.
8. (c) (continued)
(iii) 1 kg of natural vanillin costs $£ 1050$. To make a packet of sweets, $5 \mathrm{~cm}^{3}$ of vanillin solution is used. This contains $0 \cdot 184 \mathrm{~g}$ of vanillin per $100 \mathrm{~cm}^{3}$ of solution.

Calculate the cost, in pence, of the natural vanillin required to make the packet of sweets.
9. A brand of antiseptic mouthwash contains hydrogen peroxide along with several other chemicals such as water, flavourings and colouring.
(a) $100 \mathrm{~cm}^{3}$ of mouthwash contains 1.5 g of $35 \%$ hydrogen peroxide solution. A $35 \%$ hydrogen peroxide solution contains 35 g of hydrogen peroxide in $100 \mathrm{~cm}^{3}$ of solution.
(i) Calculate the mass of hydrogen peroxide, in g, present in a $300 \mathrm{~cm}^{3}$ bottle of the mouthwash.
(ii) Enzymes in saliva act as catalysts in the decomposition of hydrogen peroxide.
Name the family of compounds to which enzymes belong.
(iii) The concentration of hydrogen peroxide can be determined by a titration with a solution of potassium permanganate.
Name the two pieces of equipment that would be required to accurately measure the volumes of hydrogen peroxide and potassium permanganate used in the titration.
(b) Volatile, non-water-soluble compounds obtained from plants can be used to provide the minty aroma of the mouthwash.

State the term used to describe the mixture of volatile, non-water-soluble aroma compounds obtained from plants.
9. (continued)
(c) The mouthwash also contains menthol.

(i) Menthol is based on isoprene units. State the systematic name for isoprene.
(ii) Menthol can be oxidised to form a mint flavoured compound. State the type of compound formed when menthol is oxidised.
9. (continued)
(d) Methyl salicylate is an ester found in the mouthwash that can be formed from salicylic acid.

(i) Name reactant X .
(ii) A scientist prepared a sample of methyl salicylate using 28.3 g salicylic acid and an excess of reactant $X$.

$$
\begin{aligned}
& \mathrm{C}_{7} \mathrm{H}_{6} \mathrm{O}_{3}+X \rightarrow \mathrm{C}_{8} \mathrm{H}_{8} \mathrm{O}_{3}+\mathrm{H}_{2} \mathrm{O} \\
& \text { salicylic acid methyl salicylate } \\
& G F M=138 \mathrm{~g} \quad G F M=152 \mathrm{~g}
\end{aligned}
$$

The scientist produced 24.7 g of methyl salicylate.
Calculate the percentage yield of methyl salicylate.
9. (d) (continued)
(iii) Methyl salicylate can be toxic to humans at 0.14 g per kg of body mass. It can be obtained from a plant substance called oil of wintergreen. $5.0 \mathrm{~cm}^{3}$ of oil of wintergreen contains 7.0 g of methyl salicylate.

Calculate the minimum volume, in $\mathrm{cm}^{3}$, of oil of wintergreen that would provide a toxic dose to a human with body mass of 65 kg .
10. Cow's milk is mostly made up of water, with small amounts of fats and oils, proteins, sugars and other compounds. Milk is white because it contains small droplets of fats and oils that are dispersed in the water. It also contains small droplets of proteins.
The fats in the milk depend on what the cow eats - in summer the fats obtained from the milk have a higher melting point than those obtained from winter milk.

Milk goes off because of reactions involving the hydroxyl groups on the sugar molecules in milk.

Using your knowledge of chemistry, discuss the chemistry of cow's milk.
11. A Grignard reaction involves reacting compounds containing a carbonyl group with a Grignard reagent to make alcohols.
(a) The first step in the reaction involves heating the reactants in a solvent to form a Grignard reagent.

(i) Suggest why a water bath is used to heat the reaction.
(ii) Name the piece of apparatus labelled Y in the diagram.
11. (continued)
(b) Ethanal reacts with a Grignard reagent in two steps.
step 1


Grignard reagent
step 2

(i) Suggest a name for the reaction shown in step 1.
(ii) The alcohol that is made when propanone reacts with the same Grignard reagent is shown.


Name this alcohol.
11. (b) (continued)
(iii) Draw a structural formula for the alcohol formed when the Grignard reagent $\mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{MgBr}$ reacts with pentan-2-one.
[Turn over
12. One of the problems with recycling plastics is identifying the type of plastic.

Infrared spectroscopy is a technique that can be used to identify the bonds present in plastics. A spectrum is produced for each sample analysed. The same bond always absorbs infrared radiation in the same range of wavenumbers, even in different molecules. For example C-H bonds absorb in the wavenumber range $2700-3300 \mathrm{~cm}^{-1}$.

Four different types of plastic were analysed using infrared spectroscopy and the spectra produced are shown.

12. (continued)

(a) The spectrum obtained from the analysis of the plastic used to make a yoghurt pot is shown.


Identify the type of plastic used to make the yoghurt pot.
12. (continued)
(b) The spectrum produced from poly(ethylene terephthalate) contains an absorption at a wavenumber of $1720 \mathrm{~cm}^{-1}$.
Part of the structure of poly(ethylene terephthalate) is shown.


Using the information on page 14 of the data booklet, circle the bond in poly(ethylene terephthalate) that is responsible for this absorption.
(An additional diagram, if required, can be found on page 40.)
12. (continued)
(c) Polyacrylonitrile plastic has the following structure.


Using the information on page 14 of the data booklet, sketch the infrared spectrum you would predict for polyacrylonitrile, showing only the absorptions within the range $3500-2000 \mathrm{~cm}^{-1}$.

(An additional diagram, if required, can be found on page 40.)

## Paper 1 - Multiple choice

## Marking Instructions

Please note that these marking instructions have not been standardised based on candidate responses. You may therefore need to agree within your centre how to consistently mark an item if a candidate response is not covered by the marking instructions.

| Question | Response | Mark |
| :---: | :---: | :---: |
| 1. | A | 1 |
| 2. | D | 1 |
| 3. | B | 1 |
| 4. | A | 1 |
| 5. | C | 1 |
| 6. | C | 1 |
| 7. | D | 1 |
| 8. | B | 1 |
| 9. | B | 1 |
| 10. | C | 1 |
| 11. | C | 1 |
| 12. | B | 1 |
| 13. | C | 1 |
| 14. | B | 1 |
| 15. | D | 1 |
| 16. | A | 1 |
| 17. | D | 1 |
| 18. | B | 1 |
| 19. | C | 1 |
| 20. | D | 1 |
| 21. | A | 1 |
| 22. | B | 1 |
| 23. | C | 1 |
| 24. | A | 1 |
| 25. | A | 1 |

[END OF MARKING INSTRUCTIONS]

## Marking Instructions

Please note that these marking instructions have not been standardised based on candidate responses. You may therefore need to agree within your centre how to consistently mark an item if a candidate response is not covered by the marking instructions.

| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 1. | (a) | (i) | Increases (across period) | 1 |  |
|  |  | (ii) | They don't form (covalent) bonds | 1 | Accept: They (noble gases) are unreactive. <br> They are noble gases is not acceptable. |
|  |  | (iii) | Screening increases so less attraction (of nucleus/protons for the bonding/outer/shared electrons) <br> OR <br> Covalent radius/atomic size/number of shells increases so less attraction (of nucleus/protons for the bonding/outer/shared electrons) | 1 | Shielding is acceptable in place of screening. <br> 'Screening/shielding effect' by itself is not acceptable. <br> Information in brackets is not required but if included, the direction of attraction must be correct. |
|  | (b) | (i) | $2 \cdot 8 \pm 0.05$ | 1 |  |
|  |  | (ii) | Cross at $(2 \cdot 1,1 \cdot 8)$ on graph 2 marks <br> Partial mark <br> For calculation of both average electronegativity ( $2 \cdot 1$ ) and difference (1-8) (1 mark) <br> OR <br> For correctly plotting the point for the values candidate has calculated (1 mark) | 2 | A point other than $(2 \cdot 1,1 \cdot 8)$ plotted with no calculated values is worth 0 marks. |
|  |  | (iii) A | $\left(\mathrm{Li}^{+}\right)_{2} \mathrm{~S}^{2-}$ <br> Both charges must be shown. Brackets are required for $\mathrm{Li}^{+}$. | 1 |  |
|  |  | B | Carbon fluorine Sulfur fluorine Boron oxygen | 1 | Accept correct symbols. <br> If candidate states name of a compound then it must be correct. <br> Accept germanium and oxygen. |
|  | (c) |  | Polar (covalent) | 1 |  |

Go to Topic Grid


| Question |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: |
| 2. | (c) | $+250 \mathrm{~kJ} \mathrm{~mol}^{-1}$ (2 marks) <br> Partial marks <br> Treat as two concepts. Either would be acceptable for 1 mark. <br> Evidence of understanding of reversal of first and second enthalpy values must be seen ie +283 and +286 (or positive multiples of either/both). <br> The third enthalpy value (regardless of value) must be negative, or this partial mark cannot be awarded. <br> OR <br> Evidence of understanding of multiplying the second enthalpy value by 3 <br> (shown as $3 x+/-286$ or $+/-858$ ) <br> Multiplication of any other enthalpy value by any factor is taken as cancelling of this partial mark. | 2 | If correct answer is shown, award 2 marks. <br> Only 1 concept mark can be awarded if the final answer is incorrect. <br> If answer given is -250 , maximum of 1 mark can be awarded. <br> No units required. Only 1 mark can be awarded for the correct answer if wrong unit is given. (Wrong units would only be penalised once in any paper). <br> kJ is acceptable in place of $\mathrm{kJ} \mathrm{mol}^{-1}$ ( $\mathrm{KJ} \mathrm{or}_{\mathrm{Kj}}$ or $\mathrm{KJ} \mathrm{mol}^{-1}$ or $\mathrm{Kj} \mathrm{mol}^{-1}$ accepted). |


| Question |  | Expected response | Max <br> mark | Additional guidance |
| :--- | :--- | :--- | :---: | :--- |
| 3. | Award 1 mark where the candidate <br> has demonstrated, at an appropriate <br> level, a limited understanding of the <br> chemistry involved. They have made <br> some statement(s) which are <br> relevant to the situation, showing <br> that they have understood at least a <br> little of the chemistry within the <br> problem. | 3 | Zero marks should be awarded if: <br> The student has demonstrated, at an <br> appropriate level, no understanding, <br> of the chemistry involved. There is <br> no evidence that the student has <br> recognised the area of chemistry <br> involved or has given any statement <br> of a relevant chemistry principle. <br> This mark would also be given when <br> the student merely restates the <br> chemistry given in the question. |  |
| Award 2 marks where the candidate <br> has demonstrated, at an appropriate <br> level, a reasonable understanding of <br> the chemistry involved. They make <br> some statement(s) which are <br> relevant to the situation, showing <br> that they have understood the <br> problem. | Award 3 marks where the candidate <br> Aas demonstrated, at an appropriate <br> level, a good understanding of the <br> chemistry involved. They show a <br> good comprehension of the <br> chemistry of the situation and <br> provide a logically correct answer to <br> the question posed. This type of <br> response might include a statement <br> of the principles involved, a <br> relationship or an equation, and the <br> application of these to respond to <br> the problem. The answer does not <br> need to be 'excellent' or 'complete' <br> for the candidate to gain full marks. |  |  |  |
| Award 0 marks where the candidate <br> has not demonstrated, at an <br> appropriate level, an understanding <br> of the chemistry involved. There is <br> no evidence that they have <br> recognised the area of chemistry <br> involved, or they have not given any <br> statement of a relevant chemistry <br> principle. Award this mark also if the <br> candidate merely restates the <br> chemistry given in the question. |  |  |  |  |

Go to Topic Grid

| Question |  | Expected response | Max <br> mark | Additional guidance |
| :--- | :--- | :--- | :--- | :---: | :--- |
| 4. | (a) | Bond enthalpy is high (945)/has the <br> highest bond enthalpy value (in the <br> data booklet) | $\mathbf{1}$ | (Bond(s)) take(s) a lot of energy to <br> break/are very strong would not be <br> accepted on its own but would not <br> be cancelling. |
| (b) | Diagram shows a workable method <br> for removing carbon dioxide - must <br> include label for KOH (solution) <br> (1 mark) | $\mathbf{2}$ | Treat each mark separately. |  |
| Diagram shows a workable method <br> for passing gas over heated copper - <br> must include label for heated copper <br> (1 mark) |  |  |  |  |


| Question |  |  | Expected response <br> 2 marks for correct calculations AND 1 mark for a statement which follows on from the calculation stating that nitrogen is in excess or that lithium is the limiting reactant. <br> Partial marks <br> By calculating number of moles: <br> 1 mark for the correct calculation of number of moles of Li and $\mathrm{N}_{2}$. <br> 1 mark for correct application of the mole ratio. This can be shown by dividing a calculated number of moles of Li by 6 or multiplying a number of moles of $N_{2}$ by 6 . <br> 1 mark awarded for a correct statement following on from the candidate's calculations. <br> OR <br> By proportion: <br> 1 mark for $41.4 \mathrm{~g} \rightarrow 24$ litres <br> 1 mark for follow through from incorrect multiples of 6.9 g or 24 l <br> 1 mark awarded for a correct statement following on from the candidate's calculations. | Max <br> mark <br> 3 | Additio | al guidance |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 4. | (c) | (i) |  |  | Correct calculation of moles of lithium $=0.07 / 0 \cdot 072 / 0.0725$ moles and nitrogen $=0 \cdot 04 / 0 \cdot 038 / 0 \cdot 0375$ moles <br> The values in the tables shown provide guidance as to whether 1 mark or 2 marks for calculations should be awarded. <br> 2 marks can be awarded for any one of the following paired values in the table obtained by applying the mole ratio |  |
|  |  |  |  |  | have | need |
|  |  |  |  |  | 0.5 g Li | $0.291 \mathrm{~N}_{2}$ |
|  |  |  |  |  | $0.91 \mathrm{~N}_{2}$ | 1.55 g Li |
|  |  |  |  |  | $0.91 \mathrm{~N}_{2}$ | $0.291 \mathrm{~N}_{2}$ |
|  |  |  |  |  | 0.5 g Li | 1.55 g Li |
|  |  |  |  |  | 0.0725 mol Li | 0.225 mol Li |
|  |  |  |  |  | $0.0375 \mathrm{~mol} \mathrm{~N}_{2}$ | 0.012 mol N |
|  |  |  |  |  | 1 mark can be of the following table obtained ratio | warded for any one paired values in the thout applying mole |
|  |  |  |  |  | have | need |
|  |  |  |  |  | 0.5 g Li | $1.74 \mathrm{IN}_{2}$ |
|  |  |  |  |  | $0.91 \mathrm{~N}_{2}$ | 0.26 g Li |
|  |  |  |  |  | $0.91 \mathrm{~N}_{2}$ | $1.74 \mathrm{IN}_{2}$ |
|  |  |  |  |  | 0.5 g Li | 0.26 g Li |
|  |  |  |  |  | This mark can candidate shows calculations to | $y$ be awarded if the appropriate <br> stify the statement. |

Go to Topic Grid

| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 4. | (c) | (ii) | $\mathrm{Cu}^{+}(\mathrm{aq})+\mathrm{e}^{-} \rightarrow \mathrm{Cu}(\mathrm{s})$ | 1 | State symbols not required but if given must be correct. Accept electron without a negative sign. |
|  |  | (iii) | (ionic) lattice/network | 1 | Covalent network is not acceptable |
|  | (d) | (i) | atoms/molecules with an unpaired electron | 1 |  |
|  |  | (ii) | $676\left(\mathrm{~kJ} \mathrm{~mol}^{-1}\right)$ <br> -676 would be worth 1 mark <br> Partial marking, 1 mark can be awarded for <br> candidate correctly retrieves both of the relevant bond enthalpy data $(945,498)$ and attempts to use this with 91 <br> OR <br> calculation carried out correctly with one error in retrieval of bond enthalpy | 2 | No units are required but award only 1 mark for correct answer if incorrect unit is given. <br> (Wrong units would only be penalised once in any paper). <br> kJ is acceptable in place of $\mathrm{kJ} \mathrm{mol}^{-1}$ ( KJ or $\mathrm{Kj}^{\text {or }} \mathrm{KJ} \mathrm{mol}^{-1}$ or $\mathrm{Kj} \mathrm{mol}^{-1}$ accepted) |
|  |  | (iii) | termination | 1 |  |
|  |  | B | $\mathrm{H}-\mathrm{O}-\mathrm{N}=\mathrm{O}$ or | 1 |  |

Go to Topic Grid

| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 4. | (e) | (i) | Decreasing temperature favours the exothermic reaction/increasing temperature favours endothermic reactions (1 mark) <br> Increases the yield of ammonia (1mark) | 2 |  |
|  |  | $\begin{aligned} & \text { (ii) } \\ & \text { A } \end{aligned}$ | $\begin{aligned} & \mathrm{C}_{3} \mathrm{H}_{5} \mathrm{~N}_{3} \mathrm{O}_{9} \rightarrow \\ & 3 \mathrm{CO}_{2}+21 / 2 \mathrm{H}_{2} \mathrm{O}+1 \frac{1}{2} \mathrm{~N}_{2}+1 / 4 \mathrm{O}_{2} \end{aligned}$ <br> OR <br> correct multiples | 1 |  |
|  |  | B | The shock/bump provides the activation energy/ $E_{\mathrm{A}}$ <br> OR <br> the shock/bump provides sufficient/enough energy to start the reaction <br> OR <br> the reaction has a low activation energy/ $E_{A}$ | 1 | If candidate uses "it" in response, this can be taken as "the shock/bump". |

Go to Topic Grid

| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 5. | (a) |  | 1 mark for any correct feature and explanation as shown: <br> - Contains oxygen to ensure complete combustion <br> - Sample is surrounded by water so all energy transferred/reduce heat loss to surroundings <br> - Sealed container prevents/ reduces heat loss to the surroundings <br> - Stirring to ensure accurate temperature (measurement) | 1 |  |
|  | (b) | (i) | - $34078\left(\mathrm{~kJ} \mathrm{~mol}^{-1}\right)$ <br> Partial marks <br> 1 mark for a demonstration of the correct use of the relationship $E_{h}=c m \Delta T$ as shown by ( $4 \cdot 18 \times($ an order of magnitude of 0.775$) \times 11.9$ ) (ignore units for this partial mark) <br> 1 mark for evidence of the knowledge that enthalpy of combustion relates to 1 mole, evidenced by the scaling up of a calculated value of energy released. <br> 1 mark for correct arithmetic. This mark should be awarded if the candidate has obtained the 2 partial marks above but has applied correct early rounding within the calculation resulting in an answer that differs from -34 078). | 3 | Maximum of 2 marks can be awarded if negative enthalpy sign is not shown in final answer. <br> Units not required. Only 2 marks can be awarded for the correct answer if wrong unit is given. (wrong units would only be penalised once in any paper). <br> kJ is acceptable in place of $\mathrm{kJ} \mathrm{mol}^{-1}$ ( $\mathrm{KJ} \mathrm{or}^{\mathrm{Kj}}$ or $\mathrm{KJ} \mathrm{mol}^{-1}$ or $\mathrm{Kj} \mathrm{mol}^{-1}$ accepted). |
|  |  | (ii) | 0.71/0.713/0.7125 | 1 |  |
|  | (c) | (i) | 23.3 | 1 | Ignore any units |
|  |  | (ii) | Glycerol has 3 hydroxyl groups. | 1 | Accept glycerol is propan(e)-1,2,3triol/an alcohol with 3 hydroxyl OH ) groups |

Go to Topic Grid

| Question |  |  | Expected response |  | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 6. | (a) |  | Mass (1 mark) <br> 0.00113 <br> $1 \cdot 13$ <br> 1130 <br> Any correct line marks) <br> Correctly calcul without units <br> Appropriate unit | Unit (1 mark) <br> kg <br> g <br> mg <br> the table (2 <br> d mass of iodine <br> (1) <br> 1) | 2 | As no unit is specified, the correct answer can be expressed with any appropriate unit (as shown in table). <br> Any correct rounding accepted e.g. $1 \cdot 1278 / 1 \cdot 128 / 1 \cdot 13 \mathrm{~g}$ <br> Partial mark for appropriate units can only be awarded when the order of magnitude of an incorrectly calculated mass matches the unit. <br> If the candidate's working is unclear then the mark for units cannot be awarded. |
|  | (b) | (i) | Measuring the $m$ seaweed/sample mass of the con | of container + nd subtracting the er | 1 | Taring the balance with container and then adding the seaweed/ sample is accepted <br> "use of Tare function" on its own is not accepted. |
|  |  | (ii) | I-/iodide (ions) |  | 1 |  |
|  |  | (iii) | A solution of ac precisely known | ately/exactly/ ncentration | 1 |  |
|  |  | $\begin{aligned} & \text { (iv) } \\ & \text { A } \end{aligned}$ | $0 \cdot 00013$ (moles) |  | 1 | Units not required, but if present, must be correct. Wrong units are only penalised once per paper. |
|  |  | B | 0.03299g/0.033 | . 03 (g) | 1 | To award this mark, the candidates answer to part B must be correct for their use of their answer to part A (i.e. answer to part A $\times 253 \cdot 8$ ). <br> Units not required, but if present, must be correct. Wrong units are only penalised once per paper. |

Go to Topic Grid

| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 6. | (c) | (i) | Amino acid that must be acquired/obtained from the diet. | 1 | Amino acid that cannot be made by the body is accepted. |
|  |  | (ii) | Correctly drawn structure for dipeptide. <br> OR | 1 | Shortened structural formula accepted. <br> All atoms and bonds must be present as shown. However, in the side chains only, bonds drawn from C (or S ) to H (or N ) would not be penalised. |

Go to Topic Grid

| Question |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: |
| 7. | (a) | 1 mark for: | 2 | 1 mark for correct top half (4 responses) and 1 mark for correct bottom half (4 responses). <br> Accept correct chemical formula in place of names. <br> Accept "air" for "excess air". |

Go to Topic Grid

| Question |  |  | Expected response |  | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 7. | (b) |  | Require heat to be removed (to prevent the temperature from rising). |  | 1 |  |
|  | (c) | (i) | 1 mark for description of LDFs as forces of attraction between temporary dipoles (and induced dipoles) <br> 1 mark for an explanation of the cause of temporary dipoles in terms of uneven distribution of electrons/ electron wobble/movement of electrons in the molecule |  | 2 | Attraction involving permanent dipoles cancels this mark |
|  |  | (ii) | 1 mark Sulfur/S has more electrons than oxygen/O <br> 1 mark These forces are stronger due to sulfur structure being $\mathrm{S}_{8}$ whereas oxygen is $\mathrm{O}_{2}$ |  | 2 | The structure of $\mathrm{S}_{8}$ and $\mathrm{O}_{2}$ must be evidenced in answer (molecular formula, structural formula) for the second mark to be awarded. <br> Correctly calculated number of electrons $(16,128)$ would also be evidence of structure. |
|  | (d) |  | Effect of <br> catalyst on <br> enthalpy <br> change <br> $\frac{\text { Increase }}{\text { stay the same }}$ <br> decrease | Effect of catalyst on activation energy <br> increase stay the same decrease | 1 |  |
|  | (e) | (i) | Do not form scum. |  | 1 |  |
|  |  | (ii) | Both parts of mole described. <br> Any term to descri the table can be from the table to | cule must be <br> be the head from sed with any term describe the tail. | 1 | If answer mentions head and/or tail, then it must be correct ie head is hydrophilic. |

Go to Topic Grid

| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 8. | (a) | (i) | pentyl ethanoate | 1 |  |
|  |  | (ii) | condensation/esterification | 1 |  |
|  | (b) | (i) | Carbon dioxide is (relatively) insoluble/has very low solubility | 1 |  |
|  |  | (ii) | 0.029 (g) 2 marks <br> Partial marks <br> Correctly calculated number of moles of carbon dioxide divided by 3 to give number of moles of citric acid e.g. moles of citric acid $=0.00076(1$ mark) <br> Calculated number of moles of citric acid x 192 divided by 5 (1 mark) <br> OR <br> by proportion $\begin{array}{lll} 192 \mathrm{~g} & \rightarrow & 72 \mathrm{l}(1 \text { mark }) \\ 0.147 \mathrm{~g} & \rightarrow & 0.055 \mathrm{l} \\ 0.147 / 5 & 0.029 & \text { g) }(1 \mathrm{mark}) \end{array}$ <br> Allow follow through from incorrect multiple of 241 | 2 | Units not required, but if present, must be correct. Wrong units are only penalised once per paper. <br> Allow follow through from incorrect application of mole ratio or correct mole ratio applied to incorrectly calculated number of moles of $\mathrm{CO}_{2}$ |
|  | (c) | $\begin{aligned} & \text { (i) } \\ & \text { an } \end{aligned}$ | orange to green/blue-green/ blue | 1 |  |
|  |  | B | Tollens' reagent OR <br> Fehling's solution | 1 | Benedict's/ Schiff's reagent would be accepted. |
|  |  | (ii) | 2 | 1 |  |
|  |  | (iii) | 1 pence/ £0.01 (2 marks) <br> Partial marks <br> 1 mark can be awarded for: <br> cost per mg of vanillin $=£ 0 \cdot 00105$ OR <br> cost per $g$ of vanillin $=£ 1.05$ <br> OR <br> cost of 0.184 g of vanillin $=£ 0.1932$ <br> OR <br> mass of vanillin needed $=0.0092 \mathrm{~g}$ | 2 | Candidates final answer must be in a correct monetary number. |

Go to Topic Grid

| Question |  | Expected response | Max <br> mark | Additional guidance |
| :--- | :--- | :--- | :--- | :---: | :--- |$|$| 9. | (a) |
| :--- | :--- |


| Question |  | Expected response | Max <br> mark | Additional guidance |
| :--- | :--- | :--- | :--- | :--- |
| 10. | Award 1 mark where the candidate <br> has demonstrated, at an appropriate <br> level, a limited understanding of the <br> chemistry involved. They have made <br> some statement(s) which are <br> relevant to the situation, showing <br> that they have understood at least a <br> little of the chemistry within the <br> problem. | $\mathbf{3}$ | Zero marks should be awarded if: <br> The student has demonstrated, at an <br> appropriate level, no understanding, <br> of the chemistry involved. There is <br> no evidence that the student has <br> recognised the area of chemistry <br> involved or has given any statement <br> of a relevant chemistry principle. <br> This mark would also be given when <br> the student merely restates the <br> chemistry given in the question. |  |
| Award 2 marks where the candidate <br> has demonstrated, at an appropriate <br> level, a reasonable understanding of <br> the chemistry involved. They make <br> some statement(s) which are <br> relevant to the situation, showing <br> that they have understood the <br> problem. | Award 3 marks where the candidate <br> Aas demonstrated, at an appropriate <br> level, a good understanding of the <br> chemistry involved. They show a <br> good comprehension of the <br> chemistry of the situation and <br> provide a logically correct answer to <br> the question posed. This type of <br> response might include a statement <br> of the principles involved, a <br> relationship or an equation, and the <br> application of these to respond to <br> the problem. The answer does not <br> need to be 'excellent' or 'complete' <br> for the candidate to gain full marks. |  |  |  |
| Award 0 marks where the candidate <br> has not demonstrated, at an <br> appropriate level, an understanding <br> of the chemistry involved. There is <br> no evidence that they have <br> recognised the area of chemistry <br> involved, or they have not given any <br> statement of a relevant chemistry <br> principle. Award this mark also if <br> the candidate merely restates the <br> chemistry given in the question. |  |  |  |  |

Go to Topic Grid

| Question |  | Expected response | Max <br> mark | Additional guidance |  |  |
| :--- | :--- | :--- | :--- | :---: | :--- | :--- |
| 11. | (a) | (i) | Reactants/solvent is flammable/ <br> catches fire with a flame | $\mathbf{1}$ | accept products |  |
|  | (b) | (i) | addition | condenser | $\mathbf{1}$ |  |
|  |  | (ii) | 2-methylbutan-2-ol | $\mathbf{1}$ |  |  |
|  | (iii) | A correct structural formula for <br> 3-methylhexan-3-ol <br> e.g. a full structural formula or a <br> shortened structural formula | $\mathbf{1}$ | A mixture of full and shortened <br> structural formula is accepted, e.g. <br> H |  |  |

Go to Topic Grid

| Question |  | Expected response |  | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 12. | (a) | Poly(phenylethene) |  | 1 |  |
|  | (b) | $\mathrm{C}=0$ circled |  | 1 | accept ' $\mathrm{C}=0$ stretch' |
|  | (c) | 2 single ab 1 for C-H $\mathrm{cm}^{-1}$ and 2260-2215 <br> increasing absorption | ons (peaks) required the range 2700-3300 $\equiv \mathrm{N}$ within the range <br> venumber ( $\mathrm{cm}^{-1}$ ) | 1 | Ignore the intensity of the absorptions. <br> Ignore the width of the absorptions so long as the peak maximum is defined and within the given range. |

[END OF MARKING INSTRUCTIONS]

## Exemplification of Marking Instructions

## Exemplification of Question 2 b

Example 1

```
    \(55.8 \times 100=29.3 \%\)
\((159 \cdot 6+28)\)
1 mark
1 mark for correct use of atom economy relationship
```

Example 2

$$
55.8 \times 100
$$

$243 \cdot 6$
1 mark
1 mark for correct working shown with no final answer
Example 3

$$
\frac{55.8 \times 2}{159.6+(3 \times 28)} \times 100=45 \%
$$

## Exemplification of Question 2 c

Example 1

$$
\begin{aligned}
& 283+858-891=250 \\
& \mathbf{2} \text { marks }
\end{aligned}
$$

Example 2

$$
\begin{aligned}
849 & +286-891=244 \\
& \mathbf{1} \text { mark } \\
& 1 \text { mark for evidence of reversing first and second equation }
\end{aligned}
$$

Example 3

$$
\begin{aligned}
-283 & -858-891=-2032 \\
& 1 \text { mark } \\
1 & \text { mark for evidence of multiplying second equation by } 3
\end{aligned}
$$

Example 4


1 mark
1 mark for evidence of multiplying second equation by 3
Example 5

$$
\begin{aligned}
283 & +286+891=1460 \\
& 0 \text { marks } \\
& \text { Reversal of first and second equation cancelled by reversal of third equation }
\end{aligned}
$$

## Exemplification of Question 4 b

Example 1

potassimm
hydroxide
solution

## Example 2



1 mark

Example 3


1 mark

Example 4


## Exemplification of Question 4 ci

Example 1

$$
\begin{array}{ll}
L i & +N_{2} \\
6.9 \rightarrow 24 & \\
0.5 \rightarrow 1.74 l & \\
\\
\text { need } 0.9 l \text { marks } \\
\text { not } 1.74 l & \therefore N_{2} \text { in excess incorrect }
\end{array}
$$

Example 2
$\operatorname{Li} \frac{0.5}{6.9}=0.072$
$N_{2} \frac{0.9}{24}=0.0375$
$L i>N_{2} \therefore L i$ in excess
1 mark
1 mark for correct calculation of number of moles of Li and $\mathrm{N}_{2}$

Example 3

$$
\begin{aligned}
& \text { Li } \frac{0.5}{6.9}=0.07 \times 6=0.42 \\
& N_{2} \frac{0.9}{24}=0.0375 \\
& \text { Li } 0.42>0.0375 \quad \therefore \text { Li in excess }
\end{aligned}
$$

1 mark
1 mark for correct calculation of number of moles of Li and $\mathrm{N}_{2}$

Example 4
Li 0.072
$N_{2} 0.0375 \times 6=0.225$
0.225 moles $L i$ needed
$0.225>0.072$ not enough $L_{1}$
$\therefore N_{2}$ in excess

3 marks
1 mark for correct calculation of number of moles of Li and $\mathrm{N}_{2}$
1 mark for correct use of mole ratio
1 mark for correct statement of excess

## Exemplification of Question 4 d ii

Example 1

| bonds broken | $\Delta H$ |  |  |
| ---: | :--- | ---: | :--- |
| 945 | 91 |  |  |
| 498 |  |  |  |
| $945+498-N O$ | $=91$ |  |  |
|  |  |  |  |
|  |  |  |  |

## 1 mark

1 mark for correct retrieval of bond enthalpy data and use of this with the reaction enthalpy change

Example 2

$$
\begin{aligned}
945+498-N O & =91 \\
N O & =1352
\end{aligned}
$$

## 1 mark

1 mark for correct retrieval of bond enthalpy data and use of this with the reaction enthalpy change

Example 3

$$
945+498+91=1534
$$

1 mark
1 mark for correct retrieval of bond enthalpy data and use of this with the reaction enthalpy change

Example 4

$$
945+498-91=1352
$$

## 1 mark

1 mark for correct retrieval of bond enthalpy data and use of this with the reaction enthalpy change

Example 5
bonds broken

## $\Delta H$

945 489

## 1 mark

1 mark for correct calculation with 1 error in the bond enthalpies retrieved (489 for 498))

$$
\begin{aligned}
945+489-2 \times N O & =91 \\
N O & =671.5
\end{aligned}
$$

## Exemplification of Question 5 b ii

Example 1

$$
\begin{aligned}
& E=4.18 \times 1 \times 11.9 \\
&=49.742 \\
& 49.742=19 \\
& 43972=8849 \\
& 1 \text { mark for evidence of knowledge that enthalpy of } \\
& \text { combustion relates to } 1 \text { mole }
\end{aligned}
$$

## 2 marks

1 mark for demonstration of correct use of $E_{h}=$ $\mathrm{cm} \Delta \mathrm{T}$
1 mark for evidence of knowledge that enthalpy of combustion relates to 1 mole

Example 3

$$
\begin{aligned}
E & =4.18 \times 1 \times 11.9 \\
& =49.742
\end{aligned}
$$

## Exemplification of Question 6 a

Example 1

$$
\begin{aligned}
0.133 & =1 \mathrm{~kg} \\
0.15 & =1.13 \mathrm{~kg}
\end{aligned}
$$

Example 2

$$
\begin{aligned}
0.133 & =1000 \\
0.15 & =1127.8
\end{aligned}
$$

Example 3

$$
\begin{aligned}
0.133 & =100 \mathrm{~g} \\
0.15 & =112.78 \mathrm{~g}
\end{aligned}
$$

Example 4

$$
\begin{aligned}
0.133 \mathrm{~g} & =1000 \mathrm{~g} \\
1 \mathrm{~g} & =7518 \mathrm{~g} \\
1000 \mathrm{mg} & =7518 \mathrm{~g} \\
0.15 \mathrm{mg} & =1.12 \mathrm{~g}
\end{aligned}
$$

## 1 mark

1 mark for correct calculated mass of iodine

## 1 mark

1 mark for correct calculated mass of iodine

## 1 mark

1 mark for correct calculated mass of iodine

1 mark
1 mark for correct unit for incorrectly rounded calculated mass

## Exemplification of Question 6 bi

Example 1
Put beaker on balance,
press to zero, add seaweed
to mass required.
1 mark
Example 2
Place container on balance. set to zero. add seaweed.

## 1 mark

## Exemplification of Question 6 b iv

Example 1
(A) $n=0.00026$ moles $I_{2}$
(B) $0.00026 \times 126.9=0.0339$

## Part A 0 marks

Part B 0 marks Incorrect answer for candidates answer to Part A as incorrect GFM for iodine used

Example 2
(A) $n=0.00013$
(B) $0.00013 \times 126.9=0.01659$

Part A 1 mark
Part B 0 marks Incorrect GFM for iodine used

Example 3
(A) $n=0.00026$
(B) $0.00026 \times 253.8=0.066 \mathrm{~g}$

## Part A 0 marks

Part B 1 mark for follow through from Part A

Example 4
A) $0.000 \quad 13$
B) $m=0.0013 \times 253.8$

$$
=0.33 \mathrm{~g}
$$

Part A 1 mark
Part B 0 marks Incorrect number of moles used

## Exemplification of Question 6 c

Example 1


Example 2


## 1 marks

Incorrect connection of bonds in side chains not penalised

Example 3


Example 4


## 0 marks

Missing bond in the $\mathrm{C}=\mathrm{O}$ in amide link

Example 5


1 mark

Exemplification of Question 7 ci

Example 1


Example 2


## Exemplification of Question 7 e ii

Example 1


## 0 marks

Example 2
The head is polar and the tail is fat soluble.

Example 3
The tail dissolves in water and the
head dissolves in oil.

## 0 marks

Example 4
One part is hydrophobic and one port is ionic.

## 1 mark

## Exemplification of Question 8 b ii

Example 1

```
\mathrm { CO } _ { 2 } \frac { 5 5 } { 2 4 } = 2 . 2 9 \text { moles}
        1 }->
    0.76 \leftarrow 2.29
    mass}=0.76\times192=146.67
        *5=29.39
```


## 1 mark

1 mark for calculated number of moles x 192 divided by 5

Example 2

```
CO2 }\frac{0.055}{24}=0.00229\mathrm{ moles
    =0.00229 mole citvic acid
        +192
        0.44g\div5 =0.088g
```

Example 3

$$
\begin{aligned}
& 192 \longrightarrow 24 \\
& 0.449 \leftarrow 0.055
\end{aligned}
$$

Example 4


## Exemplification of Question 8 c iii

Example 1

```
    \(1000 \mathrm{~g}=* 1050\)
    \(0.184 \mathrm{~g}=0.1932\)
    1 mark
    1 mark for calculation with answer not rounded for a
        monetary unit
    \(0.1932=100\)
    \(\leftarrow 5\)
\(f 0.00966\)
```


## Example 2

$$
\begin{aligned}
1000 \mathrm{~g} & =f_{1050} \\
0.184 \mathrm{~g} & =\frac{0.184 \times 1050}{1000}=\ell_{0} .1932 \\
100 \mathrm{~cm}^{3} & =\ell 0.1932 \\
5 \mathrm{~cm}^{3} & =\in 0.00966
\end{aligned}
$$

Example 3

$$
\begin{aligned}
100 \mathrm{~cm}^{3} & =0.184 \mathrm{~g} \\
5 \mathrm{~cm}^{3} & =0.0092 \mathrm{~g}
\end{aligned}
$$

## 1 mark

Example 4

$$
\begin{aligned}
1000 \mathrm{~g} & =1050 \\
0.0092 \mathrm{~g} & =f 0000966
\end{aligned}
$$

## 1 mark

1 mark awarded for calculation with answer not rounded for a monetary unit

## Exemplification of Question 9 dii

Example 1

$$
\begin{array}{lll}
\text { TY. } & \begin{array}{ll}
138 \mathrm{~g} \rightarrow 152 \mathrm{~g} \\
28.3 \mathrm{~g} \rightarrow 31.2 \mathrm{~g}
\end{array} & \begin{array}{l}
1 \text { mark } \\
1 \text { mark for correct theoretical yield }
\end{array} \\
\% & \frac{28.3}{31.2} \times 100=90.7 \%
\end{array}
$$

Example 2

$$
\begin{array}{lll}
\text { TY } & 138 & \rightarrow 152 \\
& 28.3 & \rightarrow 31.29 \\
\% & \frac{24.7}{31.2} \times 100=79 \%
\end{array}
$$

Example 3
TY. $138 \rightarrow 152$

$$
28.3 \rightarrow 31 \mathrm{~g}
$$

## 2 marks

Correct early rounding of theoretical yield to 31 gives 79.67/79.7/80 \%

$$
\% \quad \frac{24.7}{31} \times 100=80 \%
$$

## Exemplification of Question 9 d iii

Example 1

$$
\begin{aligned}
& 5 \mathrm{~cm}^{3} \rightarrow 7 \mathrm{~g} \quad 1 \text { mark } \\
& 0.1 \mathrm{~cm}^{3} \Leftarrow 0.14 \mathrm{~g}
\end{aligned}
$$

Example 2

$$
65 \times 0.14=9.1 \mathrm{~g}
$$

## Example 3

$$
\begin{gathered}
65 \times 0.14=7.84 \mathrm{~g} \\
7 \mathrm{~g}=5 \mathrm{~cm}^{3} \\
7.84 \mathrm{~g}=5.6 \mathrm{~cm}^{3}
\end{gathered}
$$

Example 4

$$
\begin{aligned}
& 7 \mathrm{~g}=5 \mathrm{~cm}^{3} \\
& 0.14 \mathrm{~g}=0.12 \mathrm{~cm}^{3} \\
& 0.12 \mathrm{~cm}^{3} \times 65=7.8 \mathrm{~cm}^{3}
\end{aligned}
$$

## 1 mark

1 mark for follow through from incorrect first step of calculation

1 mark
1 mark for follow through from incorrect first step of calculation

## X813/76/12

## Paper 1 - Multiple choice

FRIDAY, 29 APRIL
9:00 AM - 9:40 AM

## Total marks - 25

Attempt ALL questions.
You may use a calculator.
Instructions for the completion of Paper 1 are given on page 02 of your answer booklet X813/76/02.

Record your answers on the answer grid on page 03 of your answer booklet.
You may refer to the Chemistry Data Booklet for Higher and Advanced Higher
Space for rough work is provided at the end of this booklet.
Before leaving the examination room you must give your answer booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

## Total marks - 25

Attempt ALL questions

1. An element contains covalent bonding and London dispersion forces.

The element could be:
A boron
B neon
C sodium
D sulfur.
2. The graph below shows the relative quantities of energy equivalent to successive ionisation energies for an element.


The most stable ion formed from an atom of this element has a charge of:
A $2+$
B $3+$
C $2-$
D 3-
3. HCl has a higher boiling point than $\mathrm{H}_{2}$ because:

A the polar covalent bonds in HCl are stronger than the covalent bonds in $\mathrm{H}_{2}$
B the polar covalent bonds in HCl are stronger than the van der Waals' forces in $\mathrm{H}_{2}$
C the van der Waals' forces in HCl are stronger than the van der Waals' forces in $\mathrm{H}_{2}$
D the van der Waals' forces in HCl are stronger than the covalent bonds in $\mathrm{H}_{2}$.
4. Which line in the table would best describe elements that act as reducing agents?

|  | Gains or loses electrons | Electronegativity |
| :---: | :---: | :---: |
| A | gains | low |
| B | loses | low |
| C | gains | high |
| D | loses | high |

5. The correct redox equation for the reaction of iron(II) ions with acidified dichromate ions is:
$\mathrm{A} \mathrm{Cr}_{2} \mathrm{O}_{7}^{2-}(\mathrm{aq})+14 \mathrm{H}^{+}(\mathrm{aq})+\mathrm{Fe}^{2+}(\mathrm{aq}) \rightarrow 2 \mathrm{Cr}^{3+}(\mathrm{aq})+7 \mathrm{H}_{2} \mathrm{O}(\ell)+\mathrm{Fe}(\mathrm{s})$
B $\mathrm{Cr}_{2} \mathrm{O}_{7}{ }^{2-}(\mathrm{aq})+14 \mathrm{H}^{+}(\mathrm{aq})+\mathrm{Fe}^{2+}(\mathrm{aq}) \rightarrow 2 \mathrm{Cr}^{3+}(\mathrm{aq})+7 \mathrm{H}_{2} \mathrm{O}(\ell)+\mathrm{Fe}^{3+}(\mathrm{aq})$
C $\mathrm{Cr}_{2} \mathrm{O}_{7}^{2-}(\mathrm{aq})+14 \mathrm{H}^{+}(\mathrm{aq})+6 \mathrm{Fe}^{2+}(\mathrm{aq}) \rightarrow 2 \mathrm{Cr}^{3+}(\mathrm{aq})+7 \mathrm{H}_{2} \mathrm{O}(\ell)+6 \mathrm{Fe}(\mathrm{s})$
D $\mathrm{Cr}_{2} \mathrm{O}_{7}{ }^{2-}(\mathrm{aq})+14 \mathrm{H}^{+}(\mathrm{aq})+6 \mathrm{Fe}^{2+}(\mathrm{aq}) \rightarrow 2 \mathrm{Cr}^{3+}(\mathrm{aq})+7 \mathrm{H}_{2} \mathrm{O}(\ell)+6 \mathrm{Fe}^{3+}(\mathrm{aq})$
6. A mixture of magnesium bromide and magnesium sulfate is known to contain 3 moles of magnesium ions and 4 moles of bromide ions.

How many moles of sulfate ions are present?
A 1
B 2
C 3
D 4
7.


The correct name for this ester is:

A butyl propanoate
B propyl butanoate
C pentyl propanoate
D propyl pentanoate.
8. The structural formula for a compound is shown.


Which of the following is not an isomer of this compound?
A octan-4-one
B 2-ethylhexanal
C 2-ethylhexan-1-ol
D 5-methylheptan-3-one
9. Gabapentin is a medicine that can be used to treat nerve pain.


Which line in the table shows the two functional groups present in this compound?

| A | amine | carboxyl |
| :---: | :---: | :---: |
| B | amine | hydroxyl |
| C | hydroxyl | carboxyl |
| D | hydroxyl | carbonyl |

10. Prenol is a compound that occurs naturally in citrus fruits.


Which line in the table correctly describes the reaction of prenol with bromine solution and with hot copper(II) oxide?

|  | Reaction with <br> bromine solution | Reaction with hot <br> copper(II) oxide |
| :---: | :---: | :---: |
| A | no reaction | no reaction |
| B | no reaction | brown solid formed |
| C | decolourises | brown solid formed |
| D | decolourises | no reaction |

11. The iodine number of an oil is the mass of iodine, in grams, that will react with 100 g of oil and is a measure of the degree of saturation.
Olive oil has an iodine number of 84 and palm oil has an iodine number of 48 .
Which of the following statements is correct?
A Palm oil is more saturated and has a lower melting point than olive oil.
B Palm oil is more saturated and has a higher melting point than olive oil.
C Palm oil is less saturated and has a lower melting point than olive oil.
D Palm oil is less saturated and has a higher melting point than olive oil.
12. The structure of a soapless detergent molecule is given below.


Which line in the table describes a step in the cleansing action of a soapless detergent?

|  | Head section | Tail section |
| :--- | :--- | :--- |
| A | The hydrophobic head dissolves in water. | The hydrophilic tail dissolves in oil. |
| B | The hydrophilic head dissolves in water. | The hydrophobic tail dissolves in oil. |
| C | The hydrophobic head dissolves in oil. | The hydrophilic tail dissolves in water. |
| D | The hydrophilic head dissolves in oil. | The hydrophobic tail dissolves in water. |

13. Which of the following is a secondary alcohol?

A 2-methylbutan-1-ol
B 2-methylbutan-2-ol
C butan-1-ol
D butan-2-ol
14. The compounds below are examples of flavour molecules found in some plants.

cucumber flavour

ginger flavour


vanilla flavour

orange flavour

Which line in the table shows the solubilities of these compounds in water and in oil?

|  | Water soluble | Oil soluble |
| :---: | :---: | :---: |
| A | cucumber and ginger | orange and vanilla |
| B | cucumber and orange | ginger and vanilla |
| C | ginger and vanilla | cucumber and orange |
| D | orange and vanilla | cucumber and ginger |

15. The structural formula for a compound is shown.


The product of oxidation of this compound is:
A 2-methylpentan-4-one
B 4-methylpentan-2-one
C 2-methylpentanal
D 4-methylpentanal.
16. Which of the following describes how to fill a burette with acid and take the initial reading in a titration?

A Rinse the burette with the acid. Fill to above the scale with acid. Drain some of the acid and read from the top of the meniscus.

B Rinse the burette with deionised water. Fill to above the scale with acid. Drain some of the acid and read from the bottom of the meniscus.
C Rinse the burette with the acid. Fill to above the scale with acid. Drain some of the acid and read from the bottom of the meniscus.
D Rinse the burette with deionised water. Fill to above the scale with acid. Drain some of the acid and read from the top of the meniscus.
17. Tomato juice contains a mixture of terpenes including lycopene and beta-carotene. Terpenes can be separated using chromatography.

lycopene

beta-carotene

Which of the following is the most suitable solvent to separate lycopene and beta-carotene?
A Ethanol
B Pentane
C Propanoic acid
D Water
18. The graph shows how the rate of a reaction varies with the concentration of a reactant.


When the concentration of the reactant is $0.06 \mathrm{moll}^{-1}$, the reaction time is:
A 0.004 s
B $\quad 0.09 \mathrm{~s}$
C 17 s
D 250 s .
19. Butene reacts with oxygen as shown.

$$
\mathrm{C}_{4} \mathrm{H}_{8}(\mathrm{~g})+6 \mathrm{O}_{2}(\mathrm{~g}) \rightarrow 4 \mathrm{CO}_{2}(\mathrm{~g})+4 \mathrm{H}_{2} \mathrm{O}(\mathrm{~g})
$$

$100 \mathrm{~cm}^{3}$ of butene was reacted with excess oxygen.
Compared with the total volume of gases before reaction, what would be the total volume of gases after complete reaction?

A $\quad 100 \mathrm{~cm}^{3}$ more
B $\quad 100 \mathrm{~cm}^{3}$ less
C $\quad 300 \mathrm{~cm}^{3}$ more
D $300 \mathrm{~cm}^{3}$ less
20. In aqueous solution ethanoic acid forms an equilibrium mixture with its ions.

$$
\mathrm{CH}_{3} \mathrm{COOH}(\mathrm{aq}) \rightleftharpoons \mathrm{H}^{+}(\mathrm{aq})+\mathrm{CH}_{3} \mathrm{COO}^{-}(\mathrm{aq})
$$

Which of the following solutions, when added to the equilibrium mixture, would favour the forward reaction?

A $\mathrm{NaCl}(\mathrm{aq})$
B $\mathrm{HCl}(\mathrm{aq})$
C $\mathrm{NaOH}(\mathrm{aq})$
D $\mathrm{CH}_{3} \mathrm{COONa}(\mathrm{aq})$
21. Some energy values associated with a chemical reaction are shown in the table.

| Enthalpy of reactants ( $\mathrm{kJ} \mathrm{mol}^{-1}$ ) | Activation energy of forward reaction (kJ mol ${ }^{-1}$ ) | Activation energy of reverse reaction (kJ mol ${ }^{-1}$ ) |
| :---: | :---: | :---: |
| 30 | 110 | 70 |

Which of the following correctly shows the potential energy diagram for the above conditions?


B


D

22. Consider the reaction pathway below.


According to Hess' law, the $\Delta H$ value, in $\mathrm{kJ} \mathrm{mol}^{-1}$, for reaction Z to Y is:
A -74
B +74
C -346
D +346
23. $50.0 \mathrm{~cm}^{3}$ of $0.100 \mathrm{moll}^{-1}$ ammonia solution was transferred to a $250 \mathrm{~cm}^{3}$ volumetric flask. The flask was made up to the mark with deionised water.
The final concentration, in moll $^{-1}$, of the ammonia solution is:
A $\quad 2.0 \times 10^{-2}$
B $\quad 2.5 \times 10^{-2}$
C $\quad 4.0 \times 10^{-2}$
D $5.0 \times 10^{-2}$
24. An experiment involves reacting 0.02 moles of silver ions with ions of a group 7 element to form 2.868 g of precipitate.
Which of the following is the precipitate?
A Silver(I) fluoride
B Silver(I) chloride
C Silver(I) bromide
D Silver(I) iodide
25. A titration experiment was carried out to determine the concentration of vitamin C in orange juice.
A sample of the orange juice solution was pipetted into a flask and $10 \mathrm{~cm}^{3}$ water was added to dilute the sample. Starch indicator was added to the flask. The mixture was then titrated in the flask using iodine solution of known concentration.
Which line in the table shows the most appropriate apparatus to use when carrying out this procedure?

|  | To add water | Type of flask |
| :---: | :---: | :---: |
| A | measuring cylinder | conical flask |
| B | beaker | conical flask |
| C | measuring cylinder | volumetric flask |
| D | beaker | volumetric flask |

[END OF QUESTION PAPER]

|  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- |

FRIDAY, 29 APRIL
10:10 AM - 12:30 PM

National Qualifications
2022
Mark
$\square$

Fill in these boxes and read what is printed below.

Full name of centre

$\square$

Town


Forename(s)


Surname


Number of seat


Date of birth

| Day |
| :--- | | Month |
| :--- | | Year |
| :--- | | Sottish candidate number |
| :--- | | Y |
| :--- |

## Total marks - 95

Attempt ALL questions.

## You may use a calculator.

You may refer to the Chemistry Data Booklet for Higher and Advanced Higher.
Write your answers clearly in the spaces provided in this booklet. Additional space for answers and rough work is provided at the end of this booklet. If you use this space you must clearly identify the question number you are attempting. Any rough work must be written in this booklet. Score through your rough work when you have written your final copy.

Use blue or black ink.
Before leaving the examination room you must give this booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

Total marks - 95

## Attempt ALL questions

1. Elements and compounds can exist as diatomic molecules.
(a) The seven elements that exist as diatomic molecules are shown in the periodic table below.

(i) Explain why diatomic elements form non-polar molecules.
(ii) Nitrogen, oxygen and fluorine are found in the second period of the periodic table.

Explain the decrease in covalent radius going from nitrogen to fluorine.
(b) First ionisation energies decrease going down a group.
(i) State what is meant by the term first ionisation energy.

1. (b) (continued)
(ii) Explain why the first ionisation energy of the group 7 elements decreases going down the group.
(c) Hydrogen halides are diatomic molecules formed between hydrogen and the elements fluorine, chlorine, bromine and iodine.

The boiling points of the hydrogen halides are shown on the graph below.

(i) Hydrogen fluoride, HF, has the highest boiling point of the hydrogen halides.

State the name of the strongest type of intermolecular force found between hydrogen fluoride molecules and explain how this type of intermolecular force arises.

MARKS
(ii) The table shows the boiling points of hydrogen chloride, hydrogen bromide and hydrogen iodide.

| Hydrogen halide | Boiling point $\left({ }^{\circ} \mathrm{C}\right)$ |
| :--- | :---: |
| Hydrogen chloride | -85 |
| Hydrogen bromide | -66 |
| Hydrogen iodide | -35 |

Explain fully why the boiling point increases from hydrogen chloride to hydrogen iodide.
2. Fireworks contain a range of chemicals including a fuel, oxidising agents and metal salts.
(a) One oxidising agent used in fireworks is potassium perchlorate, $\mathrm{KClO}_{4}$. This reacts with aluminium metal and produces a bright flash.
The equation for the reaction is

$$
\mathrm{KClO}_{4}+\mathrm{Al} \rightarrow \mathrm{KCl} \quad+\quad \mathrm{Al}_{2} \mathrm{O}_{3}
$$

Balance this equation.
(b) Fireworks were traditionally made using compounds containing the chlorate ion, $\mathrm{ClO}_{3}^{-}$, as an oxidising agent.
(i) Chlorate ions release oxygen when they decompose.

Potassium chlorate, $\mathrm{KClO}_{3},(G F M=122.6 \mathrm{~g})$ reacts as shown.

$$
2 \mathrm{KClO}_{3}(\mathrm{~s}) \rightarrow 3 \mathrm{O}_{2}(\mathrm{~g})+2 \mathrm{KCl}(\mathrm{~s})
$$

Calculate the volume of oxygen produced, in litres, when 4.6 g of potassium chlorate decomposes.

Take the volume of 1 mole of oxygen gas to be 24 litres.
2. (b) (continued)
(ii) The decomposition of potassium chlorate can be speeded up by the addition of a catalyst.
State the effect of adding a catalyst on the enthalpy change for this reaction.
(iii) A firework containing 5.5 g of potassium perchlorate ( $G F M=138.6 \mathrm{~g}$ ) releases 103 kJ of energy.

Calculate the energy, in kJ, released per mole of potassium perchlorate.
2. (b) (continued)
(iv) Explain fully why increasing temperature increases the rate of a chemical reaction.
(c) The different flame colours produced by metal salts are caused by different wavelengths of light being emitted. The flame colours associated with different wavelengths are given in the data booklet.

The following profile shows the colours emitted by one particular firework. Each peak represents a different colour of light.


Peak A has a wavelength of 620 nm , corresponding to red light.
Suggest the metal responsible for peak B on the spectrum.
3. Atoms of different elements have different attractions for bonding electrons.

Electronegativity is a measure of the attraction an atom involved in a bond has for the electrons in the bond.

Using your knowledge of chemistry, discuss the importance of electronegativity in bonding, structure and properties of compounds.
4. Coconut oil contains a mixture of compounds.
(a) Propyl octanoate is a compound found in coconut oil.

(i) Name the functional group in propyl octanoate.
(ii) Draw a structural formula for the carboxylic acid formed by hydrolysis of propyl octanoate.
(iii) An isomer of propyl octanoate with the same functional group was hydrolysed. One of the products of this hydrolysis was butanoic acid. Suggest a name for the other product.
4. (continued)
(b) Chromatography can be used to separate the fats and oils in coconut oil. The result of a chromatography experiment is shown.

(i) Using the graph and the information in the table, predict the number of carbons in glyceryl trilaurate.

| Name | Molecular formula | Melting point $\left({ }^{\circ} \mathrm{C}\right)$ |
| :--- | :---: | :---: |
| Glyceryl tricaprylate | $\mathrm{C}_{27} \mathrm{H}_{50} \mathrm{O}_{6}$ | 10 |
| Glyceryl tricaprate | $\mathrm{C}_{33} \mathrm{H}_{62} \mathrm{O}_{6}$ | 31 |
| Glyceryl trilinoleate | $\mathrm{C}_{57} \mathrm{H}_{98} \mathrm{O}_{6}$ | -5 |

4. (b) (continued)
(ii) Identify the compound listed in the table which is the most unsaturated.
(c) Edible oils such as coconut oil can be used to make emulsifiers.
(i) State how emulsifiers are made from edible oils.
(ii) Explain fully how emulsifiers prevent non-polar and polar liquids from separating into layers.
5. Fusel oil is formed as a by-product during the production of bioethanol for fuel. It is a mixture of several alcohols.
(a) The shortened structural formula of one of the alcohols contained in fusel oil is shown.

$$
\mathrm{CH}_{3} \mathrm{CH}\left(\mathrm{CH}_{3}\right) \mathrm{CH}_{2} \mathrm{CH}_{2} \mathrm{OH}
$$

State the name of this alcohol.
(b) Propan-1-ol is also found in fusel oil.

Propan-1-ol is reacted with an oxidising agent to produce propanal.
(i) Complete the ion-electron equation for the oxidation reaction.

$$
\mathrm{C}_{3} \mathrm{H}_{7} \mathrm{OH} \quad \rightarrow \quad \mathrm{C}_{3} \mathrm{H}_{6} \mathrm{O}
$$

(ii) Acidified potassium dichromate can be used as the oxidising agent and reacts as shown below.

$$
\mathrm{Cr}_{2} \mathrm{O}_{7}^{2-}(\mathrm{aq})+14 \mathrm{H}^{+}(\mathrm{aq})+6 \mathrm{e}^{-} \rightarrow 2 \mathrm{Cr}^{3+}(\mathrm{aq})+7 \mathrm{H}_{2} \mathrm{O}(\ell)
$$

Suggest why the potassium dichromate must be acidified.
5. (b) (continued)
(iii) State the colour change that would be observed when propan-1-ol reacts with acidified potassium dichromate.
(iv) The equation for the reduction of another oxidising agent that could be used to oxidise propan-1-ol is shown below.

$$
\mathrm{Ag}^{+}(\mathrm{aq})+\mathrm{e}^{-} \rightarrow \mathrm{Ag}(\mathrm{~s})
$$

Name the reagent that provides this oxidising agent.
(v) State why 2-methylbutan-2-ol cannot be oxidised using these oxidising agents.
(vi) In the reaction of butan-1-ol to butanal, oxidation can be identified by an increase in the oxygen to hydrogen ratio.
Complete the table to show the oxygen to hydrogen ratios in butan-1-ol and butanal.

|  | Oxygen to hydrogen ratio |
| :--- | :--- |
| Butan-1-ol |  |
| Butanal |  |

[Turn over
6. Sweet potatoes contain nutrients, including starch, vitamin $C$ and proteins.
(a) Catalase is an enzyme contained in sweet potatoes that speeds up the breakdown of hydrogen peroxide.
(i) State what is meant by the term enzyme.
(ii) Enzymes are a type of protein. Proteins are formed from smaller molecules called amino acids.
(A) A section of a protein is shown.


Circle a peptide link in the above structure.
(An additional diagram can be found on page 33.)
(B) Draw a structural formula for one of the amino acids used to form this section of protein.
6. (a) (ii) (continued)
(C) State what is meant by the term essential amino acid.
(D) Name the type of reaction that takes place when amino acids join to form proteins.
(iii) As sweet potatoes are cooked, the ability of catalase to break down hydrogen peroxide decreases.
Explain fully what happens to the enzyme structure to cause this reduction in activity.
(b) Sweet potatoes are a good source of the antioxidant vitamin C .
(i) Antioxidants like vitamin C are added to food. Explain why antioxidants are added to food.
6. (b) (continued)
(ii) The structure of vitamin C is shown.


Explain fully why vitamin C is soluble in water.
(c) Unlike sweet potatoes, white potatoes contain the chemical solanine, that can be toxic to humans in large doses. A dose of 3 mg per kg of body weight can cause toxic symptoms.
A typical white potato can contain 0.2 mg per g of solanine.
Calculate the mass of white potato that could produce a toxic dose to an adult weighing 65 kg .
7. Natural gas is a source of methane.
(a) Methane, $\mathrm{CH}_{4}$, can be used as a fuel.

In an experiment, methane was burned to raise the temperature of $100 \mathrm{~cm}^{3}$ of water by $27^{\circ} \mathrm{C}$.
Using the enthalpy of combustion of methane ( $891 \mathrm{~kJ} \mathrm{~mol}^{-1}$ ), calculate the mass of methane, in g , burned in this experiment.
(b) The equation for the combustion of methane is shown.

$$
\mathrm{CH}_{4}(\mathrm{~g})+2 \mathrm{O}_{2}(\mathrm{~g}) \rightarrow \mathrm{CO}_{2}(\mathrm{~g})+2 \mathrm{H}_{2} \mathrm{O}(\mathrm{~g})
$$

Bond enthalpies can be used to calculate a theoretical enthalpy change for this reaction.
Using bond enthalpies from the data booklet, calculate the enthalpy change, in $\mathrm{kJ} \mathrm{mol}^{-1}$, for the combustion of methane.
7. (continued)
(c) Methane reacts with steam to produce hydrogen.

$$
\begin{aligned}
& \mathrm{CH}_{4}(\mathrm{~g}) \\
& F M=16 \mathrm{~g} \quad \mathrm{H}_{2} \mathrm{O}(\mathrm{~g}) \\
& G F M=18 \mathrm{~g}
\end{aligned} \underset{G F M=28 \mathrm{~g}}{\mathrm{CO}(\mathrm{~g})} \quad+\begin{gathered}
3 \mathrm{H}_{2}(\mathrm{~g}) \\
G F M=2 \mathrm{~g}
\end{gathered}
$$

Calculate the atom economy for the formation of hydrogen.
(d) Another naturally occurring gas is nitrogen dioxide, $\mathrm{NO}_{2}$. Nitrogen dioxide exists in equilibrium with dinitrogen tetroxide, $\mathrm{N}_{2} \mathrm{O}_{4}$.

$$
2 \mathrm{NO}_{2}(\mathrm{~g}) \rightleftharpoons \mathrm{N}_{2} \mathrm{O}_{4}(\mathrm{~g}) \quad \Delta H=-58 \mathrm{~kJ} \mathrm{~mol}^{-1}
$$

Complete the table to show the conditions that would maximise the yield of nitrogen dioxide.

| Condition | High/Low |
| :--- | :--- |
| Temperature |  |
| Pressure |  |

7. (continued)
(e) (i) In the United States Space Shuttle, dinitrogen tetroxide was reacted with methylhydrazine.

$$
4 \mathrm{CH}_{3} \mathrm{NHNH}_{2}(\ell)+5 \mathrm{~N}_{2} \mathrm{O}_{4}(\ell) \rightarrow 4 \mathrm{CO}_{2}(\mathrm{~g})+12 \mathrm{H}_{2} \mathrm{O}(\mathrm{~g})+9 \mathrm{~N}_{2}(\mathrm{~g})
$$

Calculate the enthalpy of this reaction, in kJ , by using the data shown below.

$$
\begin{array}{rlcl}
\mathrm{C}(\mathrm{~s})+3 \mathrm{H}_{2}(\mathrm{~g})+\mathrm{N}_{2}(\mathrm{~g}) & \rightarrow & \mathrm{CH}_{3} \mathrm{NHNH}_{2}(\mathrm{l}) & \Delta H=+54 \mathrm{~kJ} \mathrm{~mol}^{-1} \\
\mathrm{~N}_{2}(\mathrm{~g})+2 \mathrm{O}_{2}(\mathrm{~g}) & \rightarrow & \mathrm{N}_{2} \mathrm{O}_{4}(\mathrm{l}) & \Delta H=-20 \mathrm{~kJ} \mathrm{~mol}^{-1} \\
\mathrm{C}(\mathrm{~s})+\mathrm{O}_{2}(\mathrm{~g}) & \rightarrow & \mathrm{CO}_{2}(\mathrm{~g}) & \Delta H=-394 \mathrm{~kJ} \mathrm{~mol}^{-1} \\
\mathrm{H}_{2}(\mathrm{~g})+\frac{1}{2} \mathrm{O}_{2}(\mathrm{~g}) & \rightarrow & \mathrm{H}_{2} \mathrm{O}(\mathrm{l}) & \Delta H=-286 \mathrm{~kJ} \mathrm{~mol}^{-1} \\
\mathrm{H}_{2} \mathrm{O}(\mathrm{l}) & \rightarrow & \mathrm{H}_{2} \mathrm{O}(\mathrm{~g}) & \Delta H=+41 \mathrm{~kJ} \mathrm{~mol}^{-1}
\end{array}
$$

(ii) Draw the full structural formula for methylhydrazine, $\mathrm{CH}_{3} \mathrm{NHNH}_{2}$.
8. Fizzy drinks are made by adding carbon dioxide gas, preservative, colouring and flavouring to water.
(a) Carbon dioxide for fizzy drinks can be produced using the water-gas shift reaction.

$$
\mathrm{CO}(\mathrm{~g})+\mathrm{H}_{2} \mathrm{O}(\mathrm{~g}) \rightleftharpoons \mathrm{CO}_{2}(\mathrm{~g})+\mathrm{H}_{2}(\mathrm{~g})
$$

(i) A catalyst for this reaction is copper(II) oxide.

Complete the table by circling one option on each line to show the effect of copper(II) oxide on the reaction.
(An additional table can be found on page 33.)

| Feature of reaction | Effect of catalyst |
| :---: | :---: |
| Rate of forward reaction | increase/decrease/no effect |
| Rate of reverse reaction | increase/decrease/no effect |
| Position of equilibrium | moves to right/moves to left/no effect |

(ii) The water-gas shift reaction is exothermic.

Draw a line on the axes below to show how the yield of carbon dioxide would vary with increasing temperature.
(An additional diagram can be found on page 33.)

8. (continued)
(b) A preservative added to some fizzy drinks is made by reacting sorbic acid and potassium hydroxide.
In an experiment, 7 g of sorbic acid, $\mathrm{C}_{6} \mathrm{H}_{8} \mathrm{O}_{2}$, is reacted with $250 \mathrm{~cm}^{3}$ of potassium hydroxide solution, concentration $0.5 \mathrm{moll}^{-1}$.

$$
\begin{aligned}
& \mathrm{C}_{6} \mathrm{H}_{8} \mathrm{O}_{2}(\mathrm{~s})+\mathrm{KOH}(\mathrm{aq}) \rightarrow \mathrm{H}_{2} \mathrm{O}(\ell)+\mathrm{C}_{6} \mathrm{H}_{7} \mathrm{O}_{2} \mathrm{~K}(\mathrm{aq}) \\
& G F M=112 \mathrm{~g}
\end{aligned}
$$

Show, by calculation, that sorbic acid is the limiting reactant.
8. (continued)
(c) Ammonium ferric citrate $(G F M=261.8 \mathrm{~g})$ gives some drinks a characteristic orange colour. A typical drink contains $0.002 \%$ of ammonium ferric citrate.
A $1 \%$ solution contains 1 g made up to $100 \mathrm{~cm}^{3}$ of solution.
Calculate the number of moles of ammonium ferric citrate required to make $330 \mathrm{~cm}^{3}$ of this fizzy drink.
8. (continued)
(d) Ginger root is used as a flavouring for some fizzy drinks.
(i) Ginger oil is an essential oil obtained from ginger root.

Zingiberene is one of the main components in this essential oil.

zingiberene
(A) State one property of an essential oil.
(B) Zingiberene is formed from isoprene units.
(I) Name the type of compound formed when isoprene units join together.
(II) Isoprene is also called 2-methyl-1,3-butadiene.

Draw a structural formula for isoprene.
(III) State the number of isoprene units in a zingiberene molecule.
8. (d) (continued)
(ii) Gingerol is another compound found in ginger root. Gingerol can form the compound shogaol as shown.


(A) Name product X .
(B) Name two functional groups present in gingerol and shogaol that are not present in zingiberene.
9. For a particular set of reaction conditions, the actual yield is the quantity of desired product made in a reaction.

Some examples of reactions with their desired products are shown.

| Equation | Desired product |
| :---: | :---: |
| $\mathrm{Ba}\left(\mathrm{NO}_{3}\right)_{2}(\mathrm{aq})+\mathrm{Na}_{2} \mathrm{SO}_{4}(\mathrm{aq}) \rightarrow \mathrm{BaSO}_{4}(\mathrm{~s})+2 \mathrm{NaNO}_{3}(\mathrm{aq})$ | $\mathrm{BaSO}_{4}(\mathrm{~s})$ |
| $\mathrm{CH}_{3} \mathrm{OH}(\ell)+\mathrm{C}_{2} \mathrm{H}_{5} \mathrm{COOH}(\ell) \rightleftharpoons \mathrm{C}_{2} \mathrm{H}_{5} \mathrm{COOCH}_{3}(\ell)+\mathrm{H}_{2} \mathrm{O}(\ell)$ | $\mathrm{C}_{2} \mathrm{H}_{5} \mathrm{COOCH}_{3}(\ell)$ |
| $\mathrm{Mg}(\mathrm{s})+2 \mathrm{HCl}(\mathrm{aq}) \rightarrow \mathrm{MgCl}_{2}(\mathrm{aq})+\mathrm{H}_{2}(\mathrm{~g})$ | $\mathrm{H}_{2}(\mathrm{~g})$ |

Using your knowledge of chemistry, describe how the actual yield in a reaction could be determined.

Your answer should include experimental procedures that could be used to determine the quantity of product made in reactions such as the examples shown in the table.
10. A refrigerant is a chemical used in cooling processes. Some refrigerant compounds can damage the ozone layer.
(a) The ozone depletion potential (ODP) of a refrigerant compound is the relative amount of damage that it can cause to the ozone layer. The higher the number, the greater the damage.

|  | Refrigerant compound | Ozone depletion potential |
| :---: | :---: | :---: |
| 1 | $\mathrm{C}_{2} \mathrm{~F}_{4} \mathrm{Br}_{2}$ | 6.00 |
| 2 | $\mathrm{CF}_{2} \mathrm{ClBr}$ | 3.00 |
| 3 | $\mathrm{C}_{2} \mathrm{FCl}_{5}$ | 1.00 |
| 4 | $\mathrm{C}_{2} \mathrm{~F}_{3} \mathrm{Cl}_{3}$ | 0.85 |
| 5 | $\mathrm{C}_{2} \mathrm{~F}_{4} \mathrm{Cl}_{2}$ | 0.58 |
| 6 | $\mathrm{C}_{2} \mathrm{H}_{3} \mathrm{Cl}_{3}$ | 0.16 |

(i) Describe a relationship between the formulae of refrigerant compounds 3, 4 and 5 and their ODP.
(ii) Identify which pair of compounds should be used to show the effect of replacing chlorine atoms with bromine atoms in refrigerant compounds.
(iii) The refrigerants carbon dioxide, $\mathrm{CO}_{2}$, and ammonia, $\mathrm{NH}_{3}$, have ODP values of 0.00 .
Suggest why this is the case.
10. (continued)
(b) The compound difluoromethane, $\mathrm{CH}_{2} \mathrm{~F}_{2}$, is also used as a refrigerant. It is made by reacting fluorine gas with fluoromethane, $\mathrm{CH}_{3} \mathrm{~F}$, in a free radical chain reaction.
(i) State what is meant by a free radical.
(ii) The first step in the reaction involves splitting a fluorine molecule to produce two fluorine radicals.

$$
\mathrm{F}_{2} \rightarrow 2 \mathrm{~F}
$$

(A) State the name given to this step.
(B) Write an equation for a possible propagation step in this reaction.
(c) Household fridges use coolants made from refrigerant compounds. A common coolant is made from $50 \%$ difluoromethane, $\mathrm{CH}_{2} \mathrm{~F}_{2},(G F M=52 \mathrm{~g})$ and $50 \%$ pentafluoroethane, $\mathrm{CF}_{3} \mathrm{CHF}_{2}$, $(G F M=120 \mathrm{~g})$.
A typical fridge contains 0.05 kg of coolant.
Calculate the number of moles of pentafluoroethane required to make this mass of coolant.
11. Spinach is a leafy green vegetable.
(a) Fertilisers containing copper(II) ethanoate are used to supply spinach with copper ions.
Copper(II) ethanoate can be made by reacting copper(II) carbonate with ethanoic acid.
(i) Name the other products of this reaction.
(ii) Write the ionic formula of copper(II) ethanoate.
(b) Spinach is a source of oxalic acid.

A standard solution of oxalic acid can be used to determine the accurate concentration of a sodium hydroxide solution.
Given an accurately known mass of oxalic acid, describe fully how $250 \mathrm{~cm}^{3}$ of a standard solution of oxalic acid could be prepared.
11. (continued)
(c) The concentration of sodium hydroxide can be determined by titration with oxalic acid.


An accurate volume of sodium hydroxide solution is measured into a conical flask using a pipette.
(i) Draw a diagram of a pipette suitable for measuring an accurate volume.
(ii) The indicator used in this titration is phenolphthalein. Phenolphthalein is colourless in acidic and neutral solutions but is pink in alkaline conditions.
State the colour change that would be observed at the end point in this titration.
11. (c) (continued)
(iii) The titration was repeated until results were obtained that were within $0.2 \mathrm{~cm}^{3}$ of each other.
State the term used to describe titre volumes within $0.2 \mathrm{~cm}^{3}$ of each other.
(d) The equation for the reaction of oxalic acid and sodium hydroxide is shown.

$$
\mathrm{H}_{2} \mathrm{C}_{2} \mathrm{O}_{4}(\mathrm{aq})+2 \mathrm{NaOH}(\mathrm{aq}) \rightarrow \mathrm{Na}_{2} \mathrm{C}_{2} \mathrm{O}_{4}(\mathrm{aq})+2 \mathrm{H}_{2} \mathrm{O}(\ell)
$$

The concentration of sodium hydroxide solution was determined by titrating $25.0 \mathrm{~cm}^{3}$ samples with $0.126 \mathrm{moll}^{-1}$ oxalic acid solution.
The average volume of oxalic acid solution required in the titration was $26.75 \mathrm{~cm}^{3}$.

Calculate the concentration, in $\mathrm{moll}^{-1}$, of the sodium hydroxide.

## 2022 Chemistry

## Higher Paper 1 - Multiple choice

## Finalised Marking Instructions

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| Question | Response | Mark |
| :---: | :---: | :---: |
| 1. | D | 1 |
| 2. | A | 1 |
| 3. | C | 1 |
| 4. | B | 1 |
| 5. | D | 1 |
| 6. | A | 1 |
| 7. | D | 1 |
| 8. | C | 1 |
| 9. | A | 1 |
| 10. | C | 1 |
| 11. | B | 1 |
| 12. | B | 1 |
| 13. | D | 1 |
| 14. | C | 1 |
| 15. | B | 1 |
| 16. | C | 1 |
| 17. | B | 1 |
| 18. | D | 1 |
| 19. | A | 1 |
| 20. | C | 1 |
| 21. | D | 1 |
| 22. | B | 1 |
| 23. | A | 1 |
| 24. | B | 1 |
| 25. | A | 1 |

## 2022 Chemistry

## Higher Paper 2

## Finalised Marking Instructions

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## Marking instructions for each question

| Question |  | Expected response | $\begin{array}{c}\text { Max } \\ \text { mark }\end{array}$ | Additional guidance |  |
| :--- | :--- | :--- | :--- | :---: | :--- |
| $\mathbf{1 .}$ | (a) | (i) | $\begin{array}{l}\text { (The atoms/nuclei) have the same attraction } \\ \text { for the bonding electrons. } \\ \text { OR } \\ \text { (The atoms have) same } \\ \text { electronegativity/electronegativity values given } \\ \text { OR } \\ \text { Bonding electrons shared equally (between the } \\ \text { atoms). }\end{array}$ | $\mathbf{1}$ | $\begin{array}{l}\text { Stating that it is a 'pure } \\ \text { covalent bond' on its own } \\ \text { is not sufficient. }\end{array}$ |
| An unlabelled diagram on |  |  |  |  |  |
| its own not sufficient |  |  |  |  |  |$]$| (ii) |
| :--- |
| Increasing/greater/stronger/larger nuclear <br> charge (holds electrons more tightly). <br> OR <br> Increasing number of/more protons. |
| (b) |
| (i) |


| Question |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: |
| (c) | (i) | Hydrogen bonds/bonding <br> (1 mark) <br> Hydrogen bonds occurs between molecules that have hydrogen: <br> - bonded to N, O or F <br> - bonded to a strongly electronegative element <br> - bonded to an element with a large d difference in electronegativity compared to hydrogen <br> - in a highly polar bond. <br> OR <br> Answers relating to the attraction between the opposite ends of the permanent dipole in molecules containing hydrogen atoms and the atoms of elements with high electronegativity/large difference in electronegativity | 2 | The first mark should not be cancelled by an incorrect explanation of how hydrogen bonding arises or an explanation of another type of bonding/interaction. <br> All three of $\mathrm{N}, \mathrm{O}$ and F must be listed. |
|  | (ii) | Correctly identify that the London dispersion forces become stronger/increase (in moving from HCl to HI ). <br> (1 mark) <br> The number of electrons in the molecules increases (from HCl to HI ). <br> (1 mark) | 2 |  |

Go to Topic Grid

| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 2. | (a) |  | $3 \mathrm{KClO}_{4}+8 \mathrm{Al} \rightarrow 3 \mathrm{KCl}+4 \mathrm{Al}_{2} \mathrm{O}_{3}$ | 1 | Correct multiples accepted. |
|  | (b) | (i) | 1.4/1.35/1.351 (litres) <br> Partial marking <br> Moles of $\mathrm{KClO}_{3}=0.03752$ moles <br> (1 mark) <br> A 2:3 ratio applied to an incorrectly calculated number of moles and multiplied by 24 (1 mark) <br> OR by proportion <br> $245.2 \mathrm{~g} \rightarrow 72$ litres <br> (1 mark) <br> Follow through from incorrect multiples of <br> 122.6 or 24 <br> (1 mark) | 2 | No units required. Only 1 mark can be awarded for the correct answer if wrong unit is given. (Wrong units would only be penalised once in any paper). |
|  |  | (ii) | None/no effect | 1 |  |
|  |  | (iii) | 2596/2595.6 (kJ) | 1 | Accept -2596/2595.6 Accept kJ per mole ( $\mathrm{kJmol}^{-1}$ ) <br> $\mathrm{KJ} / \mathrm{Kj}$ is acceptable in place of kJ <br> No units required. No mark can be awarded for the correct answer if wrong unit is given. (Wrong units would only be penalised once in any paper). |
|  |  | (iv) | Increases the number of particles with energy equal to or greater than the activation energy OR <br> Increases the number of particles with (sufficient) energy to form an activated complex/to react <br> (1 mark) <br> More successful collisions <br> (1 mark) | 2 | 'Activation' complex accepted. |
|  | (c) |  | Sodium | 1 |  |


|  | Question | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: |
| 3. |  | This is an open-ended question. <br> 1 mark: The candidate has demonstrated, at an appropriate level, a limited understanding of the chemistry involved. They have made some statement(s) that are relevant to the situation, showing that they have understood at least a little of the chemistry within the problem. <br> 2 marks: The candidate has demonstrated, at an appropriate level, a reasonable understanding of the chemistry involved. They make some statement(s) that are relevant to the situation, showing that they have understood the problem. <br> 3 marks: The maximum available mark would be awarded to a candidate who has demonstrated, at an appropriate level, a good understanding, of the chemistry involved. The candidate shows a good comprehension of the chemistry of the situation and provide a logically correct answer to the question posed. This type of response might include a statement of the principles involved, a relationship or an equation, and the application of these to respond to the problem. The answer does not need to be 'excellent' or 'complete' for the candidate to gain full marks. | 3 | Award 0 marks where the candidate has not demonstrated, at an appropriate level, an understanding of the chemistry involved. There is no evidence that they have recognised the area of chemistry involved, or they have not given any statement of a relevant chemistry principle. Award zero marks also if the candidate merely restates the chemistry given in the question. |

Go to Topic Grid

| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 4. | (a) | (i) | Ester (link) | 1 |  |
|  |  | (ii) |  | 1 | Accept correct shortened structural formula. |
|  |  | (iii) | Any correctly named alcohol with 7 carbons. | 1 | Position of OH must be given in name. |
|  | (b) | (i) | 35-45 inclusive | 1 |  |
|  |  | (ii) | Glyceryl trilinoleate | 1 |  |
|  | (c) | (i) | By reacting with glycerol. | 1 | Adding/combining/joining to glycerol not accepted. |
|  |  | (ii) | Correctly identifying that the emulsifier has two parts with different polarities or two parts that are hydrophobic/hydrophilic. <br> (1 mark) <br> Hydrophobic part/hydrocarbon chain/fatty acid chain/non-polar part dissolves in non-polar liquids whilst the hydrophilic part/hydroxyl groups/polar part dissolve in polar liquids. <br> (1 mark) | 2 | Reference to heads and tails as parts of molecule is accepted. |

Go to Topic Grid


Go to Topic Grid

| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 6. | (a) | (i) | Biological catalyst | 1 | Biochemical catalyst/protein that acts as a catalyst are accepted. |
|  |  | (ii) <br> (A) |  | 1 | Any one correctly circled peptide link from those shown. <br> Accept the C-N circled. Either the bond alone or including the C and N . |
|  |  | (ii) <br> (B) | any one of the following structures | 1 | Ignore incorrect connectivity in the side chains only. |
|  |  | (ii) <br> (C) | An amino acid that cannot be made in the body/must be obtained through diet. | 1 |  |
|  |  | (ii) <br> (D) | Condensation | 1 | Condensation polymerisation accepted. |
|  |  | (iii) | Enzyme becomes denatured/ <br> enzyme changes shape <br> (1 mark) <br> Intermolecular/hydrogen bonds are broken <br> (1 mark) | 2 |  |
|  |  | (iv) | Diagram showing closed reaction vessel with reactants in contact with each other (1 mark) <br> A means of measuring and collecting gas from the closed vessel <br> (1 mark) <br> Correct labelling of hydrogen peroxide, sweet potato and oxygen. Oxygen must be labelled inside the gas collection apparatus. <br> (1 mark) | 3 | Addition of catalase/water labels are regarded as noncancelling. <br> Graduations must be shown on gas collection apparatus. <br> First mark not awarded if delivery tube passes through the side of a measuring cylinder. |

Go to Topic Grid

| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 6. | (b) | (i) | To prevent unwanted oxidation/to oxidise in place of the compounds they have been added to protect/to stop (oxidation of edible oils) food acquiring a rancid flavour. | 1 | To 'prevent oxidation' on its own is not sufficient. <br> To stop food going rancid is accepted. |
|  |  | (ii) | Vitamin C molecule is polar due to its hydroxyl groups. <br> OR <br> Vitamin C can form hydrogen bonds due to its hydroxyl groups. (1 mark) <br> An explanation which links solubility of vitamin C to the polarity of water/hydrogen bonding of water. <br> (1 mark) | 2 | Accept (-OH) for hydroxyl. <br> 'like dissolves like' not sufficient on its own for 1 mark |
|  | (c) |  | 975 (2) g (1) <br> Partial marking <br> 195 (mg) (of solanine) <br> (1 mark) <br> OR <br> 15 (g) <br> (1 mark) <br> OR <br> Correct scaling of a calculated mass of solanine to a mass of potato (1 mark) | 3 | Allow alternative units of mass as long as these match the numerical answer eg 0.975 kg <br> Units mark can only be awarded with wrong numerical answer as long as evidence of scaling is shown. |

Go to Topic Grid

| Question |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: |
| 7. | (a) | $0.2 / 0.20 / 0.203 \mathrm{~g}$ <br> Partial marking <br> Using $\mathrm{cm} \Delta \mathrm{T}$ with $\mathrm{c}=4 \cdot 18, \mathrm{~m}=\mathrm{a}$ factor of 10 of 0.1 and $\Delta T=27$ <br> (1 mark) <br> Applying the concept that the combustion of 1 mole ( 16 g ) of methane burns to produce 891 kJ (1 mark) | 3 | No units required. Only 2 marks can be awarded for the correct answer if wrong unit is given. (Wrong units would only be penalised once in any paper). |
|  | (b) | $-816\left(\mathrm{~kJ} \mathrm{~mol}^{-1}\right)$ <br> Partial marking <br> 1 mark is available if either of the following operations is correctly executed: <br> Either <br> The four relevant values for bond enthalpies of the $\mathrm{C}-\mathrm{H}, \mathrm{O}=\mathrm{O}, \mathrm{C}=\mathrm{O}$, and $\mathrm{O}-\mathrm{H}$ (or multiples thereof) are retrieved from the data booklet (412, 498, 804, 463 - ignore signs). <br> OR <br> If only three correct values are retrieved, the candidate recognises that bond breaking is endothermic and bond forming is exothermic and have correctly manipulated the bond enthalpies and multiples that they have used with working shown. | 2 | +816 would qualify for 1 mark <br> Bond breaking $(4 \times 412)+(2 \times 498)=2644$ <br> Bond forming $[(2 \times 804)+(4 \times 463)]=-3460)$ <br> No units required. Only 1 mark can be awarded for the correct answer if wrong unit is given. (Wrong units would only be penalised once in any paper) <br> kJ is acceptable in place of $\mathrm{kJ} \mathrm{mol}^{-1}$ ( $\mathrm{KJ} \mathrm{or}_{\mathrm{Kj}}$ or $\mathrm{KJ} \mathrm{mol}^{-1}$ or $\mathrm{Kj} \mathrm{mol}^{-1}$ accepted). <br> If less than three bond enthalpies are retrieved then no mark can be awarded. |

Go to Topic Grid

| Question |  | Expected response |  | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 7. | (c) | 17.647/17.65/17 <br> Partial mark for economy relati correct use of (working must <br> Partial marking <br> Correct working answer given. $\begin{aligned} & \frac{(3 \times 2)}{(16+18)} \times 100 \\ & \frac{6}{(16+18)} \times 100 \end{aligned}$ <br> OR <br> Incorrect use of $\frac{2}{(16+18)} \times 100=$ <br> Answer and wo <br> 0.176 | (\%) <br> ct use of atom without metry n). <br> no correct <br> iometry. <br> ust be shown. | 2 | No units required. Only 1 mark can be awarded for the correct answer if wrong unit is given. (Wrong units would only be penalised once in any paper). |
|  | (d) | Condition <br> Temperature <br> Pressure | High/Low high low | 1 |  |

Go to Topic Grid

| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 7. | (e) | (i) | -4632 (kJ) $\begin{aligned} & {[(-216)+(+100)+(-1576)+(-3432)+} \\ & (+492)]=-4632(\mathrm{~kJ}) \end{aligned}$ <br> Partial marking <br> Either would be acceptable for 1 mark. <br> Evidence of understanding of reversal of first enthalpy value (ie -54 or -216 must be seen) and the second enthalpy value (ie +20 or +100 must be seen). <br> The other three enthalpy values (regardless of value) must not be reversed, or this partial mark cannot be awarded. <br> OR <br> Evidence of understanding of multiplying the first enthalpy value by 4 (+/-216) and the second enthalpy value by 5 (+/1 100) and the third enthalpy value by 4 (+/1576) and the fourth enthalpy value by $12(+/-3432)$ and the fifth enthalpy value by 12 (+/-492). Ignore the enthalpy signs associated with these numbers. | 2 |  |
|  |  | (ii) |  | 1 |  |

Go to Topic Grid

| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 8. | (a) | (i) | One mark for effect on rate (both responses needed), one mark for effect on equilibrium position. | 2 |  |
|  |  |  | Feature of reaction Effect | Effect of catalyst |  |
|  |  |  | Rate of forward reaction In | Increase |  |
|  |  |  | Rate of reverse reaction In | Increase |  |
|  |  |  | Position of equilibrium No | No effect |  |
|  |  | (ii) | Graph should show decrease in yield as temperature increases. | 1 |  |
|  | (b) |  | Correctly calculates number of moles of: <br> Sorbic acid $=0.0625$ <br> Potassium hydroxide $=0.125$ <br> OR <br> Working out that 14 g of sorbic acid would be needed to react with potassium hydroxide <br> (1 mark) <br> Statement demonstrating understanding of limiting reactant: <br> E.g. that there are fewer moles of sorbic acid therefore it is the limiting reactant <br> OR <br> there are more moles of potassium hydroxide therefore it is in excess <br> OR <br> that 0.125 moles of potassium hydroxide would require 0.125 moles of sorbic acid <br> (1 mark) | 2 |  |


| Question |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: |
| 8. | (c) | $2.52 \times 10^{-5}$ (moles) <br> Partial marking <br> $1 / 261.8(0.00382)$ in $100 \mathrm{~cm}^{3}$ <br> 0.0126 in $330 \mathrm{~cm}^{3}$ <br> (1 mark) <br> Follow through from incorrectly calculated number of moles multiplied by 0.002 (1 mark) <br> OR $0.002 \times 3.3=0.0066$ <br> (1 mark) <br> Follow through from incorrectly calculated mass divided by 261.8 | 2 |  |

Go to Topic Grid

| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 8. | (d) | (i) <br> (A) | Volatile/non-water soluble/aroma | 1 |  |
|  |  | (B) <br> (I) | Terpene | 1 |  |
|  |  | (B) <br> (II) |  | 1 |  |
|  |  | (B) (III) | 3 | 1 |  |
|  |  | (ii) <br> (A) | Water $/ \mathrm{H}_{2} \mathrm{O}$ | 1 |  |
|  |  | (ii) <br> (B) | hydroxyl AND carbonyl | 1 | Formulae $-\mathrm{OH} /-\mathrm{C}=\mathrm{O}$ not accepted. <br> Ether or benzene ring accepted. |


|  | Question | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: |
| 9. |  | This is an open-ended question. <br> 1 mark: The candidate has demonstrated, at an appropriate level, a limited understanding of the chemistry involved. They have made some statement(s) that are relevant to the situation, showing that they have understood at least a little of the chemistry within the problem. <br> 2 marks: The candidate has demonstrated, at an appropriate level, a reasonable understanding of the chemistry involved. They make some statement(s) that are relevant to the situation, showing that they have understood the problem. <br> 3 marks: The maximum available mark would be awarded to a candidate who has demonstrated, at an appropriate level, a good understanding, of the chemistry involved. The candidate shows a good comprehension of the chemistry of the situation and provide a logically correct answer to the question posed. This type of response might include a statement of the principles involved, a relationship or an equation, and the application of these to respond to the problem. The answer does not need to be 'excellent' or 'complete' for the candidate to gain full marks. | 3 | Award 0 marks where the candidate has not demonstrated, at an appropriate level, an understanding of the chemistry involved. There is no evidence that they have recognised the area of chemistry involved, or they have not given any statement of a relevant chemistry principle. Award zero marks also if the candidate merely restates the chemistry given in the question. |

Go to Topic Grid

| Question |  | Expected response | Max <br> mark | Additional guidance |
| :--- | :--- | :--- | :--- | :---: | :--- |$|$| 10. | (i) |
| :--- | :--- |

Go to Topic Grid

| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 11. | (a) | (i) | water and carbon dioxide | 1 | Formulae accepted. |
|  |  | (ii) | $\left(\mathrm{CH}_{3} \mathrm{COO}^{-}\right)_{2} \mathrm{Cu}^{2+}$ | 1 | Brackets are required. |
|  | (b) |  | Dissolve oxalic acid (in small volume of water) <br> (1 mark) <br> transfer quantitatively/with <br> rinsings/washings <br> (1 mark) <br> fill/make up to the mark/line in a volumetric/standard flask. (1 mark) | 3 | If a solvent other than water is mentioned a maximum of 2 marks can be awarded. |
|  | (c) | (i) |  | 1 | Volumetric mark must be shown. <br> End of pipette must narrow to a point. |
|  |  | (ii) | pink to colourless | 1 | 'Clear' is not accepted for colourless. |
|  |  | (iii) | concordant | 1 |  |


|  | uest | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: |
| 11. | (d) | 0.27/0.3( $\mathrm{mol} \mathrm{l}^{-1}$ ) <br> average titre $=26.75 \mathrm{~cm}^{3}$ <br> n (oxalic acid) $=0.02675 \times 0.126=$ <br> $3.3705 \times 10^{-3}$ moles <br> n (sodium hydroxide) $=2 \times 3.3705 \times$ $10^{-3}=6.741 \times 10^{-3}$ moles <br> concentration $=6.741 \times 10^{-3} \div 0.025$ $=0.27$ ( 0.26964 ) $\mathrm{moll}^{-1}$ <br> Partial marks can be awarded using a scheme of two "concept" marks, and one "arithmetic" mark. <br> 1 mark for knowledge of the relationship between moles, concentration and volume. <br> This could be shown by one of the following steps: <br> Calculation of moles oxalic acid solution e.g. $0.02675 \times 0.126=$ $3.3705 \times 10^{-3}$ moles <br> OR <br> calculation of concentration of sodium hydroxide e.g. $6.741 \times 10^{-3} \div 0.025$ <br> OR <br> Insertion of correct pairings of values for concentration and volume in a valid titration formula <br> 1 mark for knowledge of relationship between moles of oxalic acid and sodium hydroxide. <br> This could be shown by one of the following steps: <br> Calculation of moles sodium hydroxide from moles oxalic acid eg $2 \times 3.3705 \times 10^{-3}=6.741 \times 10^{-3}$ moles <br> OR <br> Insertion of correct stoichiometric values in a valid titration formula <br> 1 mark is awarded for correct arithmetic through the calculation. <br> This mark can only be awarded if both concept marks have been awarded. | 3 | No units required. Only 2 marks can be awarded for the correct answer if wrong unit is given. (Wrong units would only be penalised once in any paper). |

FRIDAY, 12 MAY
9:00 AM - 9:40 AM

## Total marks - 25

Attempt ALL questions.
You may use a calculator.
Instructions for the completion of Paper 1 are given on page 02 of your answer booklet X813/76/02.

Record your answers on the answer grid on page 03 of your answer booklet.
You may refer to the Chemistry Data Booklet for Higher and Advanced Higher.
Space for rough work is provided at the end of this booklet.
Before leaving the examination room you must give your answer booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

## Total marks - 25

Attempt ALL questions

1. Which of the following compounds has the least ionic character?

A Sodium iodide
B Sodium fluoride
C Potassium iodide
D Potassium fluoride
2. In which of the following compounds would hydrogen bonding not occur?

A


B


C


D

3. Fats are formed from glycerol molecules and fatty acid molecules.

The mole ratio of glycerol molecules to fatty acid molecules is
A $1: 2$
B $2: 1$
C $1: 3$
D $3: 1$
4. A reaction was carried out as shown in the energy diagram.


Which of the following has a value of $150 \mathrm{~kJ} \mathrm{~mol}^{-1}$ ?
A Activation energy of the reverse reaction
B Enthalpy change of the reverse reaction
C Activation energy of the forward reaction
D Enthalpy change of the forward reaction
5. The graph shows how the rate of a reaction varies with the concentration of one of the reactants.


What was the concentration, in $\mathrm{moll}^{-1}$, when the reaction time was 10 s ?
A 0.04
B 0.10
C 0.25
D 0.40
6. The diagram represents the change in concentration of a reactant against time during a reversible chemical reaction.


In which diagram below does the dotted line show the result of repeating the reaction using a catalyst?

A


B


C


D

7. The enthalpy of combustion of methanol $(G F M=32.0 \mathrm{~g})$ is $-726 \mathrm{~kJ} \mathrm{~mol}^{-1}$.

What mass of methanol has to be burned to produce 145.2 kJ ?
A 3.2 g
B $\quad 6.4 \mathrm{~g}$
C $\quad 32.0 \mathrm{~g}$
D $\quad 160.0 \mathrm{~g}$
8. Which of the following statements is true?

A The sodium atom is larger than the sodium ion.
B The chloride ion is smaller than the chlorine atom.
C The magnesium ion is larger than the magnesium atom.
D The oxygen atom is larger than the oxide ion.
9. Which of the following structures is never found in compounds?

A Covalent molecular
B Covalent network
C Monatomic
D Ionic
10. Which of the following carbon containing compounds is an isomer of hexanal?

A 2-methylbutanal
B 3-methylpentan-2-one
C 2,2-dimethylbutan-1-ol
D 3,3-dimethylpentanal
11. When two amino acids react in a condensation reaction, water is eliminated and a peptide link is formed.
Which of the following represents this process?

A


B


C


D

12. Which of the following equations represents an enthalpy of combustion?

A $2 \mathrm{CH}_{4}(\mathrm{~g})+3 \mathrm{O}_{2}(\mathrm{~g}) \rightarrow 2 \mathrm{CO}(\mathrm{g})+4 \mathrm{H}_{2} \mathrm{O}(\mathrm{l})$
B $\mathrm{CH}_{4}(\mathrm{~g})+1 \frac{1}{2} \mathrm{O}_{2}(\mathrm{~g}) \rightarrow \mathrm{CO}(\mathrm{g})+2 \mathrm{H}_{2} \mathrm{O}(\mathrm{l})$
C $2 \mathrm{C}_{2} \mathrm{H}_{6}(\mathrm{~g})+7 \mathrm{O}_{2}(\mathrm{~g}) \rightarrow 4 \mathrm{CO}_{2}(\mathrm{~g})+6 \mathrm{H}_{2} \mathrm{O}(\mathrm{l})$
D $\mathrm{C}_{2} \mathrm{H}_{6}(\mathrm{~g})+3 \frac{1}{2} \mathrm{O}_{2}(\mathrm{~g}) \rightarrow 2 \mathrm{CO}_{2}(\mathrm{~g})+3 \mathrm{H}_{2} \mathrm{O}(\ell)$
13. Two flasks, $A$ and $B$, were placed in a water bath at $40^{\circ} \mathrm{C}$.


After several days, the contents of the flasks were analysed.
Which results would be expected?
A Flask A contains ethyl ethanoate, water, ethanol and ethanoic acid; flask B is unchanged.

B Flask A contains only ethyl ethanoate and water; flask $B$ is unchanged.
C Flask A contains only ethyl ethanoate and water; flask B contains only ethanol and ethanoic acid.

D Flask A and flask B contain ethyl ethanoate, water, ethanol and ethanoic acid.
14. During a redox process in acid solution, iodate ions are converted into iodine.

$$
2 \mathrm{IO}_{3}^{-}(\mathrm{aq})+12 \mathrm{H}^{+}(\mathrm{aq})+x \mathrm{e}^{-} \rightarrow \mathrm{I}_{2}(\mathrm{aq})+6 \mathrm{H}_{2} \mathrm{O}(\ell)
$$

What value of $x$ is required to balance the equation?
A 12
B 11
C 10
D 6
15. A step in the synthesis of vitamin $B_{3}$ is shown.


What name is given to this type of reaction?
A Condensation
B Hydration
C Reduction
D Oxidation
16. A chemist analysed a mixture of four dyes, $A, B, C$ and $D$, using gas-liquid chromatography. The time taken to travel through the column (retention time) depends on the polarity of the molecule. The more polar the molecule the longer the retention time.
The following chromatogram was obtained.


Which of the following compounds corresponds to peak Z?

17. The apparatus was used to measure the enthalpy of combustion of ethanol.


Which of the following would not improve the accuracy of the result?
A Using a draught shield
B Moving the thermometer
C Using a glass beaker instead of a copper can
D Stirring the water
18. Which line in the table best describes the ball-like structures formed when soap is added to an oil and water mixture?
(
19. In an experiment, nickel oxide is added to sulfuric acid until no more nickel oxide reacts. The products are nickel sulfate and water.

The correct method to separate and collect a dry, pure sample of nickel sulfate is
A evaporation
B filtration
C filtration followed by evaporation
D evaporation followed by filtration.
20. Which of the following compounds would react with sodium hydroxide solution to form a salt?

A $\mathrm{CH}_{3} \mathrm{CHO}$
B $\mathrm{CH}_{3} \mathrm{COOH}$
C $\mathrm{CH}_{3} \mathrm{COCH}_{3}$
D $\mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{OH}$
21. Which structural formula represents a primary alcohol?

A


B


C


D

22. Reduction of 4-methylpentan-2-one to the corresponding alcohol results in the molecule

A gaining 2 g per mole
B losing 2 g per mole
C losing 16 g per mole
D not changing in mass.
23. Which of the following gas samples has the same volume as 16.0 g of oxygen?
(All volumes are measured at the same temperature and pressure)
A 21.0 g of carbon monoxide
B 44.0 g of carbon dioxide
C 46.0 g of nitrogen dioxide
D 46.0 g of dinitrogen tetroxide
24. The number of moles of positive ions in 0.25 moles of aluminium sulfate is

A 0.5
B 1.0
C 2.0
D 3.0
25. Addition of hydrogen chloride, HCl , to an alkene can give a mixture of two products. The product produced in the greatest amount in the reaction is called the major product.
The major product is formed when the hydrogen atom of HCl attaches to the carbon atom of the double bond that has the greatest number of hydrogen atoms attached.


2-methylpent-2-ene

The major product in the reaction of HCl with the 2-methylpent-2-ene is

A


B


C


D


|  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- |

## X813/76/01

Fill in these boxes and read what is printed below.

Full name of centre

$\square$


## Forename(s)

Surname
Number of seat


Date of birth

| Day |
| :--- | | Month |
| :--- | | Year |
| :--- | | Sottish candidate number |
| :--- | | Y |
| :--- |

Total marks - 95
Attempt ALL questions.

## You may use a calculator.

You may refer to the Chemistry Data Booklet for Higher and Advanced Higher.
Write your answers clearly in the spaces provided in this booklet. Additional space for answers and rough work is provided at the end of this booklet. If you use this space you must clearly identify the question number you are attempting. Any rough work must be written in this booklet. Score through your rough work when you have written your final copy.
Use blue or black ink.
Before leaving the examination room you must give this booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

Total marks - 95
Attempt ALL questions

1. Elements are arranged in the periodic table in order of increasing atomic number. Many physical and chemical properties of the elements show periodic trends.
(a) First ionisation energy is a property that has a periodic trend.

The diagram shows part of a graph of first ionisation energy against atomic number for some elements in the periodic table.

(i) Explain why there is an increase in first ionisation energy from elements d to k in the diagram.
(ii) State an element from a to m in the diagram that represents an element from group 7.

1. (a) (continued)
(iii) The table shows four ionisation energies of sodium.

| Ionisation energy (kJ mol |  |  |  |
| :---: | :---: | :---: | :---: |
| - $)$ |  |  |  |
| First | Second | Third | Fourth |
| 496 | 4562 | 6910 | 9543 |

(A) Explain fully the large increase between the first and second ionisation energies of sodium.
(B) Use the information in the table to determine the enthalpy change, in $\mathrm{kJ} \mathrm{mol}^{-1}$, for the following reaction.

$$
\mathrm{Na}^{+}(\mathrm{g}) \rightarrow \mathrm{Na}^{3+}(\mathrm{g})+2 \mathrm{e}^{-}
$$

1. (continued)
(b) Electronegativity is another property that has a periodic trend.
(i) State what is meant by the term electronegativity.
(ii) Explain fully why electronegativity decreases going down a group.
(iii) Suggest which of the group 2 elements is the best reducing agent.
2. Hydrides are compounds containing hydrogen and one other element.
(a) The graph shows the boiling points of group 4 and group 5 hydrides.

(i) Explain fully why the boiling points of the group 4 hydrides increase going down the group. In your answer you should refer to the intermolecular forces involved.
(ii) Name the type of intermolecular force that is responsible for the anomalous boiling point of ammonia, $\mathrm{NH}_{3}$.
3. (continued)
(b) (i) Silicon hydride, $\mathrm{SiH}_{4}$, can be formed by reacting silicon with hydrogen.

$$
\mathrm{Si}(\mathrm{~s})+2 \mathrm{H}_{2}(\mathrm{~g}) \rightarrow \mathrm{SiH}_{4}(\mathrm{~g})
$$

Calculate the enthalpy change, in $\mathrm{kJ} \mathrm{mol}^{-1}$, for this reaction using the following information.

$$
\begin{aligned}
& \mathrm{SiH}_{4}(\mathrm{~g})+2 \mathrm{O}_{2}(\mathrm{~g}) \rightarrow \mathrm{SiO}_{2}(\mathrm{~s})+2 \mathrm{H}_{2} \mathrm{O}(\ell) \quad \Delta \mathrm{H}=-1517 \mathrm{~kJ} \mathrm{~mol}^{-1} \\
& \mathrm{Si}(\mathrm{~s})+\mathrm{O}_{2}(\mathrm{~g}) \rightarrow \mathrm{SiO}_{2}(\mathrm{~s}) \quad \Delta \mathrm{H}=-911 \mathrm{~kJ} \mathrm{~mol}^{-1} \\
& \mathrm{H}_{2}(\mathrm{~g})+\frac{1}{2} \mathrm{O}_{2}(\mathrm{~g}) \rightarrow \mathrm{H}_{2} \mathrm{O}(\mathrm{l}) \quad \Delta \mathrm{H}=-286 \mathrm{~kJ} \mathrm{~mol}^{-1}
\end{aligned}
$$

2. (b) (continued)
(ii) One method of preparing silicon hydride involves reacting magnesium silicide, $\mathrm{Mg}_{2} \mathrm{Si}$, with hydrochloric acid, HCl .
15.32 g of magnesium silicide was reacted with excess hydrochloric acid. 2.56 g of silicon hydride was produced.
$4 \mathrm{HCl}+\underset{G F M=76.7 \mathrm{~g}}{\mathrm{Mg}_{2} \mathrm{Si}} \rightarrow \underset{G F M=32.1 \mathrm{~g}}{\mathrm{SiH}_{4}}+\quad 2 \mathrm{MgCl}_{2}$

Calculate the percentage yield of silicon hydride.
(iii) The table shows the melting points of silicon hydride, $\mathrm{SiH}_{4}$, and silicon oxide, $\mathrm{SiO}_{2}$.

|  | Melting point $\left({ }^{\circ} \mathrm{C}\right)$ |
| :---: | :---: |
| $\mathrm{SiH}_{4}$ | -185 |
| $\mathrm{SiO}_{2}$ | 1710 |

Explain fully why silicon oxide has a much higher melting point than silicon hydride.
3. Cheese is a complex substance containing a wide variety of chemicals.
(a) The structure of a fat found in cheese is shown below.

(i) (A) The alcohol needed to form fat molecules is glycerol.

State the systematic name for glycerol.
(B) Name the type of reaction used to form fat molecules from fatty acids and glycerol.
(ii) Fatty acid W reacts as shown.

(A) Identify the functional group circled in molecule X .
(B) Name molecule Y.
(C) Identify the type of reaction used to convert molecule Y into molecule $\mathbf{Z}$.
(D) State which of the reactions, (1), (2) or (3), results in an increase in the oxygen to hydrogen ratio.
3. (a) (continued)
(iii) Fatty acids can be converted into hydroxycarboxylic acids.

An example of a hydroxycarboxylic acid is shown.


The two functional groups in a hydroxycarboxylic acid react together to form a cyclic ester.

An example of a cyclic ester is shown.


Draw a structural formula for the hydroxycarboxylic acid that can be used to produce this cyclic ester.
3. (a) (continued)
(iv) The flavour of cheese changes over time as the concentrations of flavour molecules change.
Gas chromatography can be used to analyse the concentrations of flavour molecules.
(A) Chromatograms for two samples of cheese are shown below.


Determine the retention time, in minutes, of the peak in Chromatogram X that is missing in Chromatogram Y .
3. (a) (iv) (continued)
(B) The following chromatogram was obtained from another sample of cheese. The concentration of a flavour molecule in cheese can be determined by calculating the area under the peak that corresponds to that molecule.


The concentration of flavour molecule 3 cannot be determined from this chromatogram.

Suggest what would need to be done to the sample to allow the concentration of flavour molecule 3 to be determined.

## 3. (continued)

(b) The main protein in cheese is called casein.

The diagram shows part of the structure of a casein molecule.


The table shows the relative proportions of the amino acids found in this section of protein.

| Amino acid | Relative proportion |
| :--- | :---: |
| Aspartic acid | 1 |
| Glutamic acid | 2 |
| Isoleucine | 1 |
| Leucine | 2 |
| Valine | 1 |

(i) Leucine and valine are amino acids that must be obtained through the diet.

State the term for this type of amino acid.
(ii) Using information from the diagram and the table, draw a structural formula for glutamic acid.
3. (b) (continued)
(iii) When cheese is heated, the proteins change shape. State the term used to describe this process.
(c) Processed cheese is made from cheese, soluble milk proteins, water and an emulsifier.

State the function of an emulsifier.
(d) A compound added to cheese as a mould inhibitor has the formula $\mathrm{Ca}^{2+}\left(\mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{COO}^{-}\right)_{2}$. Name this compound.
4. Volumetric analysis involves using a standard solution in a reaction with a well-defined end point to determine the concentration of another substance. Correct use of the appropriate apparatus and solutions is essential to ensure accurate determination of concentration by titration.
Using your knowledge of chemistry, describe the experimental procedures, including equipment, used to accurately determine the concentration of a substance by volumetric analysis.
5. Gin is made by flavouring a mixture of ethanol and water with plant extracts.
(a) (i) The mixture of ethanol and water is made by fermentation followed by distillation.
In fermentation, enzymes in yeast convert glucose, $\mathrm{C}_{6} \mathrm{H}_{12} \mathrm{O}_{6}$, into ethanol and carbon dioxide.
The equation for fermentation is shown.

$$
\begin{array}{cccc}
\mathrm{C}_{6} \mathrm{H}_{12} \mathrm{O}_{6}(\mathrm{aq}) \\
G F M=180 \mathrm{~g} & & 2 \mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{OH}(\mathrm{aq}) \quad & +\quad 2 \mathrm{CO}_{2}(\mathrm{~g}) \\
G F M=46 \mathrm{~g} & G F M=44 \mathrm{~g}
\end{array}
$$

(A) $\mathrm{A} 50.0 \mathrm{~cm}^{3}$ sample of glucose solution contained 5.79 g of glucose.

Calculate the volume, in litres, of carbon dioxide gas that would be produced if 16 litres of this glucose solution was fermented.

Take the volume of 1 mole of carbon dioxide gas to be 24 litres.
(B) Calculate the atom economy for the production of ethanol.
5. (a) (continued)
(ii) The percentage of alcohol by volume can be calculated by measuring the specific gravity of samples taken before and after fermentation.
The specific gravity is measured using a hydrometer. The level of the sample on the hydrometer scale, read at eye level, is the specific gravity.


The \% alcohol by volume can be calculated using the formula

$$
\% \text { alcohol by volume }=\left(\frac{\text { change in specific gravity }}{0.7362}\right) \times 100
$$

Calculate the \% alcohol by volume for this sample.
5. (continued)
(b) Plant material is used to flavour the ethanol and water mixture. The mixture is then distilled.
(i) The first fraction from the distillation contains toxic methanol and propan-2-one and is discarded.
Describe a chemical test, with the expected result for both compounds, that could be used to distinguish between methanol and propan-2-one.
(ii) The second fraction from the distillation is collected for bottling as gin. Some of the plant compounds that give gin its flavour are shown.

limonene


geranyl acetate
(A) Name the class of compounds to which unsaturated hydrocarbons such as limonene and myrcene belong.
(B) Circle an isoprene unit on the limonene structure above.
(An additional structure, if required, can be found on page 40.)
5. (b) (ii) (continued)
(C) Geranyl acetate can undergo hydrolysis to produce an alcohol and another product.

Name the other product.
(c) Gin is often mixed with tonic water before drinking. Tonic water contains quinine, a bitter tasting compound. Historically quinine was used to treat malaria.
To treat malaria an intake of 10.0 mg of quinine per kilogram of body weight is required every 8 hours.
Calculate the mass of quinine required by a 70 kg adult in one day.
6. Ammonium nitrate is a commonly used fertiliser.
(a) (i) (A) Ammonium nitrate is made industrially by adding nitric acid, $\mathrm{HNO}_{3}$, to ammonia, $\mathrm{NH}_{3}$.

$$
\mathrm{HNO}_{3}(\mathrm{aq}) \quad+\quad \mathrm{NH}_{3}(\mathrm{~g}) \quad \rightarrow \quad \mathrm{NH}_{4} \mathrm{NO}_{3}(\mathrm{aq}) \quad \Delta \mathrm{H}=-\mathrm{ve}
$$

Complete the diagram to show the shape of the enthalpy diagram for this reaction.
(An additional diagram, if required, can be found on page 40.)

(B) State the term for the unstable arrangement of atoms formed at the point labelled $X$ on the potential energy diagram above.
(ii) 1316 litres of nitric acid of concentration $9.5 \mathrm{moll}^{-1}$ was reacted with 220 kg of ammonia ( $G F M=17 \mathrm{~g}$ ) to produce ammonium nitrate.

$$
\mathrm{HNO}_{3}(\mathrm{aq}) \quad+\quad \mathrm{NH}_{3}(\mathrm{~g}) \quad \rightarrow \quad \mathrm{NH}_{4} \mathrm{NO}_{3}(\mathrm{aq}) \quad \Delta \mathrm{H}=-\mathrm{ve}
$$

Show, by calculation, which reactant was in excess.
6. (a) (continued)
(iii) Ammonium nitrate can also be produced by the reaction

$$
\mathrm{Ca}\left(\mathrm{NO}_{3}\right)_{2}(\mathrm{~s})+2 \mathrm{NH}_{3}(\mathrm{~g})+\mathrm{CO}_{2}(\mathrm{~g})+\mathrm{H}_{2} \mathrm{O}(\ell) \rightarrow 2 \mathrm{NH}_{4} \mathrm{NO}_{3}(\mathrm{aq})+\mathrm{CaCO}_{3}(\mathrm{~s}) \quad \Delta \mathrm{H}=-\mathrm{ve}
$$

Suggest a reason why the method shown in part (a) (ii) is the preferred industrial route.
(b) The rate of reaction can be altered by changing the temperature or using a catalyst.
(i) Graph 1 shows the distribution of kinetic energies of molecules in a gas mixture.

## Graph 1


(A) Suggest what is represented by the area under the curve in Graph 1.
(B) Add a second curve to Graph 1 to show the distribution of kinetic energies at a higher temperature.
(An additional graph, if required, can be found on page 41.)
6. (b) (continued)
(ii) In Graph 2, the activation energy for the reaction, $\mathrm{E}_{\mathrm{a}}$, is marked on the $x$-axis.

Graph 2


Draw a line on Graph 2 to show how a catalyst affects the activation energy, $\mathrm{E}_{\mathrm{a}}$.
(An additional graph, if required, can be found on page 41.)
6. (continued)
(c) Ammonia used to produce ammonium nitrate can be made by the Haber process.

$$
3 \mathrm{H}_{2}(\mathrm{~g})+\mathrm{N}_{2}(\mathrm{~g}) \rightleftharpoons 2 \mathrm{NH}_{3}(\mathrm{~g}) \quad \Delta \mathrm{H}=-92 \mathrm{~kJ} \mathrm{~mol}^{-1}
$$

(i) Reversible reactions, such as the Haber process, can reach a state of dynamic equilibrium in a closed system.

State what is meant by the term dynamic equilibrium.
(ii) (A) The ammonia produced is continuously removed.

Explain how this will affect the production of ammonia.
6. (c) (ii) (continued)
(B) A flow diagram of the Haber process is shown.

One way to reduce costs in the process is to use a heat exchanger to transfer excess heat from one part of the process to use in another part of the process.


From the flow diagram, state another way that the manufacturing process maximises profit or minimises the impact on the environment.
6. (continued)
(d) Ammonia is currently being investigated for use in fuel cells.

The reactions taking place at the electrodes are

$$
\begin{aligned}
\mathrm{O}_{2}+2 \mathrm{H}_{2} \mathrm{O}+4 \mathrm{e}^{-} & \rightarrow 4 \mathrm{OH}^{-} \\
2 \mathrm{NH}_{3}+6 \mathrm{OH}^{-} & \rightarrow \mathrm{N}_{2}+6 \mathrm{H}_{2} \mathrm{O}+6 \mathrm{e}^{-}
\end{aligned}
$$

(i) Write the overall redox equation for the reaction taking place in the fuel cell.
(ii) Identify the reducing agent in the reaction taking place in the fuel cell.
7. Tap water contains a number of dissolved chemicals.
(a) In some parts of the country, tap water contains a high level of dissolved metal salts.
(i) State the term used to describe this type of water.
(ii) Soapless detergents are used with this type of water to prevent insoluble scum forming.
The structure of a typical soapless detergent is shown.


The circled region of the molecule is ionic and dissolves in water. State the term used to describe this part of the molecule.
7. (a) (continued)
(iii) Calcium ions are commonly found in tap water. The concentration of calcium ions in a tap water sample was determined by titrating with a chemical called EDTA, $\mathrm{C}_{10} \mathrm{H}_{12} \mathrm{~N}_{2} \mathrm{O}_{8}{ }^{4-}$.
A $50.0 \mathrm{~cm}^{3}$ water sample was collected and reacted with a standard solution of EDTA, with a concentration of $0.0045 \mathrm{moll}^{-1}$. The average titre volume was $9.3 \mathrm{~cm}^{3}$.

$$
\mathrm{Ca}^{2+}(\mathrm{aq})+\mathrm{C}_{10} \mathrm{H}_{12} \mathrm{~N}_{2} \mathrm{O}_{8}^{4-}(\mathrm{aq}) \rightarrow\left[\mathrm{Ca}\left(\mathrm{C}_{10} \mathrm{H}_{12} \mathrm{~N}_{2} \mathrm{O}_{8}\right)\right]^{2-}(\mathrm{aq})
$$

Calculate the concentration, in $\mathrm{moll}^{-1}$, of calcium ions in the tap water.
7. (continued)
(b) Another ion found in tap water is manganese(II), $\mathrm{Mn}^{2+}$.

The manganese(II) ions are oxidised to purple permanganate ions, $\mathrm{MnO}_{4}^{-}$. The concentration of permanganate ions can be determined by measuring how much light is absorbed by the solution.
The higher the concentration of permanganate ions in the solution, the more light is absorbed.
The absorbances of several standard solutions of permanganate were measured, and the results plotted.


A water sample had an absorbance of 0.08 .
Estimate the concentration of permanganate ions, in $\mathrm{mgl}^{-1}$, in this sample.
7. (continued)
(c) Chlorine is added to tap water to make it safe to drink.

The chlorine can react with substances in the water to produce trichloromethane, $\mathrm{CHCl}_{3}$.
(i) Trichloromethane is more soluble in water than tetrachloromethane due to the polarities of the molecules.

trichloromethane

tetrachloromethane

Explain the difference in polarities of trichloromethane and tetrachloromethane molecules.
7. (c) (continued)
(ii) Trichloromethane is used on an industrial scale to produce plastics. The first step in this reaction is to react it with hydrogen fluoride, HF.


Using bond enthalpies and mean bond enthalpies from the data booklet, calculate the enthalpy change, in $\mathrm{kJ} \mathrm{mol}^{-1}$, for the reaction of trichloromethane with hydrogen fluoride.
8. Dog food contains many different compounds including fats, vegetable oils, fatty acids, flavour and aroma molecules, proteins, water, antioxidants and emulsifiers.
It is important that dog food has a long shelf life, retains its appearance and texture, as well as providing sufficient nutritional value.

Using your knowledge of chemistry, explain the role of different compounds in dog food.
9. Haloalkanes are alkane molecules that contain at least one group 7 atom.
(a) The table shows information on the boiling points of some haloalkanes.

| Haloalkane | Boiling point $\left({ }^{\circ} \mathrm{C}\right)$ |  |  |
| :--- | :---: | :---: | :---: |
|  | $\mathrm{X}=\mathrm{Cl}$ | $\mathrm{X}=\mathrm{Br}$ | $\mathrm{X}=\mathrm{I}$ |
| $\mathrm{CH}_{3}-\mathrm{X}$ | -24.2 | 3.6 | 42.4 |
| $\mathrm{CH}_{3} \mathrm{CH}_{2}-\mathrm{X}$ | 12.3 | 38.4 | 72.3 |
| $\mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{CH}_{2}-\mathrm{X}$ | 46.6 | 71.0 | 102.0 |

(i) Using the information in the table, describe two different trends in the boiling points.
(ii) Name the strongest type of intermolecular forces broken when bromoethane, $\mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{Br}$, boils.
9. (continued)
(b) Haloalkanes can be classified as primary, secondary or tertiary depending on the position of the group 7 atom.


## 2-bromobutane

(i) State why 2-bromobutane can be classified as a secondary haloalkane.
(ii) Draw a structural formula for an isomer of 2-bromobutane that is a tertiary haloalkane.
[Turn over
9. (continued)
(c) Alkanes can react with group 7 molecules in free radical reactions to form haloalkanes.

| Reaction step | Name of step |
| :---: | :---: |
| $\mathrm{Br}_{2} \rightarrow 2 \mathrm{Br} \bullet$ | Initiation |
| $\mathrm{Br} \cdot$ <br> $\bullet \mathrm{CH}_{4} \rightarrow \mathrm{HBr}+\mathrm{Cr}_{2} \rightarrow \mathrm{CH}_{3}$ <br>  <br>  | Propagation |
|  | Termination |

(i) State what is required for initiation to take place.
(ii) Complete the table to show a possible termination step.
9. (continued)
(d) Haloalkanes can react to form alcohols as shown.


Depending on the structure of the haloalkane used, the alcohol produced can be oxidised to form an aldehyde or ketone.

Compound P was converted to compound R in two steps.


Compound $\mathbf{R}$ does not react with Tollens' reagent or Fehling's solution. Draw a structural formula for compound $\mathbf{P}$.
9. (continued)
(e) The structures of two haloalkanes are shown.


1,2-dichlorobutane


1,2-dibromo-1-chlorobutane

The names of haloalkanes are derived from their structures using the following rules.

1. The name is based on the longest chain of carbon atoms.
2. The presence of group 7 atoms is shown by shortening the name of the group 7 atom.

| Group 7 atom | Shortened name |
| :---: | :---: |
| fluorine | fluoro- |
| chlorine | chloro- |
| bromine | bromo- |

3. The chain is numbered to assign numbers to the group 7 atoms. The numbers should be assigned so the lowest possible numbers are used.
4. If two or more of the same group 7 atoms are present, use the prefixes di, tri or tetra.
5. The shortened name of the group 7 atoms attached to the chain are listed alphabetically (ignoring the prefixes di, tri and tetra for alphabetical purposes).

Using these rules, name this molecule.

10. A student was given a sample known to be a mixture of magnesium oxide, MgO , and magnesium carbonate, $\mathrm{MgCO}_{3}$, and asked to determine the mass of magnesium carbonate in the mixture.
(a) The first step was to accurately measure a mass of 1.5 g of the mixture into a crucible, using a balance.
Describe fully how the student could carry out this step.
(b) Metal carbonates decompose on heating to give metal oxides and carbon dioxide gas.

$$
\mathrm{MgCO}_{3}(\mathrm{~s}) \rightarrow \mathrm{MgO}(\mathrm{~s})+\mathrm{CO}_{2}(\mathrm{~g})
$$

The apparatus was used to strongly heat the mixture of $\mathrm{MgCO}_{3}$ and MgO . The student used a pair of tongs to lift the lid from time to time.

(i) Suggest why the student had to lift the lid from time to time.
(c) Once the crucible had cooled, the final mass of the sample was determined. The mass of $\mathrm{CO}_{2}$ lost is used to calculate the mass of $\mathrm{MgCO}_{3}$ in the mixture. The results are shown below.

| Mass of sample before heating | 1.598 g |
| :--- | :---: |
| Mass of sample after heating | 1.294 g |
|  |  |
| $\mathrm{MgCO}_{3}(\mathrm{~s}) \quad \rightarrow \quad \mathrm{MgO}(\mathrm{s})+$ <br> $G F M$ $\mathrm{CO}(\mathrm{g})$ |  |
| $G 4.3 \mathrm{~g}$ | $G F M=44.0 \mathrm{~g}$ |

Calculate the mass, in g , of magnesium carbonate present in the mixture.
(d) Another experiment to determine the mass of magnesium carbonate in the mixture involves measuring the volume of $\mathrm{CO}_{2}$ produced.
This experiment is carried out by reacting the mixture of magnesium oxide and magnesium carbonate with excess acid. The volume of carbon dioxide gas produced can be measured by collecting the gas over water as shown.

(i) Complete a labelled diagram to show an apparatus suitable for the production of gas.
(An additional diagram, if required, can be found on page 42.)
(ii) Suggest why carbon dioxide can be collected over water.

## 2023 Chemistry

## Higher

## Finalised Marking Instructions

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Marking instructions for each question in Paper 1

| Question | Answer | Mark |
| :---: | :---: | :---: |
| 1. | A | 1 |
| 2. | D | 1 |
| 3. | C | 1 |
| 4. | A | 1 |
| 5. | C | 1 |
| 6. | B | 1 |
| 7. | B | 1 |
| 8. | A | 1 |
| 9. | C | 1 |
| 10. | B | 1 |
| 11. | C | 1 |
| 12. | D | 1 |
| 13. | D | 1 |
| 14. | C | 1 |
| 15. | D | 1 |
| 16. | B | 1 |
| 17. | C | 1 |
| 18. | B | 1 |
| 19. | C | 1 |
| 20. | B | 1 |
| 21. | D | 1 |
| 22. | A | 1 |
| 23. | D | 1 |
| 24. | A | 1 |
| 25. | B | 1 |

Marking instructions for each question in Paper 2

| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 1. | (a) | (i) | Increasing greater/stronger/larger nuclear charge (holds electrons more tightly). <br> OR <br> Increasing number of/more protons. | 1 | Increased nuclear pull is not accepted on its own. Mention must be made of nuclear charge or number of protons. <br> Increased attraction of electron for the nucleus would be considered cancelling. |
|  |  | (ii) | b or j | 1 | A correct letter must be shown. |
|  |  | (iii) <br> (A) | Second ionisation energy involves removal of an electron from an electron shell that is inner/ full(whole)/(more) stable/closer to the nucleus. <br> OR <br> Second electron is removed from an electron shell that is inner/ full(whole)/(more) stable/closer to the nucleus. <br> (1 mark) <br> The second electron is less screened/the second electron shell is less screened. <br> OR <br> The second electron is more strongly attracted to/pulled towards the nucleus. <br> (1 mark) | 2 | Correct statements made about the $1^{\text {st }}$ ionisation energy/electron can also be credited. <br> Stating that the $2^{\text {nd }}$ electron requires more energy than the $1^{\text {st }}$ electron is not sufficient on its own. <br> Shielding is acceptable in place of screening. <br> Increased attraction of the electron for the nucleus would be considered cancelling. |
|  |  | (iii) <br> (B) | 11472 ( $\mathrm{kJ} \mathrm{mol}^{-1}$ ) | 1 | No units required. No mark can be awarded for correct answer if wrong unit is given (where no unit required, wrong units would only be penalised once in any paper). kJ is acceptable in place of $\mathrm{kJ} \mathrm{mol}^{-1}(\mathrm{KJ}$ or $\mathrm{Kj}^{\circ}$ or $\mathrm{KJ} \mathrm{mol}^{-1}$ or $\mathrm{Kj} \mathrm{mol}^{-1}$ accepted). |

Go to Topic Grid

| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 1. | (b) | (i) | Electronegativity is the (measure of) attraction an atom/nucleus has for the electrons in a bond/shared electrons. <br> (1 mark) | 1 |  |
|  |  | (ii) | (More shells so) increased screening/more screening. (1 mark) <br> (Covalent radius increases/atom size increases/more shells so) attraction of the nucleus/protons for the (outer/shared) electron(s) decreases. <br> (1 mark) | 2 | Shielding is acceptable in place of screening. <br> Increased attraction of the electron for the nucleus would be considered cancelling. |
|  |  | (iii) | Barium <br> OR <br> Radium <br> OR <br> Strontium | 1 | Correct symbols accepted. |

Go to Topic Grid

| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 2. | (a) | (i) | (Intermolecular/van der Waals) forces increase (going down the group). <br> (1 mark) <br> LDFs are the forces (broken between the molecules). <br> (1 mark) <br> The more electrons the stronger the LDFs. <br> (1 mark) | 3 |  |
|  |  | (ii) | Hydrogen bonding | 1 |  |
|  | (b) | (i) | $\begin{aligned} & (+) 34\left(\mathrm{~kJ} \mathrm{~mol}^{-1}\right) \\ & {[(+1517)+(-911)+(-572)]=(+) 34(\mathrm{~kJ}} \\ & \left.\mathrm{mol}^{-1}\right) \end{aligned}$ <br> Partial marks <br> Treat as two concepts. Either would be acceptable for 1 mark. <br> Evidence of understanding of reversal of first enthalpy value ie +1517 or 1517 must be seen. The other two enthalpy values (regardless of value) must be negative, or this partial mark cannot be awarded. <br> OR <br> Evidence of understanding of multiplying the third enthalpy value by 2 . Ignore the enthalpy sign associated with these numbers. | 2 | If answer given is -34 , maximum of 1 mark can be awarded. <br> No units required. Only 1 mark can be awarded for the correct answer if wrong unit is given. (wrong units would only be penalised once in any paper). kJ is acceptable in place of $\mathrm{kJ} \mathrm{mol}{ }^{-1}$ (KJ or Kj or $\mathrm{KJ} \mathrm{mol}^{-1}$ or Kj $\mathrm{mol}^{-1}$ accepted). |
|  |  | (ii) | 39.9/ 40 (\%) <br> (2 marks) <br> Partial marks <br> Calculates theoretical mass $=6.4(\mathrm{~g})$ <br> (1 mark) <br> OR <br> Correctly calculates no of moles reactant (0.2) and product (0.08) <br> (1 mark) | 2 |  |


| Question |  | Expected response | Max <br> mark | Additional guidance |  |
| :--- | :--- | :--- | :--- | :---: | :---: |
| 2. | (b) | (iii) | In $\mathrm{SiO}_{2}$ covalent bonds are broken. <br> (1 mark) | 3 |  |
| In SiH ${ }^{2}$ Van der <br> Waals/LDFs/intermolecular forces <br> are broken. <br> (1 mark) | Covalent bonds need more energy to <br> break than van der Waals/LDFs/ <br> intermolecular forces. <br> OR <br> Covalent bonds are stronger than <br> van der Waals/LDFs/intermolecular <br> forces. | (1 mark) | A correct description of the relative <br> strength of covalent bonds and van <br> der Waals/LDFs/intermolecular <br> forces is accepted for this mark. |  |  |

Go to Topic Grid



Go to Topic Grid

| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 5. | (a) | (i) <br> (A) | 494.08, 494.1, 494 (litres) <br> 494080, $494100 \mathrm{~cm}^{3}$ <br> Partial marking <br> Calculating the mass of glucose in 16L ie 1852.8 (g). <br> (1 mark) <br> OR <br> Number of moles of glucose in 16L 10.29 (moles) (or correctly calculated number of moles from incorrectly calculated mass of glucose). <br> (1 mark) <br> An incorrectly calculated number of moles of glucose $\times(2 \times 24)$. ( 1 mark) OR <br> by proportion <br> Failure to scale up to 16 litres of glucose solution but correct use of $50 \mathrm{~cm}^{3}$ and 5.79 g and $1: 2$ mole ratio will give an answer of 1.544 litres of carbon dioxide. This would be awarded 2 marks. (working must be shown) | 3 | No units required. Only 2 marks can be awarded for the correct answer if wrong unit is given. <br> (Wrong units would only be penalised once in any paper). |

Go to Topic Grid

| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 5. | (a) | (i) <br> (B) | 51, 51.1 (\%) <br> Partial mark for correct use of atom economy relationship without correct use of stoichiometry (working must be shown). $\frac{46}{180} \times 100=25.6$ <br> (1 mark) <br> OR <br> Partial mark for correct working with no correct answer given. $\frac{(2 \times 46)}{180} \times 100$ <br> 0.51 <br> (1 mark) <br> OR <br> Partial mark for correct use of atom economy relationship with correct use of stoichiometry (working must be shown) for carbon dioxide $\begin{aligned} & 2 \times \frac{44}{180} \times 100 \\ & =48.9 \% \end{aligned}$ <br> (1 mark) | 2 | No units required. Only 1 mark can be awarded for the correct answer if wrong unit is given. <br> (Wrong units would only be penalised once in any paper). |

Go to Topic Grid

| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 5. | (a) | (ii) | $\text { 12, 12.2, } 12.22 \text { (\% / abv) }$ <br> Partial mark for correctly calculated change in specific gravity. 1.075-0.985 or 0.09. <br> (1 mark) <br> Partial mark for correctly calculated value using an incorrect value for change in specific gravity. <br> (1 mark) | 2 | Ignore any units. |
|  | (b) | (i) | Acidified dichromate changes from orange to green (blue-green/ blue) with methanol AND no colour change would be observed with propan-2one. <br> (2 marks) <br> OR <br> Using hot copper oxide a brown solid forms/copper forms/colour change from black to brown would be observed with methanol AND no colour change would be observed with propan-2-one. <br> (2 marks) | 2 | Acidified dichromate (1 mark) <br> Hot copper oxide (1 mark) |
|  |  | (ii) <br> (A) | Terpene(s) | 1 |  |
|  |  | (ii) <br> (B) |  <br> limonene <br> Only one correct unit needed. | 1 |  |
|  |  | (ii) <br> (C) | Ethanoic acid/acetic acid | 1 |  |
|  | (c) |  | 2100 (1 mark) mg (1 mark) OR <br> $2 \cdot 1$ (1 mark) g (1 mark) <br> OR <br> 0-0021 (1 mark) kg (1 mark) | 2 | If an incorrect mass is calculated but the units are appropriate to the calculation then 1 mark would be awarded. <br> If the candidate's working is unclear in terms of what is being worked out then the mark for units cannot be awarded. |

Go to Topic Grid

| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 6. | (a) | (i) <br> (A) |  | 1 |  |
|  |  | (i) <br> (B) | Activated complex | 1 | Accept activation complex or transition state. |
|  |  | (ii) | $n \mathrm{HNO}_{3}=1316 \times 9.5=12502$ moles <br> AND <br> $n \mathrm{NH}_{3}=220 \times 10^{3} / 17=12941$ <br> (1 mark) <br> 1:1 ratio therefore $\mathrm{NH}_{3}$ is in excess <br> (1 mark) <br> OR <br> $12502 \mathrm{HNO}_{3}$ moles requires 12502 moles $\mathrm{NH}_{3}$ but have 12941 moles therefore $\mathrm{NH}_{3}$ in excess. (2 marks) <br> 1316 l of $\mathrm{HNO}_{3}$ needs $212.5 \mathrm{~kg} \mathrm{NH}_{3}$ <br> (1 mark) <br> OR <br> 220 kg NH 3 needs $1362.2 \mathrm{I} \mathrm{HNO}_{3}$ (1 mark) <br> OR <br> $12502 \mathrm{HNO}_{3}$ moles requires 12502 moles $\mathrm{NH}_{3}$ but have 12941 moles (1 mark) <br> OR <br> 12941 moles $\mathrm{NH}_{3}$ requires 12941 moles $\mathrm{HNO}_{3}$ but only have 12502 moles $\mathrm{HNO}_{3}$ <br> (1 mark) <br> Therefore, $\mathrm{NH}_{3}$ is in excess <br> (1 mark) | 2 | Accept correct statement for incorrectly calculated values using 1:1 ratio. |

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| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 6. | (a) | (iii) | It has 100\% atom economy OR <br> Only has 1 product | 1 |  |
|  | (b) | (i) <br> (A) | The total number of molecules/ particles. | 1 |  |
|  |  | (i) <br> (B) | Second line displaced to right of original. Peak of curve should be further to the right and no higher than the original peak. | 1 |  |
|  |  | (ii) | A vertical line drawn at a lower kinetic energy than the original $\mathrm{E}_{\mathrm{a}}$ shown on graph. | 1 |  |
|  | (c) | (i) | The rate of the forward reaction equals the rate of the reverse reaction. | 1 |  |
|  |  | (ii) <br> (A) | (Removal of ammonia/product will) shift equilibrium to right hand side. <br> (1 mark) <br> OR <br> Increases the yield of ammonia. <br> (1 mark) <br> Decreases the rate of the reverse reaction. <br> (1 mark) <br> OR <br> The rate of the forward reaction is then greater than the rate of the reverse reaction. <br> (1 mark) | 2 |  |
|  |  | (ii) <br> (B) | Recycles unreacted gases/ reactants. <br> OR <br> Uses a catalyst (to reduce energy costs). <br> OR <br> Air is a low cost/free resource. | 1 |  |
|  | (d) | (i) | $4 \mathrm{NH}_{3}+3 \mathrm{O}_{2} \rightarrow 2 \mathrm{~N}_{2}+6 \mathrm{H}_{2} \mathrm{O}$ | 1 | Any correct multiple is accepted. Ignore any state symbols if given. |
|  |  | (ii) | Ammonia/ $\mathrm{NH}_{3}$ | 1 |  |

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| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 7. | (a) | (i) | Hard (water) | 1 |  |
|  |  | (ii) | Hydrophilic | 1 | Polar is not accepted. |
|  |  | (iii) | 0.000837 ( $\mathrm{mol} \mathrm{l}^{-1}$ ) (3 marks) <br> Partial marks can be awarded using a scheme of two "concept" marks, and one "arithmetic" mark. <br> 1 mark for knowledge of the relationship between moles, concentration and volume. <br> This could be shown by one of the following steps: <br> - Calculation of moles EDTA solution eg $0.0045 \times 0.0093=$ 0.00004185 <br> - Calculation of concentration of calcium ions eg $0.00004185 \div 0.05$ <br> - Insertion of correct pairings of values for concentration and volume in a valid titration formula. <br> If the relationship between moles, concentration and volume is used more than once, it must be used correctly every time. <br> 1 mark for the relationship between a calculated number of moles of EDTA and calcium ions. <br> OR <br> Insertion of correct stoichiometric values in a valid titration formula. <br> 1 mark is awarded for correct arithmetic through the calculation. This mark can only be awarded if both concept marks have been awarded. | 3 | No units required. Only 2 marks can be awarded for the correct answer if wrong unit is given. <br> (Wrong units would only be penalised once in any paper). |


| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 7. | (b) |  |  <br> 4.4 to 5.4 <br> OR <br> Accurate reading from candidate's drawn line of best fit if value given is out with the range 4.4 to 5.4. | 1 | No units required. No mark can be awarded for the correct answer if wrong unit is given. <br> (Wrong units would only be penalised once in any paper). |
|  | (c) | (i) | Trichloromethane is polar and tetrachloromethane is non-polar. <br> (1 mark) <br> Trichloromethane has a permanent dipole and tetrachloromethane does not. <br> (1 mark) | 2 | Correct description of a permanent dipole is accepted. |
|  |  | (ii) | $-14\left(\mathrm{~kJ} \mathrm{~mol}^{-1}\right)$ <br> Partial marks: <br> Evidence of the use of all the correct bond enthalpies (or correct multiples thereof) (338, 412, 431, 484, 570 (ignore signs). <br> (1 mark) <br> OR <br> If only four values are retrieved, the candidate recognises that bond breaking is endothermic and bond formation is exothermic and correctly manipulates the bond enthalpy values they have used to give their answer. <br> (1 mark) | 2 | $(+) 14\left(\mathrm{~kJ} \mathrm{~mol}^{-1}\right)$ would be awarded 1 mark. <br> No units required. Only 1 mark can be awarded for the correct answer if wrong unit is given. kJ is acceptable in place of $\mathrm{kJ} \mathrm{mol}^{-1}$ ( KJ or Kj or KJ $\mathrm{mol}^{-1}$ or $\mathrm{Kj} \mathrm{mol}^{-1}$ accepted). <br> (Wrong units would only be penalised once in any paper). |



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| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 9. | (a) | (i) | The more carbons/longer carbon chain the higher the boiling point. <br> (1 mark) <br> The further down group 7/the halogen is the higher the boiling point. <br> (1 mark) | 2 | Reference to group 7 molecule is cancelling. |
|  |  | (ii) | Permanent dipole- Permanent dipole interactions. | 1 | Allow permanent dipole-dipole interaction. Accept pd-pd i's. |
|  | (b) | (i) | The halogen/bromine (atom) is attached to a carbon that is attached to two other carbons. <br> OR <br> The halogen/bromine (atom) is attached to a carbon that has only one hydrogen attached. | 1 |  |
|  |  | (ii) |  | 1 | Accept shortened structural formula |
|  | (c) | (i) | Ultraviolet/UV (radiation/light) | 1 |  |
|  |  | (ii) | 1 mark for one of the following $\bullet \mathrm{CH}_{3}+\mathrm{Br} \bullet \rightarrow \mathrm{CH}_{3} \mathrm{Br}$ <br> - $\mathrm{CH}_{3}+\cdot \mathrm{CH}_{3} \rightarrow \mathrm{CH}_{3} \mathrm{CH}_{3}$ <br> $\mathrm{Br} \bullet+\mathrm{Br} \bullet \rightarrow \mathrm{Br}_{2}$ | 1 |  |
|  | (d) |  |  | 1 | Accept shortened structural formula |
|  | (e) |  | 2-bromo-3-chloro-1,1,1trifluoropentane | 1 | Apply general marking principle (0) |

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| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 10. | (a) |  | Tare the balance with the crucible. <br> (1 mark) <br> Transfer 1.5 g (into the crucible). <br> (1 mark) <br> OR <br> Tare a weighing boat, transfer the 1.5 g onto the weighing boat. Record mass. Transfer into the crucible. <br> (1 mark) <br> Reweigh the weighing boat and record the mass/calculate the difference. <br> (1 mark) <br> OR <br> Weigh mixture and weighing boat, record the mass. Transfer mixture into the crucible. <br> (1 mark) <br> Reweigh the weighing boat and record the mass/calculate the difference. <br> (1 mark) <br> Weigh the crucible (empty) and then with ( 1.5 g of) mixture. (1 mark) <br> Subtract the mass of crucible from mass of crucible and mixture. <br> (1 mark) | 2 | Accept use of a filter paper/paper towel/watch glass or other appropriate container instead of a weighing boat. |
|  | (b) | (i) | Allow $\mathrm{CO}_{2} /$ gas to escape. | 1 |  |
|  |  | (ii) | Reactants/products/mixture are not flammable. | 1 |  |

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| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 10. | (c) |  | $0.582,0.58(\mathrm{~g})$ <br> (2 marks) <br> Partial marking <br> Calculating number of moles of $\mathrm{CO}_{2}$ <br> (0.0069). <br> (1 mark) <br> Calculating mass of $\mathrm{MgCO}_{3}$ from incorrectly calculated number of moles of $\mathrm{CO}_{2}$. <br> (1 mark) | 2 |  |
|  | (d) | (i) | Diagram shows a workable method of generating gas with mixture in contact with acid. Labels required for mixture/powder/magnesium oxide + magnesium carbonate and (excess) acid. | 1 |  |
|  |  | (ii) | Carbon dioxide is (relatively) insoluble/has very low solubility (in water). | 1 |  |

[END OF MARKING INSTRUCTIONS]

