PEARSON EDEXCEL IAL CHEMISTRY · YCH11

CHEMISTRY



EXAM QUESTION PACK

UNIT 1: FORMULAE, EQUATIONS AND AMOUNT OF SUBSTANCE

SCORE	PERCENTAGE
/363	%

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Q1.

Airbags protect occupants by inflating when a car crashes.

Airbags rely on chemical reactions to produce large volumes of gases quickly.
In some airbags, solid sodium azide (NaN_3) decomposes forming nitrogen gas and sodium as the only products.

(a) Write an equation for the decomposition of sodium azide.

State symbols are not required.

(1)

(b) A passenger airbag requires 120 dm^3 of gas to fill it.

Calculate, using the ideal gas equation, the mass of sodium azide required to fill a passenger airbag in this reaction under standard conditions (101 000 Pa, 25°C).

Give your answer to an appropriate number of significant figures.

$$[pV = nRT \qquad R = 8.31\,JK^{-1}mol^{-1}]$$

(6)

(c) Two further reactions take place in the airbag.

Reaction **A** $10Na + 2KNO_3 \rightarrow K_2O + 5Na_2O + N_2$

Reaction **B** $K_2O + Na_2O + SiO_2 \rightarrow Na_2K_2SiO_4$

(i) Reaction **A** produces more nitrogen to inflate the airbag.

Calculate the atom economy, by mass, for the production of nitrogen in reaction **A**

Give your answer to an appropriate number of significant figures.

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(3)

(ii) State the type of reaction taking place in reaction **B**.

(1)

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(Total for question = 11 marks)

Q2.

This question is about alkenes.

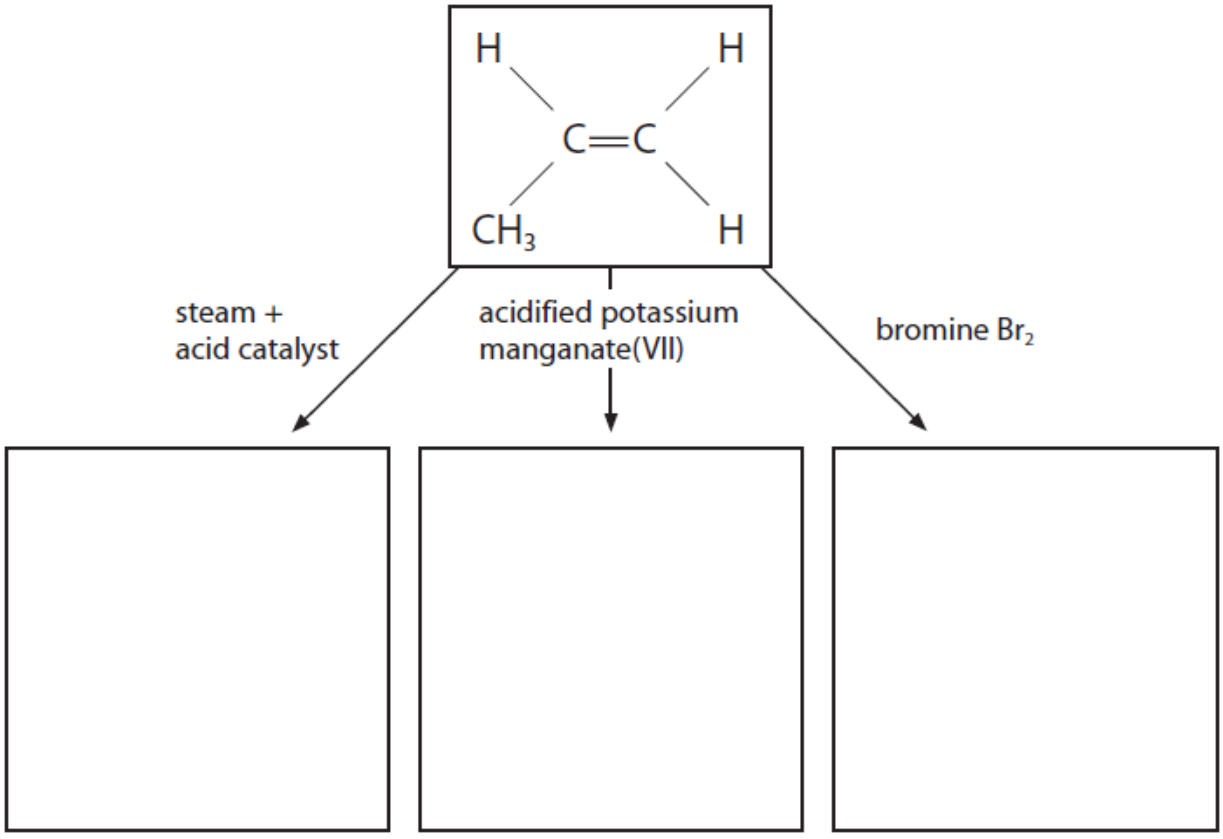
Alkenes contain a carbon to carbon double bond that consists of a σ bond and a π bond.

(a) Complete the diagram to show the areas of electron density for each bond. Label the σ bond and the π bond.

(2)



(b) Propene, C_3H_6 , is an alkene. The reagents needed for three reactions of propene are shown.



(i) In each box, draw the structure of the organic product of the reaction.

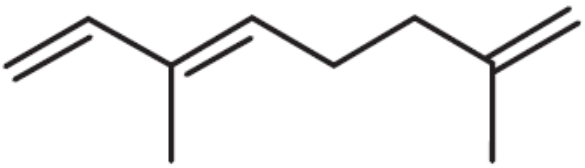
(3)

(ii) Propene also reacts with hydrogen bromide, HBr.

Give the mechanism for this reaction to form the **major** product.
Include curly arrows, and relevant lone pairs and dipoles.

(3)

(c) Alpha-ocimene contains three carbon to carbon double bonds. It is found in plants and has a sweet smell. The skeletal formula of alpha-ocimene is shown.



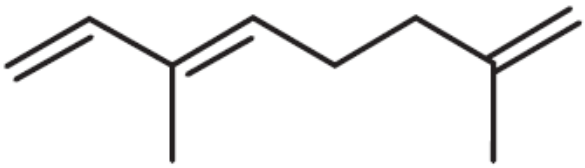
(i) Give the molecular formula of alpha-ocimene.

(1)

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(ii) On the skeletal formula, draw a circle around the part of the molecule that gives rise to the geometric isomerism of alpha-ocimene.

(1)



(iii) Draw the **skeletal** formula of the other geometric isomer of alpha-ocimene.

(1)

(iv) In an experiment, 0.050 mol of alpha-ocimene reacted with 3.6 dm^3 of hydrogen, H_2, in the presence of a catalyst.

Deduce the structure of the product of this reaction.
You **must** show your working.

[Molar volume of H_2 = 24 dm^3 mol^{-1}]

(3)

Calculation

Structure

(Total for question = 14 marks)

Q3.

This question is mainly about alkenes.

(a) A few drops of bromine water are added to separate test tubes of propane and propene and the mixtures are shaken.

Describe what is seen at the end of each experiment.

(2)

Propane

.....

Propene

.....

(b) Give the reagents and conditions for each of these conversions.

(i) $CH_2{=}{=}CH_2 \rightarrow CH_3CH_2OH$

(1)

.....

.....

(ii) $CH_2{=}{=}CH_2 \rightarrow CH_2OHCH_2OH$

(1)

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.....

(c) Draw the structure of *Z*-3-methylpent-2-ene.

(1)

(d) Exactly 720 cm^3 of hydrogen gas, measured at room temperature and pressure (r.t.p.), reacted with 0.010 mol of an alkene to form an alkane.

Deduce the number of double bonds in one molecule of the alkene.
You **must** show your working.

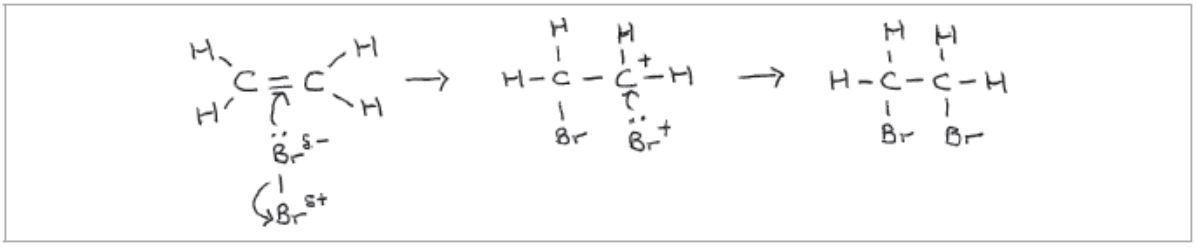
[Molar volume of gas at r.t.p. = 24 000 $cm^3\ mol^{-1}$]

(2)

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(e) A student drew a mechanism for the addition of bromine to ethene.



Describe the three changes needed to correct this student's mechanism.

(3)

Change 1

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Change 2

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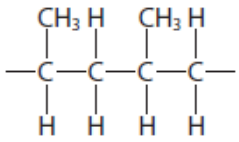
Change 3

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(f) Part of the structure of a polymer is shown.



Draw the structure of the monomer used to make this polymer.

(1)

(Total for question = 11 marks)

Q4.

This question is about the compound ammonium dichromate(VI), $(NH_4)_2Cr_2O_7$.

(a) $(NH_4)_2Cr_2O_7$ breaks down at around 180 °C, producing an oxide of chromium, nitrogen and water as the only products.

(i) Write an equation for the reaction.

State symbols are not required.

(2)

(ii) Give a name for this type of reaction.

(1)

.....

(b) When 0.00100 mol of ammonium dichromate(VI) was heated, 25.2 cm^3 of nitrogen gas, measured at laboratory temperature, was formed.

Calculate the temperature in the laboratory, in degrees Celsius, using the ideal gas equation. Use atmospheric pressure = 101 kPa.

$$[pV = nRT \quad R = 8.31\,J\,mol^{-1}\,K^{-1}]$$

(4)

(c) (i) Draw a dot-and-cross diagram of the ammonium ion.

Use dots (●) for the nitrogen electrons and crosses (X) for the hydrogen electrons.

(2)

(ii) Explain the shape of the ammonium ion using electron-pair repulsion theory.

(2)

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(d) Ammonium dichromate(VI) comes with several warnings on its packaging.

- This compound is toxic when inhaled and by passing through the skin.
- Handle with extreme caution.
- Contact can irritate and burn the skin and eyes, with possible eye damage.
- Inhaling can irritate the nose and throat.
- Ammonium dichromate(VI) is a strong oxidiser that enhances the combustion of other substances.

(i) Some of the symbols shown are used for ammonium dichromate(VI).

Identify the symbols for ammonium dichromate(VI) by placing a tick (✓) in the box under each relevant symbol.

(2)

(ii) Suggest why ammonium dichromate(VI) is **not** stored in the same cupboard as alkanes.

(1)

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(Total for question = 14 marks)

Q5.

How many **atoms** are there in 36.0 g of water?

[Avogadro constant = 6.02×10^{23} mol^{-1}]

(1)

☒ **A** 3.010×10^{23}

☒ **B** 1.204×10^{24}

☒ **C** 2.408×10^{24}

☒ **D** 3.612×10^{24}

(Total for question = 1 mark)

Q6.

This question is about alkenes.

(a) An alkene has a molar mass of 112 g mol^{-1}.

Deduce the molecular formula of this alkene.

(1)

(b) There are a number of different alkenes with the molecular formula C_4H_8.

(i) Draw the structure of the **branched-chain** alkene with the molecular formula C_4H_8.

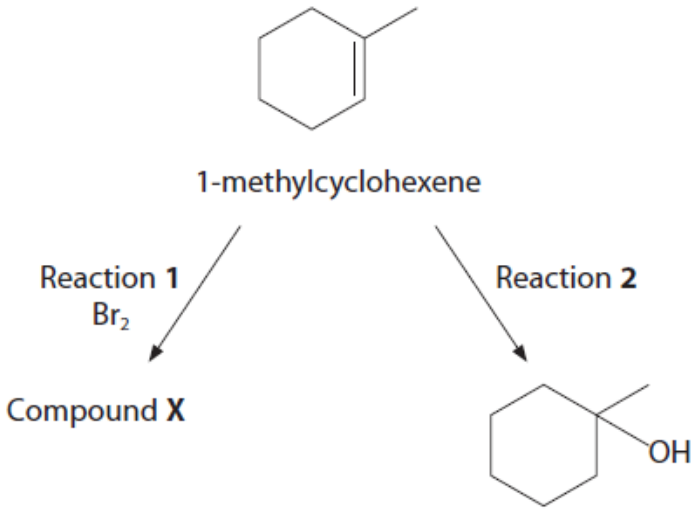
(1)

(ii) Give the structures and names of the two geometric isomers with the molecular formula C_4H_8.

(2)

Structure of geometric isomer 1	Structure of geometric isomer 2
Name of isomer 1	Name of isomer 2

(c) Two reactions of 1-methylcyclohexene are shown.



(i) Draw the **skeletal** formula of compound **X** formed in Reaction **1**.

(1)

(ii) Give the reagent and condition needed for Reaction **2**.

(2)

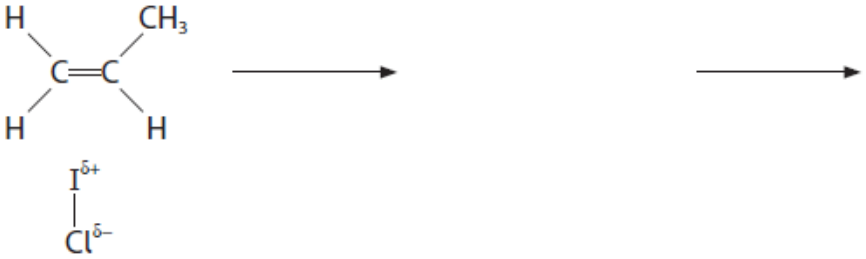
Reagent
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Condition
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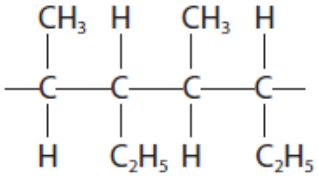
(d) Iodine monochloride, ICl, reacts with alkenes in a similar way to hydrogen bromide.

Complete the mechanism for the reaction of iodine monochloride with propene to form the **major** product.
Include curly arrows, the relevant lone pair and the structures of the intermediate and product.

(4)



(e) A section of a polymer showing two repeat units is given.



Give the **name** of the monomer that forms this polymer.

(1)

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(f) 0.0100 mol of an alkene reacts completely with exactly 600 cm^3 of hydrogen gas, measured at 298 K and 1.24×10^5 Pa
pressure, to form an alkane.

Use the ideal gas equation to deduce the number of double bonds in **one** molecule of the alkene. You **must** show your working.

[$pV = nRT$ $R = 8.31$ J mol^{-1} K^{-1}]

(4)

(Total for question = 16 marks)

Q7.

This question is about compounds containing chlorine.

(a) A precipitate of silver chloride is formed when silver nitrate solution reacts with sodium chloride solution.

A student wrote an ionic equation for the reaction.

$$Ag^{2+}(l) + 2Cl^{-}(l) \rightarrow AgCl_2(s)$$

Explain why this equation is incorrect, even though it is balanced.

(2)

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(b) A sample of a compound is analysed and found to contain **only** 3.09 g carbon, 0.26 g hydrogen and 9.15 g chlorine.

The molar mass of the compound is 97.0 g mol^{-1}.

Calculate the molecular formula of this compound.

You **must** show your working.

(3)

(c) Nitrogen trichloride has the formula NCl_3.

(i) A sample of nitrogen trichloride contained only nitrogen atoms with mass number 14, and chlorine atoms with mass numbers 35 and 37.

Give the formula and mass/charge ratio for each of the **four** ions responsible for the molecular ion peaks in the mass spectrum of nitrogen trichloride.

(2)

(ii) Complete the table to predict the shape and Cl—N—Cl bond angle in nitrogen trichloride.

(3)

Number of bonding pairs of electrons on nitrogen	
Number of lone pairs of electrons on nitrogen	
Shape of molecule	
Cl—N—Cl bond angle	

(d) Aluminium chloride exists as an ionic lattice in the solid state and as a covalent dimer, Al_2Cl_6, in the gas phase, just above its boiling temperature.

(i) Explain why aluminium chloride in the solid state has significant covalent character.

(2)

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(ii) Describe how two $AlCl_3$ molecules are joined together in the dimer.

Include a diagram in your answer.

(2)

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(Total for question = 14 marks)

Q8.

This question is about iron and some of its compounds.

(a) Complete the table to show the numbers of subatomic particles in $^{56}Fe^{2+}$.

(1)

Number of protons	Number of neutrons	Number of electrons

(b) A sample of iron contains the following isotopes.

Isotope	Percentage abundance
^{54}Fe	5.84
^{56}Fe	91.68
^{57}Fe	2.17
^{58}Fe	0.31

Calculate the relative atomic mass of this sample of iron.
Give your answer to **three** significant figures.

(2)

(c) Magnesium reacts with aqueous iron(II) sulfate in a displacement reaction.

Write the **ionic** equation for this reaction.
Include state symbols.

(2)

(d) 25.00 g of a compound contains 6.98 g of iron and 6.03 g of sulfur.

The remaining mass is oxygen.

Calculate the **empirical** formula of this compound.

[A_r values: O = 16.0 S = 32.1 Fe = 55.8]

(3)

(e) When 6.95 g of $FeSO_4.\mathbf{x}H_2O$ is heated, 2.00 g of iron(III) oxide, 0.80 g of sulfur dioxide and 1.00 g of sulfur trioxide
are produced.
The only other product is water.

Deduce the overall equation for the reaction using these data.
State symbols are not required.

You **must** show your working.

[A_r values: H = 1.0 O = 16.0 S = 32.1 Fe = 55.8]

(5)

(Total for question = 13 marks)

Q9.

This question is about nitrogen.

(a) The table shows the successive ionisation energies of nitrogen.

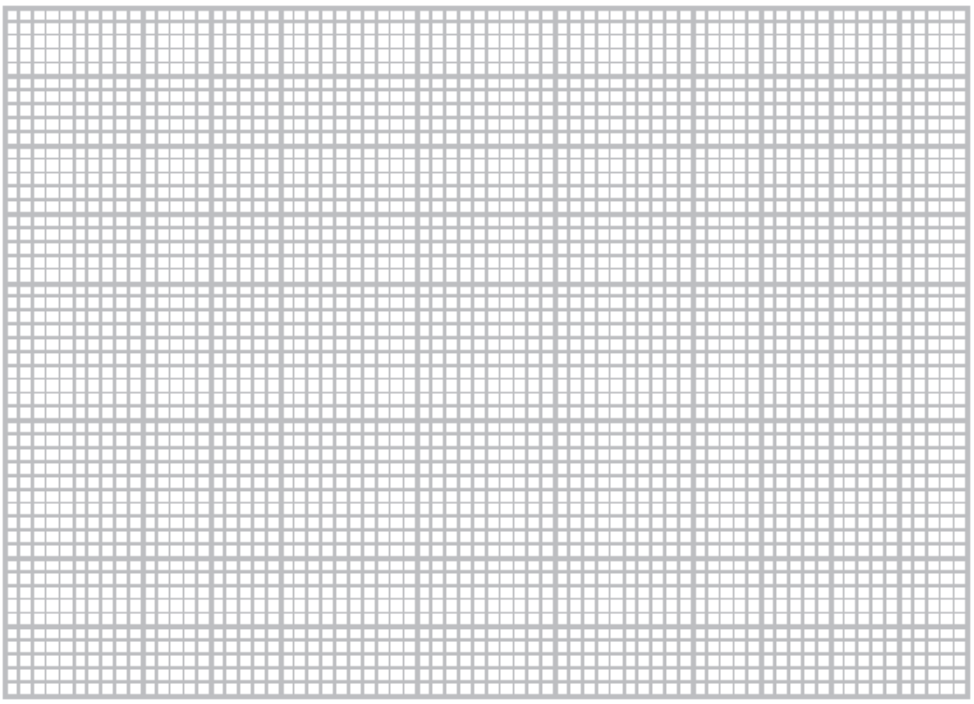
Ionisation number	Ionisation energy / kJ mol^{-1}	log (ionisation energy)
1	1 402	3.15
2	2 856	3.46
3	4 578	3.66
4	7 475	3.87
5	9 445	3.98
6	53 268	
7	64 362	

(i) Complete the table.

(1)

(ii) Plot a graph of log (ionisation energy) against ionisation number.

(3)



(iii) Give a reason why the logarithm of the ionisation energy, rather than just the ionisation energy, is used to plot this graph.

(1)

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(iv) Explain what can be deduced from the graph about the electronic structure of nitrogen.

(3)

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(v) Explain why the first ionisation energy of oxygen is lower than that of nitrogen.

(3)

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(b) Nitrogen gas consists of nitrogen molecules.

(i) Draw a dot-and-cross diagram to show the bonding in a molecule of nitrogen.

(1)

(ii) Calculate the number of nitrogen **atoms** in 5.60 g of nitrogen gas.

[Avogadro constant = $6.02 \times 10_{23}$ mol^{-1}]

(2)

(iii) A sample of nitrogen gas occupied 108 cm^3 at a temperature of 25 °C and a pressure of 1.36×10^5 Pa.

Using the ideal gas equation, calculate the number of moles of nitrogen gas in this sample.

[$pV = nRT$ $R = 8.31$ J mol^{-1} K^{-1}]

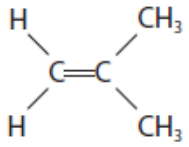
(4)

(Total for question = 18 marks)

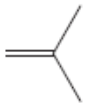
Q10.

This question is about the alkene 2-methylpropene.

The formulae show two different ways of representing a molecule of 2-methylpropene.



formula **1**



formula **2**

(a) Give the **empirical** formula of 2-methylpropene.

(1)

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(b) Give a reason why 2-methylpropene does **not** show geometric isomerism.

(1)

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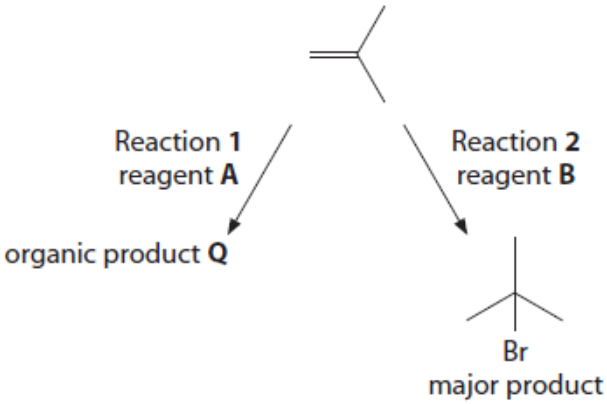
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(c) Draw the mechanism for the reaction between 2-methylpropene and bromine, Br_2. Include curly arrows, and relevant lone pairs and dipoles.

Use formula 1 to represent 2-methylpropene.

(4)

(d) Two reactions of 2-methylpropene are shown.



(i) In Reaction **1** the reagent **A** is acidified potassium manganate(VII).

Give the **skeletal** formula of organic product **Q**.

(1)

(ii) Give the colour change seen during Reaction **1**.

(1)

From ..... to .....

(iii) Identify, by name or formula, reagent **B** in Reaction **2**.

(1)

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(iv) Explain why 2-bromo-2-methylpropane is the major organic product in Reaction **2**.

(2)

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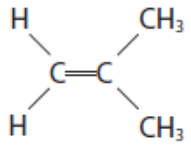
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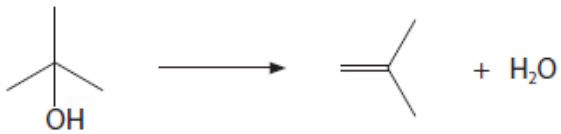
(e) Draw **two** repeat units of poly(2-methylpropene).



2-methylpropene

(2)

(f) A sample of 2-methylpropene was prepared from 2-methylpropan-2-ol.



2-methylpropan-2-ol
$M_r = 74.0$

2-methylpropene
$M_r = 56.0$

The yield of this reaction was 58.2%.

Calculate the mass of 2-methylpropene formed from 6.85 g of 2-methylpropan-2-ol.
Give your answer to an appropriate number of significant figures.

(4)

(Total for question = 17 marks)

Q11.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which aqueous solution contains the greatest number of **ions**?

☒ **A** 200 cm^3 of 1.5 mol dm^{-3} $MgCl_2$

☒ **B** 400 cm^3 of 0.8 mol dm^{-3} $MgSO_4$

☒ **C** 500 cm^3 of 1.0 mol dm^{-3} NaCl

☒ **D** 1000 cm^3 of 0.25 mol dm^{-3} Na_2SO_4

(Total for question = 1 mark)

Q12.

For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Potassium chlorate(V) decomposes on heating to form oxygen.

$$2KClO_3 \rightarrow 2KCl + 3O_2$$

What is the atom economy (by mass) for the formation of oxygen?

[A_r values: O = 16.0 Cl = 35.5 K = 39.1]

☒ **A** 13.1 %

☒ **B** 26.1 %

☒ **C** 39.2 %

☒ **D** 64.3 %

(Total for question = 1 mark)

Q13.

What is the atom economy, by mass, for the formation of iron in this reaction?

$$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$$

[A_r values: C = 12.0 O = 16.0 Fe = 55.8]

(1)

☒ **A** 29.7 %

☒ **B** 45.8 %

☒ **C** 55.9 %

☒ **D** 71.7 %

(Total for question = 1 mark)

Q14.

This question is about atomic structure and gases.

(a) Chlorine exists as two isotopes with mass numbers 35 and 37.

(i) State the number and type of each of the particles in the **nucleus** of a chlorine-35 atom.

(2)

.....

.....

(ii) Complete the electronic configuration of a chloride **ion**, Cl^-, using the s, p, d notation.

(1)

$1s^2$ .....

(iii) A sample of chlorine contains 75.53 % of chlorine-35 atoms.

Calculate the relative atomic mass of this sample of chlorine.
Give your answer to **two** decimal places.

(2)

(b) Fluorine has one naturally occurring isotope with mass number 19.

Chlorine and fluorine react to form chlorine trifluoride, ClF_3 .

(i) Draw a dot-and-cross diagram to show the bonding in a molecule of chlorine trifluoride.

Show the outer shell electrons only.

(2)

(ii) State, in terms of electrons, what is unusual about the dot-and-cross diagram you have drawn.

(1)

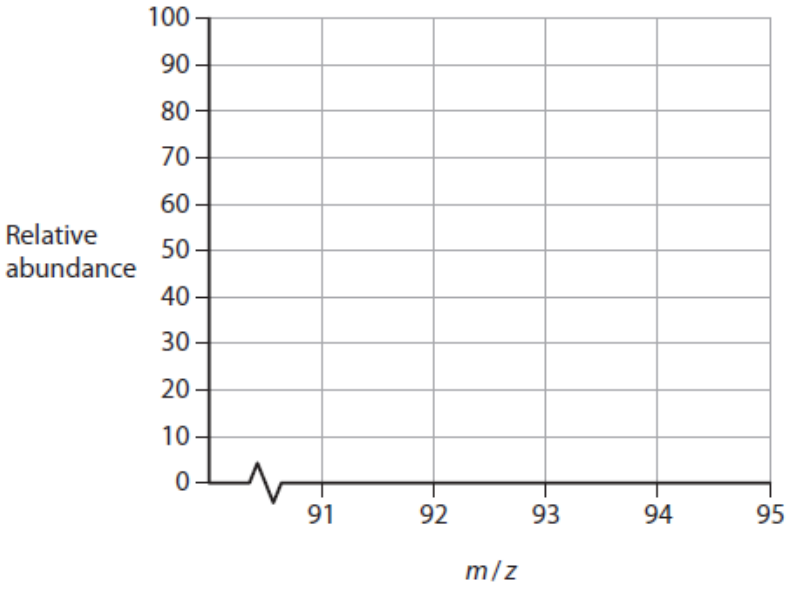
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(iii) Complete the mass spectrum to show the peaks you would expect for the molecular ion ClF_3^+ .

(3)



(iv) Calculate, using the ideal gas equation, the volume in **cm^3** occupied by 0.0200 mol of ClF_3 gas at a temperature of 60 °C and a pressure of 1.28×10^5 Pa.

Give your answer to an appropriate number of significant figures.

[$pV = nRT$ $R = 8.31$ J mol^{-1} K^{-1}]

(4)

(Total for question = 15 marks)

Q15.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A sample of seawater with a mass of 1 kg contains 6×10^{-9} g of gold.

How many atoms of gold, to one significant figure, are there in 1 g of this seawater?

[A_r value: Au = 197 Avogadro constant = 6×10^{23} mol^{-1}]

☐ **A** 2×10^{10}

☐ **B** 4×10^{12}

☐ **C** 2×10^{13}

☐ **D** 4×10^{15}

(Total for question = 1 mark)

Q16.

For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The equation for the complete combustion of hexane is shown.

$$C_6H_{14} + 9½O_2 \rightarrow 6CO_2 + 7H_2O$$

How many molecules of carbon dioxide are formed when 2×10^{-3} mol of hexane undergoes complete combustion?

[Avogadro constant $L = 6.02 \times 10^{23}$ mol^{-1}]

☒ **A** 1.20×10^{21}

☒ **B** 7.22×10^{21}

☒ **C** 8.43×10^{21}

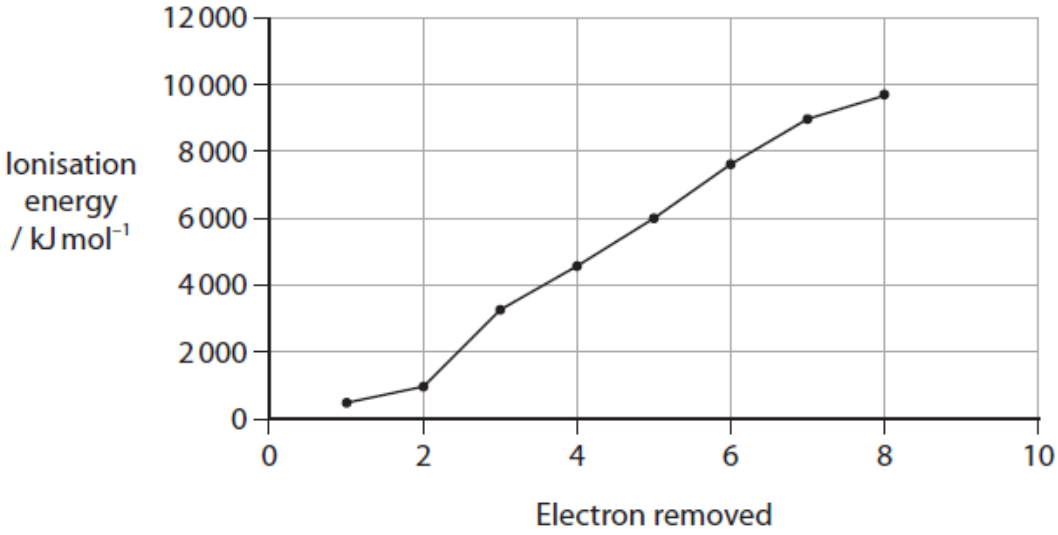
☒ **D** 3.18×10^{23}

(Total for question = 1 mark)

Q17.

This question is about barium and barium compounds.

(a) The graph shows the first eight ionisation energies of barium.



(i) Write an equation, including state symbols, for the **third** ionisation energy of barium.

(1)

(ii) State how the graph confirms that barium is in Group 2 in the Periodic Table.

(1)

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.....

(b) An acidified aqueous solution of barium chloride, $BaCl_2$, is used to test for sulfate ions.

(i) Draw a dot-and-cross diagram for barium chloride.

Show the outer electrons only.

(2)

(ii) Calculate the mass of barium chloride needed to form 150 cm^3 of $BaCl_2(aq)$ with a concentration of 0.200 mol dm^{-3}.

Give your answer to an appropriate number of significant figures.

(2)

(iii) The barium chloride solution is acidified to prevent carbonate ions giving a false positive result.

Write the **ionic** equation for the reaction of hydrochloric acid with carbonate ions. State symbols are not required.

(1)

(c) Give a reason why solid barium chloride does not conduct electricity.

(1)

.....

.....

(Total for question = 8 marks)

Q18.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The formula of barium chloride is $BaCl_2$.

Which is correct for barium chloride?

[A_r values: Ba = 137.3 Cl = 35.5]

☐ **A** barium chloride exists as a molecule

☐ **B** barium chloride is a compound

☒ **C** the empirical formula of barium chloride is BaCl

☒ **D** the M_r of barium chloride is 172.8

(Total for question = 1 mark)

Q19.

Naturally occurring bromine has two isotopes: bromine-79 and bromine-81.

(a) State what is meant by the term isotopes.

(1)

.....

.....

.....

(b) Complete the table to show the numbers of subatomic particles in the two isotopes of bromine.

(2)

Isotope	Protons	Neutrons	Electrons
bromine-79			
bromine-81			

(c) The mass spectrum of a sample of bromine is obtained.

(i) Draw a dot-and-cross diagram to show the bonding in a molecule of bromine.

Only the outer electrons should be shown.

(2)

(ii) Describe the formation of the molecular ion of bromine in the mass spectrometer. Include an equation.

State symbols are not required.

(2)

.....

.....

.....

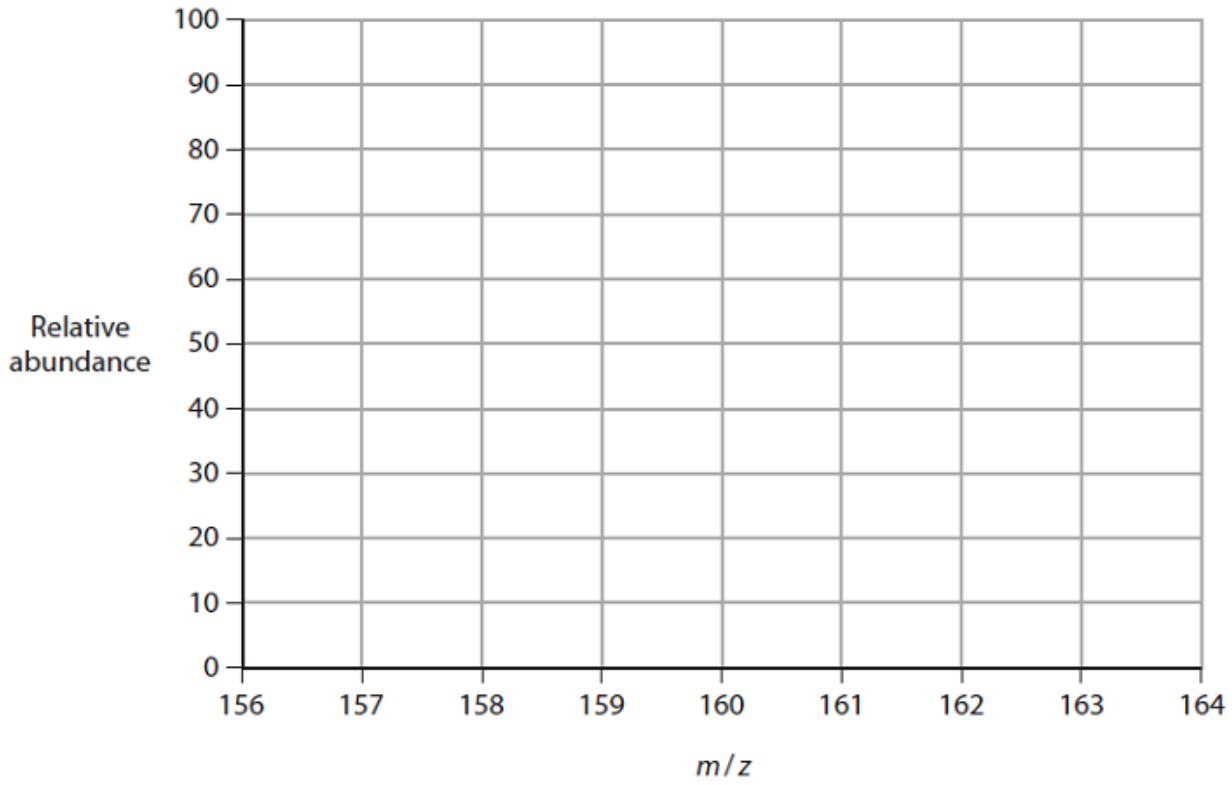
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(iii) On the mass spectrum grid, draw the peaks for the bromine molecular ions, showing the relative peak heights.

The bromine isotopes in this sample have the **same** relative abundance.

(2)



(d) The percentage abundances of the isotopes in a different sample of bromine are shown.

Isotope	Percentage abundance
bromine-79	56.38%
bromine-81	43.62%

Calculate the relative **molecular** mass of this sample of bromine, giving your answer to **two** decimal places.

(3)

(Total for question = 12 marks)

Q20.

This question is about bromine.

(a) Complete the electronic configuration for a bromine atom, using the s, p, d notation.

(1)

[Ar] .....

(b) Bromine exists as two isotopes with mass numbers 79 and 81.

(i) Complete the table to show the numbers of subatomic particles in a ^{79}Br atom and a $^{81}Br^-$ ion.

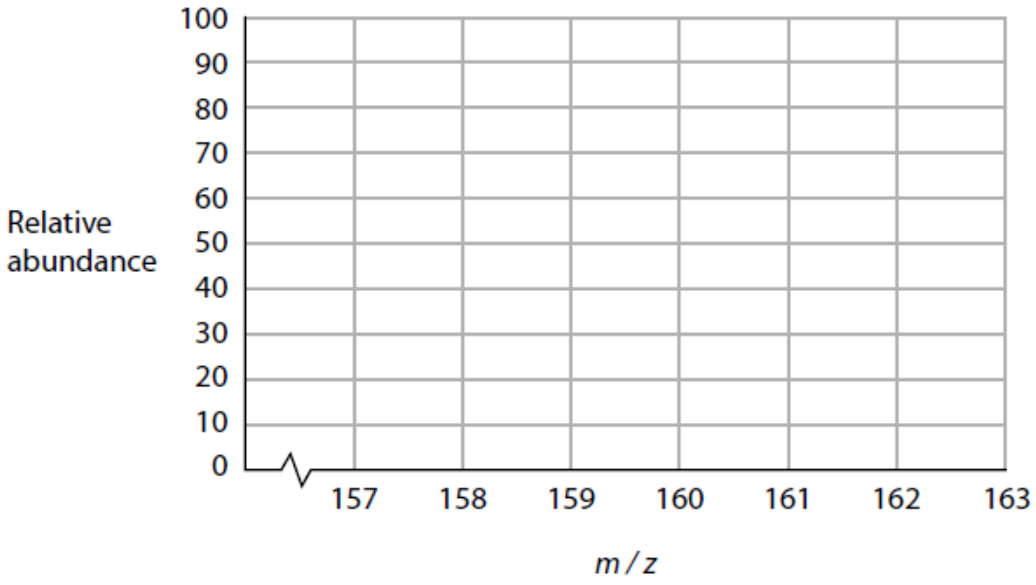
(2)

Species	Protons	Neutrons	Electrons
^{79}Br			
$^{81}Br^-$			

(ii) A sample of bromine contained equal amounts of the two isotopes.

Complete the mass spectrum to show the peaks you would expect for Br_2^+ from this sample of bromine gas.

(2)



(iii) Calculate the number of bromine molecules in 2.00 g of Br_2.

[Avogadro constant = 6.02×10^{23} mol^{-1}]

(2)

Number of molecules = ...

(c) A sample of bromine gas occupied 200 cm^3 at a temperature of 77 °C and a pressure of 1.51 × 10^5 Pa.

Calculate, using the ideal gas equation, the amount in moles of bromine molecules in this sample.

[$pV = nRT$ $R = 8.31$ J mol^{-1} K^{-1}]

(4)

Amount of bromine molecules = ... mol

(Total for question = 11 marks)

Q21.

Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

The maximum permitted concentration of sulfur in diesel fuel is 10 mg of sulfur in 1 kg of diesel fuel.

(a) What is this concentration of sulfur in ppm?

(1)

☐ **A** 0.00001

☐ **B** 0.01

☐ **C** 10

☐ **D** 10 000

(b) 3.2 kg of this diesel fuel is burned in air.

What is the maximum volume, in dm^3, of sulfur dioxide which can be produced, measured at room temperature and pressure (r.t.p.)?

[Molar volume of a gas at r.t.p. = 24 dm^3 mol^{-1}]

(1)

☐ **A** 0.024

☐

B 0.77

☒ **C** 2.4

☒ **D** 24

(Total for question = 2 marks)

Q22.

Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

A mass of 0.23 g of sodium was added to 350 cm^3 water to form hydrogen and a solution of sodium hydroxide.

$$Na(s) + H_2O(l) \rightarrow NaOH(aq) + \tfrac{1}{2}H_2(g)$$

(a) What is the concentration, in mol dm^{-3}, of sodium hydroxide in the solution formed?

(1)

☒ **A** 0.010

☒ **B** 0.029

☒ **C** 0.29

☒ **D** 0.66

(b) What is the maximum volume, in cm^3, of hydrogen which could be formed, measured at r.t.p.?

[Molar volume of a gas at r.t.p. = 24 dm^3 mol^{-1}]

(1)

☒ **A** 120

☒ **B** 240

☒ **C** 480

☒ **D** 2800

(c) The sodium hydroxide solution was neutralised with sulfuric acid.

Which is the ionic equation for this reaction?

(1)

☒ **A** $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

☒ **B** $SO_4^{2-}(aq) + 2Na^+(aq) \rightarrow Na_2SO_4(aq)$

☒ **C** $H_2SO_4(aq) + 2Na^+(aq) + 2OH^-(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$

☒ **D** $2H^+(aq) + SO_4^{2-}(aq) + 2Na^+(aq) + 2OH^-(aq) \rightarrow 2Na^+(aq) + SO_4^{2-}(aq) + 2H_2O(l)$

(d) Sodium hydroxide solution was added to magnesium sulfate solution.

The equation for the reaction is shown.

$$2NaOH(aq) + MgSO_4(aq) \rightarrow Mg(OH)_2(s) + Na_2SO_4(aq)$$

What is the atom economy (by mass) for the production of magnesium hydroxide?

[A_r values: H = 1.0 O = 16.0 Na = 23.0 Mg = 24.3 S = 32.1]

(1)

☒ **A** 29.1 %

☒ **B** 41.0 %

☒ **C** 48.4 %

☒ **D** 50.0 %

(Total for question = 4 marks)

Q23.

For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Iron(III) oxide is reduced by hydrogen in a two-step process.

$$\text{Step 1: } 3Fe_2O_3 + H_2 \rightarrow 2Fe_3O_4 + H_2O$$

$$\text{Step 2: } Fe_3O_4 + 4H_2 \rightarrow 3Fe + 4H_2O$$

What is the maximum mass of iron that could be produced from 39.9 tonnes of Fe_2O_3 ?

[A_r values: H = 1.0 O = 16.0 Fe = 55.8]

☒ **A** 6.98 tonnes

☒ **B** 13.95 tonnes

☒ **C** 27.90 tonnes

☒ **D** 41.85 tonnes

(Total for question = 1 mark)

Q24.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A mass of 4.08 g of hydrated copper(II) sulfate, $CuSO_4 \cdot 5H_2O$, was dissolved in deionised water to form 250 cm^3 of solution.

What is the concentration of the copper(II) sulfate solution formed, in mol dm^{-3}?

(1)

☒ **A** 0.0163

☒ **B** 0.0256

☒ **C** 0.0654

☒ **D** 0.102

(Total for question = 1 mark)

Q25.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A mass of 2.50 g of sodium chloride reacts with excess lead(II) nitrate solution forming lead(II)

chloride with a
yield of 95 %.

What is the mass of lead(II) chloride, $PbCl_2$, formed?

$$2NaCl + Pb(NO_3)_2 \rightarrow PbCl_2 + 2NaNO_3$$

[M_r values: NaCl = 58.5 $PbCl_2$ = 278.2]

(1)

☒ **A** 5.65 g

☒ **B** 5.94 g

☒ **C** 11.3 g

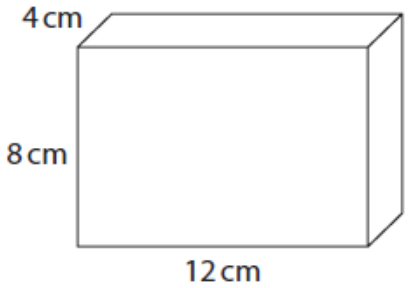
☒ **D** 11.9 g

(Total for question = 1 mark)

Q26.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A piece of copper is shown.



How many moles of copper atoms are there in this piece of copper?

[Density of copper = 8.96 g cm^{-3}]

☒ **A** 0.675

☒ **B** 1.48

☒ **C** 6.05

☒ **D** 54.2

(Total for question = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

Q27.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A solution of sodium chloride, NaCl, is prepared by dissolving 10.0 g of the solid in distilled water and making the solution up to 250.0 cm^3.

What is the concentration of the solution, in mol dm^{-3} ?

[M_r NaCl = 58.5]

☒ **A** 0.171

☒ **B** 0.684

☒ **C** 10.0

☒ **D** 40.0

Use this space for any rough working. Anything you write in this space will gain no credit.

(Total for question = 1 mark)

Q28.

There is 0.045 g of solute in 1500 g of a solution.

What is the concentration of the solution in parts per million (ppm)?

(1)

☒ **A** 3.00

☒ **B** 6.75

☒ **C** 30.0

☒ **D** 67.5

(Total for question = 1 mark)

Q29.

What is the concentration, in mol dm^{-3}, of a solution containing 7.84 g of phosphoric(V) acid, H_3PO_4, in 400 cm^3 of solution?

(1)

☒ **A** 0.02

☒ **B** 0.08

☒ **C** 0.20

☒ **D** 19.6

(Total for question = 1 mark)

Q30.

Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

Which aqueous solution has the **highest** concentration, in mol dm^{-3}, of chloride ions?

☒ **A** 0.1 g dm^{-3} HCl

☒ **B** 0.1 g dm^{-3} NaCl

☒ **C** 0.1 g dm^{-3} KCl

☒ **D** 0.1 g dm^{-3} $BaCl_2$

(Total for question = 1 mark)

Mark Scheme

Q1.

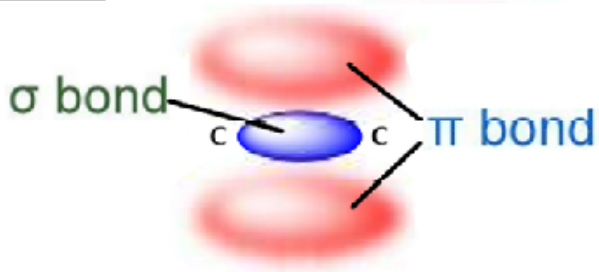
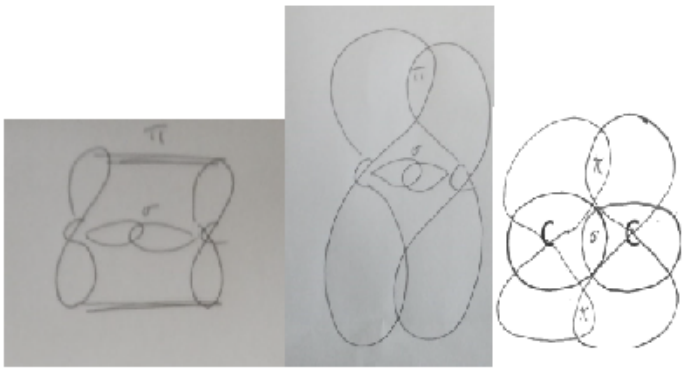
Question Number	Answer	Additional guidance	Mark
(a)	• correct equation	$2NaN_3 \rightarrow 2Na + 3N_2$ Accept $NaN_3 \rightarrow Na + 1.5N_2$ Accept $NaN_3 \rightarrow Na + 3/2\ N_2$ Allow multiples Ignore state symbols even if incorrect Do not award Na_2	**(1)**

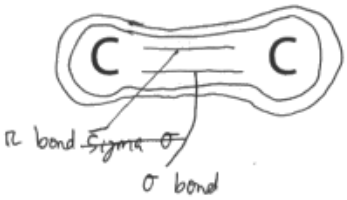
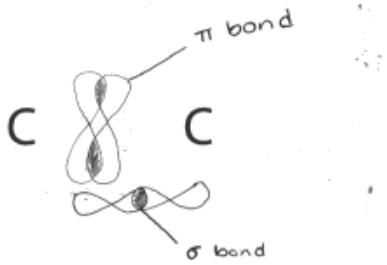
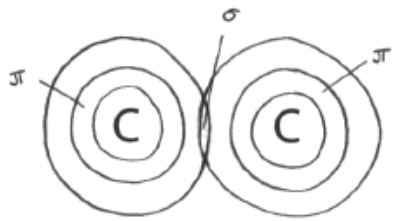
Question Number	Answer		Additional guidance	Mark
(b)	• conversion of volume m^3	**(1)**	$V = 0.12\ m^3$	**(6)**
	• conversion of temperature to K	**(1)**	$T = 298$ K Accept 298.15K	
	• correct substitution into the equation / rearrangement of the equation	**(1)**	$101000 \times 0.12 = n \times 8.31 \times 298$ $n = 101000 \times 0.12 / 8.31 \times 298$ or $n = PV/RT$	
	• calculation of n for N_2	**(1)**	$n = 4.89(424)$	
	• calculation of n for NaN_3 (2:3)	**(1)**	$n = 4.89 \times 2/3$ $= 3.2628$	
	• calculation of mass to **2 or 3 SF**	**(1)**	$M_r (NaN_3) = 65$ $m = 3.26 \times 65 = 212.08$ (g) $= 212$ (g) (210 to 2SF) Correct answer scores 6 Do not award incorrect units for MP6 TE throughout 318 (g) or 320 (g) scores 5 317.8(5) (g) scores 4 0.32 (g) scores 4	

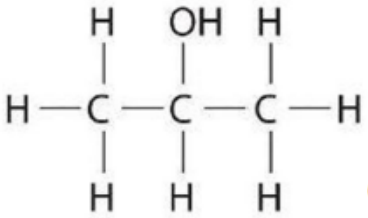
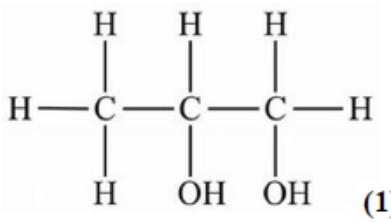
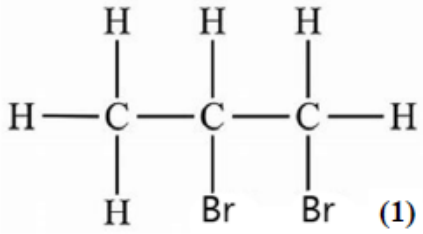
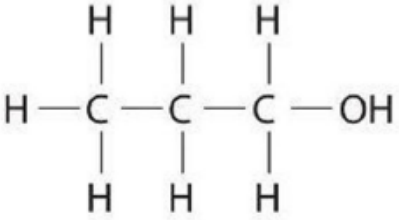
Question Number	Answer	Additional guidance	Mark
(c)(i)	• quoting or using atom economy formula **(1)** • calculation of total molar masses of reactants or products **(1)** • calculation of atom economy to **2 or 3 SF** **(1)**	Example of calculation: $\frac{\text{molar mass desired product}}{\text{sum of all product molar masses}} \times 100\%$ OR $\frac{28}{[(39.1 \times 2)+16] + [5\times(23\times2)+16] + [14\times2]} \times 100\%$ 432.2 Allow 432 TE on incorrect numerical atom economy expression **if** 39.1, 16, 23 and 14 are in the denominator and correctly used (28.0 ÷ 432.2) × 100 = 6.4785 = 6.5 / 6.48(%) TE on incorrect quoted molar masses Correct answer scores 3 Correct answer to <2 or >3 SF scores 2 Penalise omission of 100% once only	**(3)**

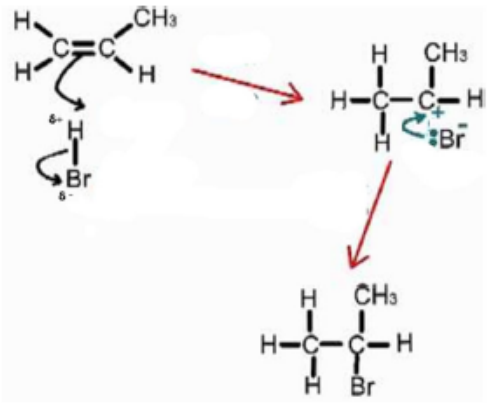
Question Number	Answer	Additional guidance	Mark
(c)(ii)	• neutralisation	Allow acid-base	**(1)**
			(Total for Question 24 = 11 marks)

Q2.

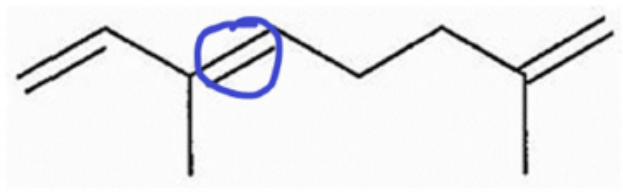
Question Number	Answer	Additional Guidance	Mark
(a)	An answer that makes reference to the following points:  σ (1) π (1)  All three of the above score 2 marks	One mark for each of the bonds labelled. The π bond **must** be above **and** below the carbons but only one of the lobes of the π bond needs to be labelled Ignore overlap of orbitals where the sigma bond extends beyond the carbon atoms Ignore extra labelled sigma bonds to hydrogen	(2)

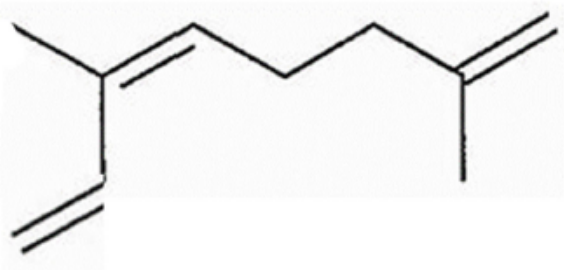
	 Scores 0	Do not award single lines as there must be an area of electron density.	
	 Scores 0	Do not award if the orbits are shown overlapping in a random position away from the Cs.	
	 Scores 0	Do not award electron rings or contour lines Allow if both bonds are correct and labelled the wrong way round score (1)	

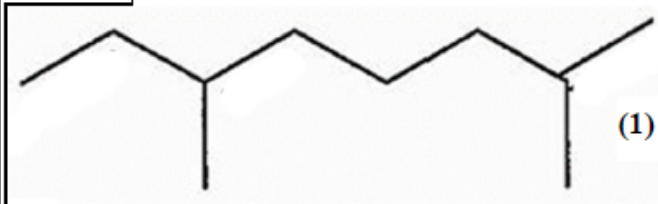
Question Number	Answer	Additional Guidance	Mark
(b)(i)	Steam and catalyst  (1) Acidified potassium manganate(VII)  (1) Bromine  (1)	Accept skeletal / structural formulae/ or a combination Allow  Ignore connectivity of OH unless horizontal but penalise only once Ignore names even if incorrect If wrong number of carbon atoms penalise once only. Do not award any structure with missing bonds.	(3)

Question Number	Answer	Additional Guidance	Mark
(b)(ii)	An explanation that makes reference to the following points: 		(3)
	• dipole on HBr and two correct curly arrows **(1)**	Arrows must start from the covalent bond. From the H—Br bond it must go to the Br or beyond. From the C=C bond is must go to the H or in the space.	
	• correct intermediate **(1)**		
	• curly arrow from **lone pair** on Br^- to C^+ or the space between the Br^- to C^+ **(1)**	If Br_2 is added M2 and M3 can be scored If 1-bromopropane is the product the intermediate mark cannot be scored so Max 2 Penalise half curly arrows once only If wrong alkene Allow M1 and M3 only. Ignore the product even if incorrect	

Question Number	Answer	Additional Guidance	Mark
(c)(i)	• $C_{10}H_{16}$	$H_{16}C_{10}$ Ignore working and any names	(1)

Question Number	Answer	Additional Guidance	Mark
(c)(ii)	 or 	Allow any circle that includes the correct double bond and does not extend beyond the OR answer.	(1)

Question Number	Answer	Additional Guidance	Mark
(c)(iii)	• correct skeletal formula	Example of formula:  Ignore angles and lengths of bonds	(1)

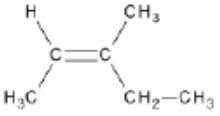
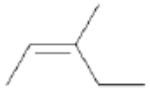
Question Number	Answer	Additional Guidance	Mark
(c)(iv)	An answer that makes reference to the following points: • moles of hydrogen / H_2 (1) • ratio of moles hydrogen / H_2 to alpha-ocimene = number of C=C that react (1) • Correct structure  (1) If there is no calculation or calculation says H_2 is in excess M3 can be awarded.	Example of calculation $3.6 \div 24 = 0.15$ (mol) $0.15 \div 0.05 = 3$ Allow TE incorrect moles of H_2 Allow TE on incorrect ratio of 1 or 2. Ignore length of bonds/bond angles Allow structural or displayed formulae	(3)

Q3.

Question number	Answer	Additional guidance	Mark
(a)	A description that makes reference to the following points: • (propane) yellow (solution) (1) • (propene) colourless (solution) (1)	 Allow brown or orange or any combination of yellow, orange and brown Allow no (colour) change / no change in bromine water / remains yellow / turns yellow Allow upper layer / both layers are yellow / orange / brown etc Ignore just 'no reaction' Do not award any mention of red Do not award lower layer is yellow / orange / brown etc Allow decolorises / colour disappears Allow (both) layers are colourless Ignore initial colour of red in M2 only Do not award remains colourless	(2)

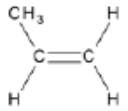
Question number	Answer	Additional guidance	Mark
(b)(i)	• steam / $H_2O(g)$ **and** acid (catalyst) / phosphoric acid / H_3PO_4	In (b)(i) and (ii) allow names or formulae for reagents but if both are given, both must be correct Allow water / H_2O **and** heat for steam Do not award steam **and** room temperature Allow name or formula of any strong acid (catalyst) / H^+ Ignore concentration of acid / pressure	(1)

Question number	Answer	Additional guidance	Mark
(b)(ii)	• potassium manganate((VII)) (solution)/ $KMnO_4$ **and** sulfuric acid / H_2SO_4 / acid(ified) / H^+ / sodium hydroxide / NaOH / potassium hydroxide / KOH / alkali(ne) / OH^-	Allow potassium permanganate Do not award K_2MnO_4 Ignore heat / concentration of acid or alkali Allow (1) in (ii) if reagents **and** conditions for (i) and (ii) are interchanged If no other mark is awarded: Allow (1) in (ii) if reagents for both (i) and (ii) are correct but conditions are omitted / incorrect	(1)

Question number	Answer	Additional guidance	Mark
(c)	• structure of *Z*-3-methylpent-2-ene	Examples of structure:  or  Allow C_2H_5 / displayed formula Ignore connectivity of methyl and ethyl groups Ignore bond lengths and bond angles on skeletal formula	(1)

Question number	Answer	Additional guidance	Mark
(d)	• calculation of number of moles of hydrogen **or** calculation of volume of alkene (1) • deduction of number of double bonds (1)	Example of calculation: $\frac{720}{24000} = 0.030$ or $\frac{0.72}{24} = 0.030$ **or** volume of alkene = 0.01 x 24000 = 240 (cm^3) mole ratio alkene : hydrogen = (0.01 : 0.03 or 720/240) = 1 : 3 so there are 3 double bonds TE on mol hydrogen Correct answer with no working scores (1)	(2)

Question number	Answer	Additional guidance	Mark
(e)	• the dipole on the bromine (molecule) should be the other way around (1) • the arrow should go from the double / pi / π bond to the bromine / (pair of) electrons move from the double bond to the bromine **or** the curly arrow should go from C=C to $Br^{\delta+}$ (1) • the Br ion should have a negative charge (1)	Allow the changes in any order and they may be shown on the diagram Ignore references to lone pairs Allow the top bromine should be δ+ / the bottom bromine should be δ– Allow the bromine (atom) should have a negative charge Ignore just 'Br is not positive' Do not award the bromine molecule should have a negative charge Do not award $Br^{\delta-}$	(3)

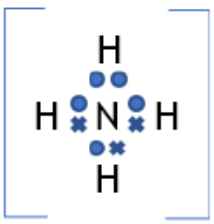
Question number	Answer	Additional guidance	Mark
(f)	• structure of propene	Example of structure:  Allow any unambiguous structure of propene showing the double bond e.g. $CH_3CH=CH_2$ Ignore name, even if incorrect Ignore n / brackets Ignore connectivity of CH_3 group	(1)

Q4.

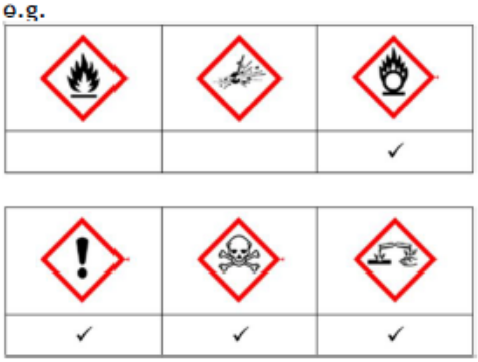
Question Number	Answer	Additional guidance	Mark
(a)(i)	• $(NH_4)_2Cr_2O_7 \rightarrow N_2 + 4H_2O + Cr_2O_3$	1 mark for Cr_2O_3 1 mark for all the rest being correct Allow multiples Marks are standalone	(2)

Question Number	Answer	Additional guidance	Mark
(a)(ii)	• (thermal) decomposition **or** redox	Ignore oxidation or reduction on their own	(1)

Question Number	Answer	Additional guidance	Mark
(b)	• conversion of units for *P* and *V* (1) • substitution in equation and rearrange (1) • answer in K (1) • convert to °C (1)	Example of calculation: $P = 101000 / 1.01 \times 10^5$ Pa $V = 0.0000252 / 2.52 \times 10^{-5}$ m^3 Allow incorrect use standard form e.g. 10.1×10^4 Pa $T = \frac{101000 \times 0.0000252}{0.001 \times 8.31}$ T = 306.28 (K) T = 33.3(°C) (33.1°C if 273.15 is used for conversion of kelvin to Celsius) Ignore SF except 1 SF on final answer TE throughout but only award for MP4 if final answer in °C is between 0 and 50°C Units if given must be correct *Comment:* *Correct answer with no working scores 4* *306.28(K) scores 3* *30.85 °C scores 3* *33.7 °C scores 3 as they have used R as 8.3* *33.55 °C scores 3 using 8.3 and 273.15* *306.7K scores 2 as they have used R as 8.3*	(4)

Question Number	Answer	Additional guidance	Mark
(c)(i)	A drawing that shows: • four pairs of electrons and 4 hydrogen atoms around nitrogen (1) • one dative covalent bond **and** plus sign (1)	 Allow answers without brackets Allow use of any symbol for the electrons as long as it is clear which is the dative covalent bond (e.g. by use of an arrow) Ignore placement of positive sign	(2)

Question Number	Answer	Additional guidance	Mark
(c)(ii)	An explanation that makes reference to: • tetrahedral / tetrahedron (1) • (four) **pairs of electrons** arranged in position of minimum repulsion / maximum separation (1)	MP1 may be scored with a 3D diagram or an answer given in 19(c)(i) Allow phonetic spelling Allow equal repulsion of electron-pairs Allow reference to bonding pairs Ignore reference to bonds Ignore all bond angles Do not award references to lone pairs Marks are standalone	(2)

Question Number	Answer	Additional guidance	Mark
(d)(i)	Four correct ticks scores 2 marks, Three correct ticks scores 1 mark Four correct ticks and one incorrect tick scores 1 mark	e.g.  	(2)

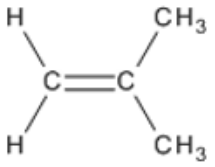
Question Number	Answer	Additional guidance	Mark
(d)(ii)	An answer containing an appropriate suggestion: • dichromate/oxidising agents promote(s) combustion/burning of alkanes/fuels OR alkanes are flammable/combustible **and** dichromate is an oxidising agent	Allow fuels/alkanes would catch fire more easily Ignore dichromate causes alkanes to burn Do not award dichromate catches fire	(1)

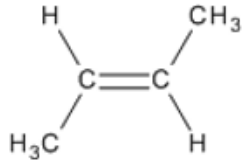
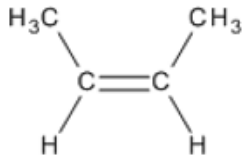
Q5.

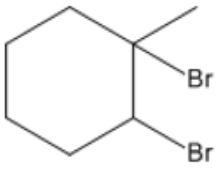
Question number	Answer	Mark
	The only correct answer is D (3.612×10^{24}) *A is incorrect because this is the number of molecules in 0.5 mol of water* *B is incorrect because this is the number of molecules of water* *C is incorrect because this is the answer if there are 2 atoms in a molecule*	(1)

Q6.

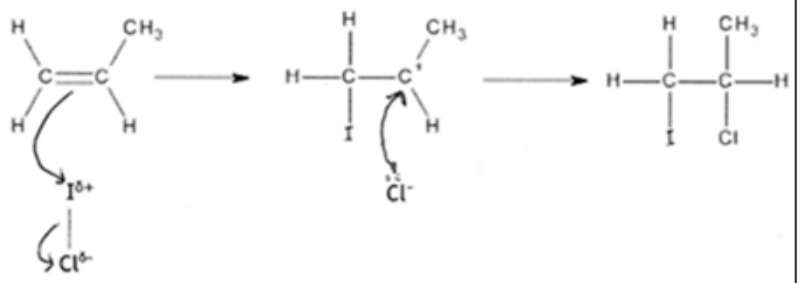
Q	Answer	Additional guidance	Mark
(a)	• (alkene is) C_8H_{16}	Allow $H_{16}C_8$ Allow large numbers e.g. C8H16 Do not award C^8H^{16}	1

Q	Answer	Additional guidance	Mark
(b)(i)	• structure of C_4H_8 branched alkene	Example of structure:  Allow any unambiguous structure e.g. structural or displayed formula or any combination of these / skeletal formula Ignore name even if incorrect	1

Q	Answer	Additional guidance	Mark
(b)(ii)	• structure of one geometric isomer **and** name **(1)** • structure of the other geometric isomer **and** name **(1)**	Examples of structures and names:  **and** *trans*-but-2-ene / *E*-but-2-ene  **and** *cis*-but-2-ene / *Z*-but-2-ene Allow isomers in either order Allow 2-butene for but-2-ene Allow any unambiguous structures e.g. displayed formulae or skeletal formulae Ignore missing hyphens If no other mark is scored, allow (1) for two correct structures **or** two correct names	2

Q	Answer	Additional guidance	Mark
(c)(i)	• skeletal formula of product	Example of skeletal formula:  Ignore structural / displayed formula	1

Q	Answer	Additional guidance	Mark
(c)(ii)	An answer that makes reference to one of the following pairs: **Either** • steam / $H_2O(g)$ **(1)** • phosphoric((V)) acid (catalyst) / H_3PO_4 **(1)** **Or** • (concentrated) sulfuric acid / H_2SO_4 **(1)** • **followed by** water / H_2O **(1)**	Allow reagent and condition written on either dotted line for the steam and phosphoric acid answer Allow water / H_2O **and** heat / any temperature above 100°C Ignore pressure If oxidation number is given, it must be correct Allow just 'acid catalyst' Ignore hydrochloric acid / just 'H^+' Ignore specified temperature / heat / reflux Do not award $H_2O(g)$	**2**

Q	Answer	Additional guidance	Mark
(d)	• curly arrow from C=C bond to / towards $I^{\delta+}$ **and** curly arrow from I-Cl bond to, or just beyond Cl **(1)** • intermediate **(1)** • lone pair on Cl^- **and** curly arrow from lone pair to carbon with positive charge **(1)** • structure of major product **(1)**	Example of mechanism:  Do not award δ+ charge on intermediate Do not award δ− charge on chloride ion Allow curly arrow from lone pair to positive charge **Note** Mechanism for the formation of the minor product can score M1, M3 and M4	**4**

Q	Answer	Additional guidance	Mark
(e)	• pent-2-ene	Allow 2-pentene Ignore *E* / *Z* / *cis* / *trans* Do not award just 'pentene'	**1**

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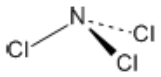
Q	Answer	Additional guidance	Mark
(f)	• conversion of volume to m^3 **(1)** • rearrangement of ideal gas equation **(1)** • evaluation to give n **(1)** • deduction of number of double bonds **(1)**	Example of calculation: volume of H_2 = $\frac{600}{1 \times 10^6}$ = 6×10^{-4} / 0.0006 m^3 $n = \frac{pV}{RT}$ **or** $n = \frac{1.24 \times 10^5 \times 6 \times 10^{-4}}{8.31 \times 298}$ TE on volume n = 0.03004 / 0.0300 / 0.030 / 0.03 TE on volume ratio alkene : H_2 = 0.01 : 0.03 / 1 : 3 **and** so there are 3 double bonds TE on volume Final answer with no working scores (1) Ignore SF including 1SF	**4**
			(Total for Question = 16 marks)

Q7.

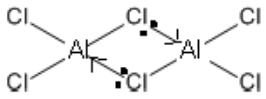
Question number	Answer	Additional guidance	Mark
24(a)	An explanation that makes reference to the following points: • (I) is incorrect because the solutions are aqueous **or** ions are (in the) aqueous (state) the state symbols should be (aq) instead of (I) • silver ions should have one positive charge / Ag^+ **or** silver chloride is AgCl	Allow silver nitrate and sodium chloride are aqueous Do not award if incorrect state symbol for one of the species in the equation e.g. Ag is (s) / AgCl is (aq) Ignore just the charge on the silver ion is incorrect / the formula of silver chloride is incorrect	**(2)**

Question number	Answer	Additional guidance	Mark
(b)	• calculation of mol of C, H and Cl **(1)** • calculation of empirical formula **(1)** • calculation of molecular formula **(1)**	Example of calculation: C : H : Cl mol $\frac{3.09}{12} : \frac{0.26}{1} : \frac{9.15}{35.5}$ = 0.2575 : 0.26 : 0.2577 (ratio 1 : 1 : 1) Empirical formula is CHCl molar mass CHCl = 12 + 1 + 35.5 = 48.5 $\frac{\text{molar mass } (CHCl)_n}{\text{molar mass CHCl}} = \frac{97}{48.5} = 2$ Molecular formula is $C_2H_2Cl_2$ Allow symbols in any order Do not award 2CHCl Ignore SF in mol and ratio Correct molecular formula with some working scores (3) **Alternative method** scores (3) no. C atoms = $\frac{3.09 \times 97}{12.5 \times 12} = 2 / 1.9982$ no. H atoms = $\frac{0.26 \times 97}{12.5 \times 1} = 2(.0176)$ no. Cl atoms = $\frac{9.15 \times 97}{12.5 \times 35.5} = 2$	**(3)**

Question number	Answer	Additional guidance	Mark
(c)(i)	• all 4 ion formulae • all 4 (corresponding) *m* / *z* values	Example of answer: ions *m* / *z* $N(^{35}Cl)_3^+$ 119 $N(^{35}Cl)_2{}^{37}Cl^+$ 121 $N^{35}Cl(^{37}Cl)_2^+$ 123 $N(^{37}Cl)_3^+$ 125 Allow any other unambiguous way of representing the formulae e.g. in words Allow (1) for any two *m* / *z* values with corresponding ion formulae Ignore missing / incorrect charge on ion Ignore mass number on N Ignore bonds or + between Cl atoms / order of atoms e.g. $N\text{-}^{35}Cl\text{-}^{35}Cl\text{-}^{35}Cl$	(2)

Question number	Answer	Additional guidance	Mark
(c)(ii)	• number of bonding pairs **and** number of lone pairs • shape • bond angle	Example of table: Number of bonding pairs of electrons on nitrogen: 3 Number of lone pairs on electrons on nitrogen: 1 Shape of molecule: trigonal pyramidal Bond angle: 107° **Shape:** Allow 3-dimensional drawing e.g.  There must be at least 1 dotted/dashed line or wedge for 3-d Allow just 'pyramidal' Allow pyramid for pyramidal Do not award tetrahedral **Bond angle:** Allow any number in the range 106-108° Ignore missing °	(3)

Question number	Answer	Additional guidance	Mark
24(d)(i)	An explanation that makes reference to one of the following pairs of points: **Polarisation route** • an aluminium ion / cation is (very) small **and** highly charged **or** Al^{3+} has a small ionic radius / is small • so it polarises / distorts the chloride ion / Cl^- / anion **Allow Electronegativity route** • there is a (relatively) small difference in electronegativity between aluminium and chlorine • so the electrons are (partially) shared	Marks must come from the same route – maximum 1 mark if one point from one route and one point from the other route Allow the aluminium ion has a high charge density Allow a description of polarisation Allow chlorine anion / ion Ignore the aluminium chloride is polarised Ignore size of chloride ion	(2)

Question number	Answer	Additional guidance	Mark
24(d)(ii)	A description including the following points: • diagram showing two $AlCl_3$ molecules joined through two chlorine atoms • dative (covalent) bonds **or** coordinate bonds	Example of diagram:  Allow dot-and-cross diagram Ignore missing arrow heads and lone pairs from diagram Do not award diagram with Al-Al / Cl-Cl bond(s) Allow dative covalent bonds labelled on diagram / shown as arrows from Cl to Al Allow description of dative bonds Allow M2 even if only 1 dative bond shown / mentioned Do not award M2 if dative bonds starting from aluminium Do not award M2 for any answer that mentions ions / ionic bonds	(2)

Q8.

Q	Answer	Additional guidance	Mark
(a)	• all three numbers correct	Example of table: Number of protons: 26 Number of neutrons: 30 Number of electrons: 24	1

Q	Answer	Additional guidance	Mark
(b)	• expression to calculate relative atomic mass **(1)** • correct answer to 3SF **(1)**	Example of calculation: $\frac{(54 \times 5.84) + (56 \times 91.68) + (57 \times 2.17) + (58 \times 0.31)}{100}$ Relative atomic mass (= 55.911) = 55.9 TE on incorrect numbers in correct expression Ignore units of g mol^{-1} or g mol^{-} Do not award other incorrect units e.g. g or % Correct answer with some working scores (2)	**2**

Q	Answer	Additional guidance	Mark
(c)	• ionic equation **(1)** • all state symbols **(1)**	Example of equation: $Mg(s) + Fe^{2+}(aq) \rightarrow Fe(s) + Mg^{2+}(aq)$ Allow multiples State symbols conditional on correct equation Allow state symbols if equation includes correct metals combined with ions with incorrect charges e.g. $3Mg(s) + 2Fe^{3+}(aq) \rightarrow 2Fe(s) + 3Mg^{2+}(aq)$ Or $2Mg(s) + Fe^{2+}(aq) \rightarrow Fe(s) + 2Mg^{+}(aq)$ Allow state symbols for balanced non-ionic equation $Mg(s) + FeSO_4 \rightarrow Fe(s) + MgSO_4(aq)$ or multiples	**2**

Q	Answer	Additional guidance	Mark
(d)	• calculation of mass of oxygen **and** working to find mol **(1)** • calculation of mol of Fe, S and O **(1)** • calculation of simplest whole number ratio **and** deduction of empirical formula **(1)**	Example of calculation: mass of oxygen = 25.00 – 6.98 – 6.03 = 11.99 (g) Fe : S : O mol $\frac{6.98}{55.8}$: $\frac{6.03}{32.1}$: $\frac{11.99}{16.0}$ = 0.12509 : 0.18785 : 0.74938 Ignore SF except 1 SF in M2 ratio 1 : 1.5 : 6 = 2 : 3 : 12 **and** empirical formula is $Fe_2S_3O_{12}$ TE on mol Fe, S and O Allow symbols in any order Correct empirical formula with no working scores (3) Penalise incorrect rounding / truncation of numbers once only in M2 e.g. 0.12 / 0.18 / 0.74 **Note** Allow (3) for correct working with $Fe_2(SO_4)_3$ but $Fe_2(SO_4)_3$ with no working scores (0)	**3**

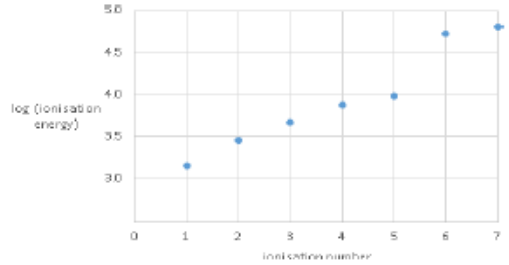
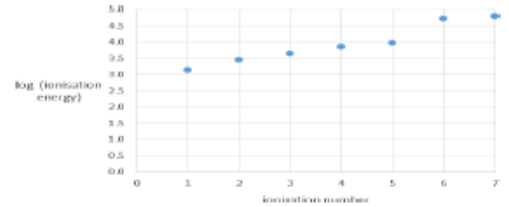
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Q	Answer	Additional guidance	Mark
(e)	• calculation of mol of iron(III) oxide **(1)** • calculation of mol of sulfur dioxide **and** mol of sulfur trioxide **(1)** • calculation of mass **and** mol of H_2O **(1)** • calculation of value of x **(1)** • balanced equation **(1)**	Example of calculation: mol Fe_2O_3 = $\frac{2.00}{159.6}$ = 0.012531 / 1.2531 x 10^{-2} mol SO_2 = $\frac{0.80}{64.1}$ = 0.0124805 / 1.24805 x 10^{-2} **and** mol SO_3 = $\frac{1.00}{80.1}$ = 0.012484 / 1.2484 x 10^{-2} mass of H_2O = 6.95 – (2.00 + 0.80 + 1.00) = 3.15 (g) **and** mol of H_2O = $\frac{3.15}{18}$ = 0.175 (mol) Ratio SO_2 : SO_3 : H_2O = 1 :1 : 14 There must be $2FeSO_4$ to produce SO_2 and SO_3 So x = 7 TE on M1, M2, and M3 This mark may be awarded in M5 Example of equation: $2FeSO_4.7H_2O \rightarrow Fe_2O_3 + SO_2 + SO_3 + 14H_2O$ Stand alone mark Allow multiples Allow fractions for numbers of moles TE on value of x in M4 provided equation is balanced Ignore state symbols even if incorrect See next page for alternative methods Alternative methods for M3 and M4:	**5**

Q	Answer	Additional guidance	Mark
		Method 1 mol $FeSO_4$ = 2 x 1.2531 x 10^{-2} = 0.025062 (1) M_r of hydrate = 6.95 / 0.025062 = 277.305 **and** mass of water = 265.34 – 151.9 = 125.405 (g) **and** mol water = 125.405/18 = 6.9669 = 7 (1) **Method 2** mass of water = 6.95 – (2.00 + 0.80 + 1.00) = 3.15 (g) **and** mass of $FeSO_4$ = 3.8(0) (g) (1) mol $FeSO_4$ and water: $FeSO_4$ $\frac{3.80}{151.9}$ = 0.025; H_2O $\frac{3.15}{18}$ = 0.175 simplest ratio: 1 : 7 (1)	
		(Total for Question = 13 marks)	

Q9.

Question number	Answer	Additional guidance	Mark
(a)(i)	• two correct values	(6) (53 268) 4.73 (7) (64 362) 4.81 Both numbers correct and must be to 2 d.p.	(1)

Question number	Answer	Additional guidance	Mark
(a)(ii)	• axes correct way round **and** linear scale points covering at least half the grid horizontally **(1)** • both axes labelled **(1)** • points plotted correctly **(1)**	Example of graph:  Allow  **Labels**: Allow log(IE / kJ mol^{-1}) Do not award log(IE) / kJ mol^{-1} **Points**: TE on values in table for 6th and 7th log(IE) Allow ±1 small square Allow points joined by lines / bar chart Ignore lines drawn from x axis to each point Do not award a best fit straight line Do not award lines joined to the origin	**(3)**

Question number	Answer	Additional guidance	Mark
(a)(iii)	An answer that makes reference to the following: • the range of numbers / 1402 to 64362 is too large (to fit on a graph / axis) **or** logarithms make it easier to plot the numbers	Allow: A (very) long y axis would be needed The difference between the ionisation energies is too large So the numbers will fit on the graph Allow logs give smaller (range of) numbers	**(1)**

Question number	Answer	Additional guidance	Mark
(a)(iv)	An explanation that makes reference to the following points: • the (large) jump (between ionisations 5 and 6) shows the start of a new (quantum) shell **(1)** • there are two electrons that are harder to remove and they are closer to the nucleus **(1)** • there are five electrons that are easier to remove and they are further from the nucleus **(1)**	Penalise use of orbitals instead of shells once only Allow any answer relating the jump / large increase to two (quantum) shells Allow jump linked to **1s** and **2s** sub-shells Do not award jump between incorrect numbers Allow there are two electrons in the inner (quantum) shell Allow there are five electrons in the outer (quantum) shell / five valence electrons	**(3)**

Question number	Answer	Additional guidance	Mark
(a)(v)	An explanation that makes reference to the following points: **Oxygen** • oxygen (atom) loses a paired electron (from a 2p orbital / 2p sub-shell) **or** electron is lost from a full (2p) orbital **(1)** **Nitrogen** • nitrogen (atom) loses an electron from a singly-occupied orbital **or** loses an electron from a half-filled subshell **(1)** **Repulsion** • there is (more) repulsion between **paired** electrons (than between electrons in different orbitals so less energy is required to remove the electron in oxygen) **(1)**	Penalise mention of incorrect orbital e.g. 3p once only Ignore any reference to nuclear charge / numbers of protons / shielding / atomic radius Allow M1 and M2 from diagrams showing electrons in boxes Allow oxygen has a pair of electrons in a (2)p orbital **or** there is spin pairing in oxygen in a (2)p orbital Allow nitrogen has no paired electrons in the (2)p sub-shell / (2)p orbitals **or** nitrogen only has 1 electron in each (2)p orbital / has 3 unpaired (2)p electrons / has a half-filled (2)p sub-shell / has half-filled (2)p orbitals Do not award just 'nitrogen has a half-filled p orbital'	**(3)**

Question number	Answer	Additional guidance	Mark
(b)(i)	• dot-and-cross diagram	Example of dot-and-cross diagram:  Allow overlapping circles Allow all dots / all crosses Allow dots and crosses in any order in the triple bond Allow the dots and crosses side-by-side in the triple bond e.g. x o x o x o Allow the non-bonded electrons on each N shown separately Ignore inner shell electrons, even if incorrect Ignore lines as bonds e.g. x x x o o o	(1)

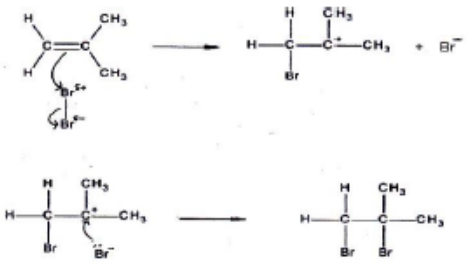
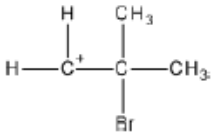
Question number	Answer	Additional guidance	Mark
(b)(ii)	• calculation of moles of nitrogen atoms • calculation of number of nitrogen atoms	Example of calculation: mol $N_2 = \frac{5.60}{28} = 0.20$ **and** mol N atoms = 0.20 x 2 = 0.40 **or** $\frac{5.60}{14} = 0.40$ number of N atoms = $0.40 \times 6.02 \times 10^{23}$ $= 2.408 \times 10^{23}$ / 2.41×10^{23} / 2.4×10^{23} TE on moles of nitrogen Ignore SF except 1SF Correct answer with no working scores (2)	(2)

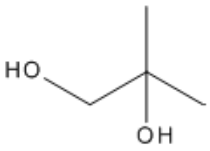
Question number	Answer	Additional guidance	Mark
(b)(iii)	• conversion of volume to m^3 **(1)** • conversion of temperature to K **(1)** • rearrangement of ideal gas equation **(1)** • evaluation to give n **(1)**	Example of calculation: volume of $N_2 = \frac{108}{1 \times 10^6} = 1.08 \times 10^{-4}$ m^3 temperature = 25 + 273 = 298 K $n = \frac{pV}{RT}$ **or** $n = \frac{1.36 \times 10^5 \times 1.08 \times 10^{-4}}{8.31 \times 298}$ TE on volume and temperature $n = 5.9312 \times 10^{-3}$ / 0.0059312 (mol) Conditional on correctly rearranged equation in M3 Ignore SF except 1SF Correct answer with no working scores full marks	**(4)**

Q10.

Question number	Answer	Additional guidance	Mark
(a)	• CH_2	Allow H_2C Ignore C_nH_{2n} / C_4H_8 Do not award C_3H_6	**(1)**

Question number	Answer	Additional guidance	Mark
(b)	• there are two hydrogens / both hydrogens on one of the carbons (in C=C) **or** there are two / both methyl / CH_3 groups on one of the carbons (in C=C)	Allow there are two identical (functional) groups / atoms on each carbon (in C=C) Allow there is not CH_3 and H on each carbon (in C=C) Allow there are not 2 different (functional) groups / atoms on each carbon (in C=C) Do not award two identical groups on the top / bottom of the double bond Do not award molecule or radical for ((functional) groups / atoms	**(1)**

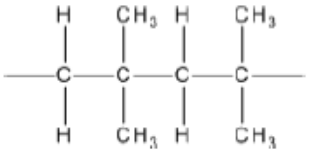
Question number	Answer	Additional guidance	Mark
23(c)	• dipole on bromine molecule **and** final product **(1)** • curly arrow from C=C to Br **and** curly arrow from Br-Br to, or just beyond, Br **(1)** • intermediate • lone pair on Br^- **and** curly arrow from lone pair to positive charge **(1)**	Example of mechanism:  Allow intermediate with positive charge on other carbon atom  Allow full marks for using formula 2 / any combination of structural and displayed formula Penalise half arrow heads once only Do not award δ+ on intermediate in M3 Do not award δ- on Br in M4	**(4)**

Question number	Answer	Additional guidance	Mark
(d)(i)	• skeletal formula	Example of skeletal formula:  Ignore bond lengths and bond angles Do not allow O-H-C horizontally	**(1)**

Question number	Answer	Additional guidance	Mark
(d)(ii)	• (From)purple (to) colourless	Both colours needed for the mark Allow pink or violet for purple Ignore clear	**(1)**

Question number	Answer	Additional guidance	Mark
(d)(iii)	• hydrogen bromide / HBr	Ignore state symbols (g) / (l) / (aq) / (s) Do not award bromine	(1)

Question number	Answer	Additional guidance	Mark
(d)(iv)	An explanation that makes reference to the following points: • (2-bromo-2-methylpropane is formed from a) tertiary carbocation / tertiary intermediate **(1)** • (tertiary carbocation / intermediate) is more stable than primary (carbocation) **or** a tertiary carbocation is the **most** stable **(1)**	Allow a description of a tertiary carbocation Do not award secondary carbocation for M1 Allow primary carbocation is less stable than tertiary Allow secondary carbocation is more stable than primary, if secondary carbocation identified in M1 Ignore just 'tertiary carbocation is more stable' Ignore any explanation of why one cation is more stable than another Ignore any reference to Markovnikov's rule Do not award tertiary **product** is more stable (than primary)	(2)

Question number	Answer	Additional guidance	Mark
(e)	• 4 carbon atoms linked by single bonds **and** both extension bonds **(1)** • rest of structure correct **(1)**	Example of repeat units:  Allow any combination of structural and displayed formulae or skeletal formulae Do not award 1, or more than 2, repeat units / 2 separate repeat units in M1 Penalise one or both extension bonds missing in M1 only M2 is conditional on M1 **or** 1 or more than 2 repeat units / 2 separate repeat units Allow both methyl groups on carbons one and three or two and three or one and four Ignore any brackets and any 'n's or numbers Ignore bond lengths and bond angles Ignore connectivity of CH_3 groups	**(2)**

Question number	Answer	Additional guidance	Mark
(f)	• calculation / working of mol of alcohol **(1)** • calculation / working of mol of alkene if 58.2% **(1)** • calculation / working of mass of alkene **(1)** • answer given to 2 or 3 SF **(1)** **Alternative method for M2 and M3** • calculation / working of theoretical mass of alkene **(1)** • calculation / working of actual mass of alkene **(1)**	Example of calculation: mol alcohol used = $\frac{6.85}{74}$ = 0.092568 / 9.2568 x 10^{-2} mol alkene if 58.2% = 0.092568 x $\frac{58.2}{100}$ = 0.053874 / 5.3874 x 10^{-2} TE on mol alcohol mass alkene = 0.053874 x 56 = 3.017 (g) TE on mol alkene answer to 2 or 3 SF = 3.0 / 3.02 (g) Conditional on working involving 74 and 56 Correct answer to 2 or 3SF with or without working scores (4) **Alternative method for M2 and M3** mass alkene if 100% = 0.092568 x 56 = 5.1838 (g) TE on mol alcohol mass alkene if 58.2% = 5.1838 x $\frac{58.2}{100}$ = 3.017 (g) TE on theoretical mass	**(4)**

Q11.

Q	Answer	Mark
	The only correct answer is C (500 cm^3 of 1.0 mol dm^{-3} NaCl) ***A*** *is incorrect because this contains 0.2 x 1.5 x 3 = 0.9 mol of ions but* ***C*** *contains 0.5 x 1.0 x 2 = 1.0 mol of ions* ***B*** *is incorrect because this contains 0.4 x 0.8 x 2 = 0.64 mol of ions but* ***C*** *contains 1.0 mol of ions* ***D*** *is incorrect because this contains 1.0 x 0.25 x 3 = 0.75 mol of ions but* ***C*** *contains 1.0 mol of ions*	**1**

Q12.

Question Number	Answer	Mark
	The only correct answer is C (39.2%) **A** *is not correct because the O on the right-hand side has been multiplied by 2, not 6* **B** *is not correct because the O on the right-hand side has been multiplied by 4, not 6* **D** *is not correct because the mass of oxygen has been divided by the mass of KCl*	(1)

Q13.

Question number	Answer	Mark
	The only correct answer is B (45.8 %) *A is incorrect because the relative atomic mass of Fe on the right-hand side has not been multiplied by 2* *C is incorrect because the relative atomic mass of Fe has not been multiplied by 2 and the relative molecular mass of CO_2 has not been multiplied by 3* *D is incorrect because the relative molecular mass of CO_2 has not been multiplied by 3*	(1)

Q14.

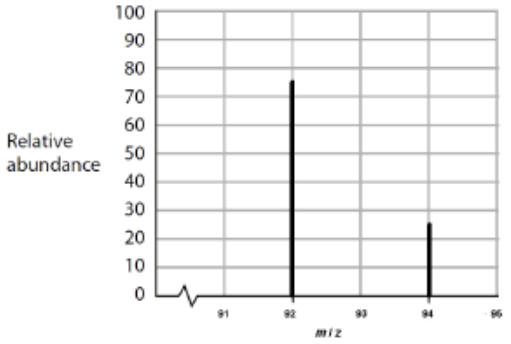
Question number	Answer	Additional guidance	Mark
(a)(i)	• 17 protons (1) • 18 neutrons (1)	Any reference to electrons scores (1) for an answer that includes 17 protons **and** 18 neutrons	(2)

Question number	Answer	Additional guidance	Mark
(a)(ii)	• $(1s^2)2s^22p^63s^23p^6$	Allow $2p_x^22p_y^22p_z^2$ and/or $3p_x^23p_y^23p_z^2$ Allow numbers of electrons written as subscripts or large numbers Ignore repeated $1s^2$	(1)

Question number	Answer	Additional guidance	Mark
(a)(iii)	• correct working (1) • answer given to 2 dp (1)	Example of calculation: $\frac{(35 \times 75.53) + (37 \times 24.47)}{100}$ (= 35.4894) or (35 x 0.7553) + (37 x 0.2447) (= 35.4894) 35.49 TE on working involving two different species Correct answer to 2 dp with no working scores (2) 35.50 with no working scores (0) Ignore units, even if incorrect	(2)

Question number	Answer	Additional guidance	Mark
(b)(i)	• dot-and-cross diagram showing three pairs of electrons between one Cl and three F atoms (1) • rest of diagram correct conditional on M1 (1)	Example of dot-and-cross diagram:  Allow overlapping circles Allow all dots / all crosses Allow 4 non-bonded electrons on Cl shown as: 2 lone pairs together or 2 lone pairs between any two of the bonded pairs or 1 lone pair and 2 unpaired electrons or 3 electrons and 1 electron Ignore inner shell electrons / lines for bonds Penalise a charged species in M2 only	(2)

Question number	Answer	Additional guidance	Mark
(b)(ii)	• there are 10 electrons / 5 pairs of electrons in the outer / valence shell of chlorine	Allow there are more than 8 electrons in the outer / valence shell of chlorine Allow there are 3 bond pairs and 2 lone pairs (in the outer shell of chlorine) Allow chlorine has expanded its octet Allow chlorine does not have a noble gas electronic structure / does not have 8 electrons in the outer / valence shell Allow just 'chlorine has 10 electrons' / 'more than 8 electrons' Ignore chlorine is the central atom Ignore just 'chlorine has 2 lone pairs' Do not award incorrect numbers of electrons / orbitals	(1)

Question number	Answer	Additional guidance	Mark
(b)(iii)	• a peak at *m/z* = 92 (1) • a peak at *m/z* = 94 (1) • peaks at 92 and 94 are in the ratio 3:1 approximately (1)	Example of mass spectrum:  Allow any 3:1 ratio for the peaks e.g. 100:33, 30:10 Ignore any labels on the peaks M3 is a stand alone mark for peaks at 92 and 94 only	(3)

Question number	Answer	Additional guidance	Mark
(b)(iv)	• conversion of temperature to K (1) • rearrangement of Ideal Gas Equation (1) • evaluation to give volume (1) • conversion of volume to cm^3 **and** answer given to 2 or 3 SF (1)	Example of calculation: temperature = 60 + 273 = 333 K $V = \frac{nRT}{P}$ or $V = \frac{0.0200 \times 8.31 \times 333}{1.28 \times 10^5}$ $V = 4.3238 \times 10^{-4}$ (m^3) TE on temperature volume = $4.3238 \times 10^{-4} \times 1 \times 10^6$ = (432.38) = 432 / 430 / 4.32×10^2 / 4.3×10^2 (cm^3) TE on volume in M3 Penalise rounding to 1SF once only in M1, M2 and M3 Correct answer with no working scores full marks	(4)

Q15.

Q	Answer	Mark
	The only correct answer is A (2×10^{10}) ***B*** *is incorrect because the mass of gold has not been converted into moles* ***C*** *is incorrect because kg has not been converted into g* ***D*** *is incorrect because the mass of gold has not been converted into moles and kg has not been converted into g*	**1**

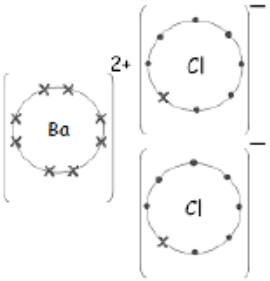
Q16.

Question Number	Answer	Mark
	The only correct answer is B (7.22×10^{21}) **A** *is not correct because a 1:1 ratio has been used instead of 1:6* **C** *is not correct because a 1:7 ratio has been used instead of 1:6* **D** *is not correct because this is the number of atomic mass units in the product*	(1)

Q17.

Question Number	Correct Answers	Additional Guidance	Mark
(a)(i)	$Ba^{2+}(g) \rightarrow Ba^{3+}(g) + e^{(-)}$ OR $Ba^{2+}(g) - e^{(-)} \rightarrow Ba^{3+}(g)$	Allow $e^{(-)}(g)$ / $1e^{(-)}$ Do not award multiples Allow ions shown as $Ba^{+2}(g)$ and $Ba^{+3}(g)$ Allow Ba^{++} / Ba^{+++} Comment – allow lower case 'ba^{2+}' etc	1

Question Number	Correct Answers	Additional Guidance	Mark
(a)(ii)	An answer that makes reference to the following: • there is a **large** increase (in ionisation energy) **and** • between the 2nd and 3rd ionisations	Note – there must be some indication of a significant increase Allow just there is a jump Allow 'after 2 electrons are removed' / between the 2nd and 3rd electrons Ignore comments related to first ionisation energy	1

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(i)	An answer that makes reference to one of the following points: • barium ion shown correctly (1) • one chloride ion shown correctly **and** an indication of two chloride ions present (1) example of dot-and-cross diagram  	Allow barium ion with no electrons shown Allow lower case 'ba' Ignore any inner shells shown for Ba^{2+} If inner shells shown for Cl^- they must be correct Allow all dots or all crosses Ignore absence of square brackets Ignore any working Do not award covalent diagrams Comment If all charges are omitted, we assume the bonding is covalent so scores zero	2

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(ii)	• calculation of moles of barium chloride (1) • calculation of mass of barium chloride to 2 or 3 SF (1)	<u>Example of calculation</u> $0.200 \times (150 \div 1000) = 0.03$ (mol) Ignore units in M1 even if incorrect $0.03 \times 208.3 = 6.249$ = 6.2 / 6.25 (g) Do not award 6.3 Ignore absence of units but if given must be correct in M2 Correct answer with no working scores 2 marks Allow 0.03 x 208 = 6.24 / 6.2 for M2 Allow TE from M1 to M2	2

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(iii)	$2H^+ + CO_3^{2-} \rightarrow H_2O + CO_2$	Accept $2H_3O^+ + CO_3^{2-} \rightarrow 3H_2O + CO_2$ Allow H_2CO_3 Allow multiples Ignore state symbols even if incorrect Do not award uncancelled chloride ions	1

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)	An answer that makes reference to the following point: • (the) ions are not free to move (and carry charge) / (the) ions are in a fixed position (so cannot carry charge)	Do not award 'electrons are not free to move' Do not award if any statement that $BaCl_2$ is covalent	1

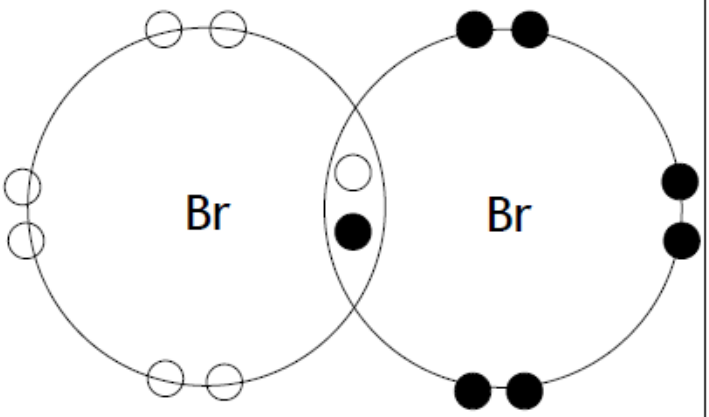
Q18.

Question number	Answer	Mark
	The only correct answer is B (barium chloride is a compound) *A is incorrect because barium chloride is ionic* *C is incorrect because this is not the simplest ratio* *D is incorrect because the M_r is 208.3*	(1)

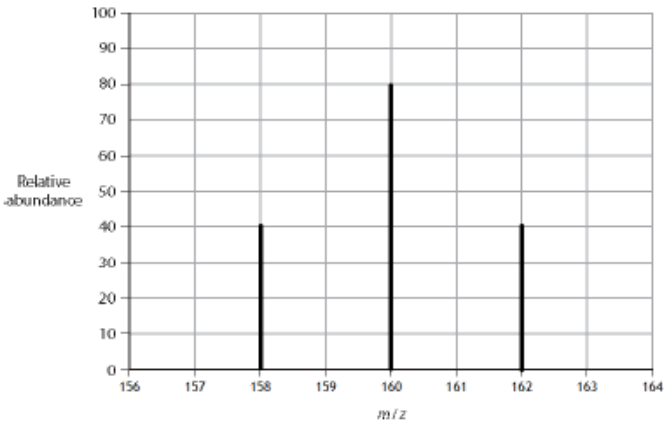
Q19.

Question number	Answer	Additional guidance	Mark
(a)	An answer that makes reference to • (atoms with the) same atomic number and different mass numbers	Accept proton number for atomic number or same number of protons but different numbers of neutrons Allow bromine-79 has 35 protons & 44 neutrons **and** bromine-81 has 35 protons & 46 neutrons Allow "an atom" or "element" Do not award molecule Ignore same number of electrons	1

Question number	Answer	Additional guidance	Mark
(b)	An answer that makes reference to: • all subatomic particles correct for bromine-79 (1) • all subatomic particles correct for bromine-81 (1)	<table><tr><th>Protons</th><th>Neutrons</th><th>Electrons</th></tr><tr><td>35</td><td>44</td><td>35</td></tr><tr><td>35</td><td>46</td><td>35</td></tr></table> Any four correct scores 1	2

Question number	Answer	Additional guidance	Mark
(c)(i)	A diagram showing: • one shared pair of electrons (1) • six non-bonding electrons on **both** atoms in the molecule (1)	Example of diagram:  Accept shared electrons on circles between the atoms Accept omission of circles or chemical symbols Allow any symbols for the electrons or elements (even if incorrect) Allow non-bonding electrons to be unpaired Allow horizontal sharing of bond pair Ignore horizontal line representing the bond	2

Question number	Answer	Additional guidance	Mark
(c)(ii)	An answer that makes reference to: • (a beam of) high energy electrons striking the (gaseous) bromine (molecule) (1) • equation for the formation of the molecular ion (1)	Both marks may be scored with a correct equation and any indication the **bombarding** electrons are high energy Allow 'high speed electrons' Allow electron gun Allow "fast moving" Allow bromine atoms $Br_2 + e^{(-)} \rightarrow Br_2^+ + 2e^{(-)}$ Allow $Br_2 \rightarrow Br_2^+ + e^{(-)}$ $Br_2 - e^{(-)} \rightarrow Br_2^+$ Allow $^{81}Br^{81}Br$ (etc) instead of Br_2 on either side of the equation Ignore state symbols even if incorrect Do not award $Br_2 \rightarrow 2Br^+ + 2e^{(-)}$ or $\frac{1}{2}Br_2 \rightarrow Br^+ + e^{(-)}$	2

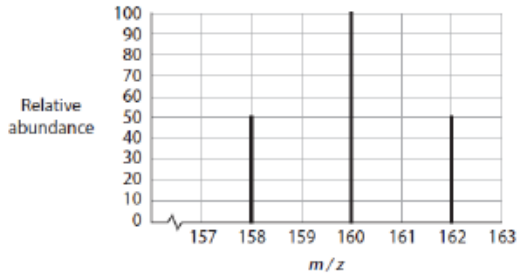
Question number	Answer	Additional guidance	Mark
(c)(iii)	An answer on the grid showing: • three peaks: at *m/z* = 158, *m/z* = 160 and *m/z* = 162 (1) • peak heights in the ratio 1:2:1 (for 158: 160: 162) (1)	Example of grid:  Allow bars or "X" at the top of any lines Allow bars shown around the m/z values Do not award if a line is drawn from peak to peak Do not award if more than three peaks Allow any abundance values No TE on incorrect *m/z* values	2

Question number	Answer	Additional guidance	Mark
(d)	• weighted mean mass expression (1) • evaluation of relative atomic mass for Br (1) • calculation of relative molecular mass for Br_2 corrected to 2 d.p. (1)	Example of calculation: $A_r = \frac{79 \times 56.38 + 81 \times 43.62}{100}$ = 79.87 2 x 79.87 = 159.74 = 159.74 Allow TE to M2 for values between 79 and 81 Allow TE for M3 of double M2 value Ignore units even if incorrect Penalise rounding errors once only Correct answer to 2 d.p. scores (3) A **final** answer of 79.9 or 79.872 only scores 1 mark	3

Q20.

Question number	Answer	Additional guidance	Mark
(a)	• $[Ar]3d^{10}4s^24p^5$	Allow $4s^23d^{10}4p^5$ Ignore $1s^22s^22p^63s^23p^6$ for (Ar) written out but do not allow incorrect electronic configuration for Ar	1

Question number	Answer					Additional guidance	Mark
(b)(i)						1 mark for each row correct	2
	Species	Protons	Neutrons	Electrons			
	^{79}Br	35	44	35	(1)		
	$^{81}Br^-$	35	46	36	(1)		

Question number	Answer	Additional guidance	Mark
(b)(ii)	 • lines at 158 and 160 and 162 (1) • relative abundances 50:100:50 (1)	Allow relative abundances in any ratio 1:2:1, e.g. 25:50:25	2

Question number	Answer	Additional guidance	Mark
(b)(iii)	• calculation of amount (mol) of Br_2 (1) • calculation of molecules of Br_2 (1)	Example of calculation: Amount of Br_2 = $\frac{2.00}{160}$ = 0.0125 (mol) Molecules of Br_2 = $0.0125 \times 6.02 \times 10^{23}$ = 7.525×10^{21} or Amount of Br_2 = $\frac{2.00}{(2 \times 79.9)}$ = 0.012516 (mol) Molecules of Br_2 = $0.012516 \times 6.02 \times 10^{23}$ = 7.5344×10^{21} TE on amount Br_2 Correct answer with no working scores both marks Ignore SF except 1 SF	2

Question number	Answer	Additional guidance	Mark
(c)	• conversion of volume to m^3 (1) • conversion of temperature to K (1) • rearrangement of expression (1) • evaluation to give n (1)	Example of calculation: Volume of bromine = $\frac{200}{1 \times 10^6} = 2.00 \times 10^{-4}$ m^3 77+273 = 350 $1.51 \times 10^5 \times 2.00 \times 10^{-4} = n \times 8.31 \times 350$ TE on volume bromine $n = \frac{1.51 \times 10^5 \times 2.00 \times 10^{-4}}{8.31 \times 350}$ $n = 1.03834 \times 10^{-2}$ Ignore SF except 1SF Correct answer with no working scores full marks	4

Q21.

Question Number	Answer	Mark
(a)	**The only correct answer is C** (10) ***A*** *is incorrect because this is the ratio by mass* ***B*** *is incorrect because in the mass ratio the unit of kg has been ignored and this is based on 10 mg of sulfur in 1 g of fuel* ***D*** *is incorrect because this is based on 10 g of sulfur in 1 kg of fuel*	(1)

Question Number	Answer	Mark
(b)	**The only correct answer is A** (0.024 dm^3) ***B*** *is incorrect because the molar mass of sulfur has not been taken into account* ***C*** *is incorrect because the mass ratio has been ignored* ***D*** *is incorrect because the units of mg have been ignored*	(1)

Q22.

Question Number	Answer	Mark
(a)	**The only correct answer is B** (0.029) ***A*** *is incorrect because this is just the number of moles of sodium* **C** *is incorrect because this assumes the number of moles of sodium is 0.1* **D** *is incorrect because this is the concentration in g* dm^{-3}	**(1)**

Question Number	Answer	Mark
(b)	**The only correct answer is A** (120) ***B*** *is incorrect because the mole ratio of 1:1 has been used* ***C*** *is incorrect because the mole ratio has been taken as 2:1 rather than 1:2* ***D*** *is incorrect because the mass of sodium has been taken as the number of moles*	**(1)**

Question Number	Answer	Mark
(c)	**The only correct answer is A** ($H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$) ***B*** *is incorrect because the water has been ignored* ***C*** *is incorrect because the sulfuric acid has not been shown as ions* ***D*** *is incorrect because all the ions are shown but none are cancelled*	**(1)**

Question Number	Answer	Mark
(d)	**The only correct answer is A** (29.1 %) ***B*** *is incorrect because this is the percentage ratio of magnesium hydroxide to sodium sulfate* ***C*** *is incorrect because this is the percentage ratio of magnesium hydroxide to magnesium sulfate* ***D*** *is incorrect because this is the percentage mole ratio of the product*	**(1)**

Q23.

Question Number	Answer	Mark
	The only correct answer is C (27.90 tonnes) **A** *is not correct because the wrong ratio (2:1) has been used instead of 1:2* **B** *is not correct because the wrong ratio (1:1) has been used instead of 1:2* **D** *is not correct because the wrong ratio (1:3) has been used instead of 1:2*	(1)

Q24.

Question Number	Correct Answer	Mark
	The only correct answer is C (0.0654) *A is incorrect because this is the moles of hydrated copper(II) sulfate used* *B is incorrect because this is the moles of anhydrous copper(II) sulfate used* *D is incorrect because the $5H_2O$ are not included in the molar mass*	1

Q25.

Question Number	Correct Answer	Mark
	The only correct answer is A (5.65) *B is incorrect because the yield of 95% has not been used* *C is incorrect because the 2:1 ratio in the equation has not been used* *D is incorrect because the yield of 95% and the 2:1 ratio in the equation have not been used*	1

Q26.

Question Number	Correct Answer	Mark
	The only correct answer is D (54.2) *A is incorrect because the volume has been divided by the density rather than multiplied* *B is incorrect because the volume has been divided by the density, then divided by the atomic number* *C is incorrect because the volume has been divided by the relative atomic mass*	1

Q27.

Question number	Answer	Mark
	The only correct answer is B (0.684) ***A*** *is not correct because this is the number of moles of sodium chloride in 250 cm^3* ***C*** *is not correct because this is the mass of sodium chloride in 250 cm^3* ***D*** *is not correct because this is the concentration of sodium chloride in g dm^{-3}*	1

Q28.

Question number	Answer	Mark
	C 30.0	1

Q29.

Question number	Answer	Mark
	C 0.20	1

Q30.

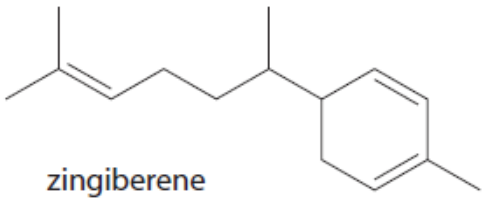
Question number	Answer	Mark
	The only correct answer is A (0.1 g dm^{-3} HCl) ***B*** *is incorrect because HCl has a higher concentration of chloride ions* ***C*** *is incorrect because HCl has a higher concentration of chloride ions* ***D*** *is incorrect because HCl has a higher concentration of chloride ions*	1

Q1.

Zingiberene is the compound that gives ginger its characteristic flavour. Its IUPAC name is 2-methyl-5-(6-methylhept-5-en-2-yl)cyclohexa-1,3-diene.

(a) On the structure of zingiberene, draw a circle around the '2-methyl' group referred to in the IUPAC name.

(1)



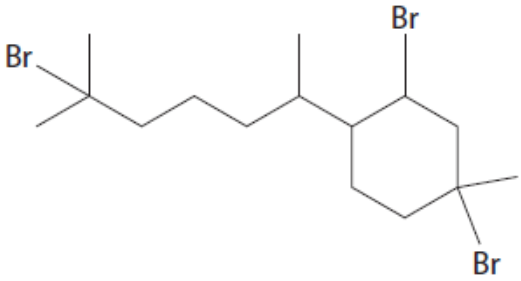
zingiberene

(b) Deduce the molecular formula of zingiberene.

(2)

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(c) When zingiberene reacts with excess hydrogen bromide, there are a number of possible products. The structure of the major product is shown.



(i) Name the type and mechanism of the reaction.

(1)

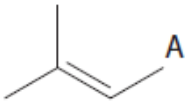
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(ii) The diagram shows a simplified structure of zingiberene, in which part of the molecule is represented by A.

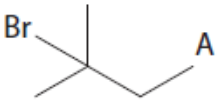
Complete the mechanism for the reaction of zingiberene with **one** molecule of hydrogen bromide.

Include curly arrows, and any relevant dipoles and lone pairs.

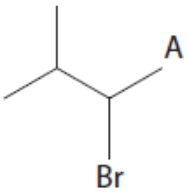
(4)



(iii) For the reaction in (c)(ii) there are two possible products:



I



II

Explain why I is the major product, by referring to your mechanism.

(2)

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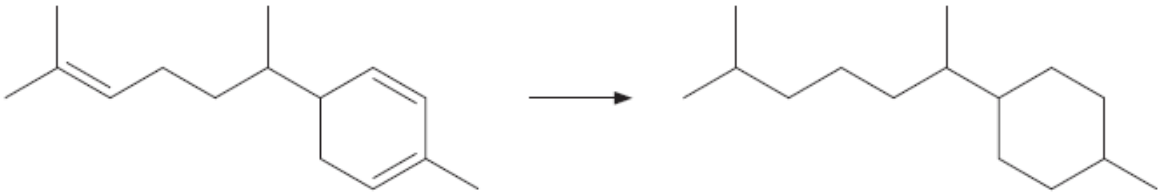
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(d) Zingiberene reacts with hydrogen gas in the presence of a catalyst.



(i) Identify the catalyst, by name or formula.

(1)

.....

(ii) 2.0 mol of zingiberene react completely with hydrogen at 150 °C and a pressure of 120 kPa.

Calculate the minimum volume of hydrogen needed under these conditions, stating your units.

[Ideal gas equation is $pV = nRT$ Gas constant (R) = 8.31 J mol^{-1} K^{-1}]

(4)

(Total for question = 15 marks)

Q2.

Answer the questions with a cross in the boxes you think are correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

When zinc is added to copper(II) sulfate solution, copper is formed.

(a) Which of these is the best name for this type of reaction?

(1)

☒ **A** addition

☒ **B** displacement

☒ **C** neutralisation

☒ **D** substitution

(b) Which is the ionic half-equation for a process that takes place during this reaction?

(1)

☒ **A** $Cu^{2+} + e^- \rightarrow Cu^+$

☒ **B** $Cu^+ + e^- \rightarrow Cu$

☒ **C** $Zn \rightarrow Zn^+ + e^-$

☒ **D** $Zn \rightarrow Zn^{2+} + 2e^-$

(Total for question = 2 marks)

Q3.

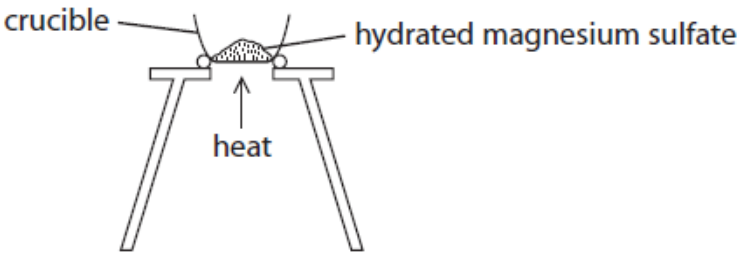
This question is about the amount of water of crystallisation in hydrated magnesium sulfate, $MgSO_4 \cdot \mathbf{x}\ H_2O$.

(a) The value of **x** in the formula was determined in an experiment.

Procedure

Step 1 A crucible was weighed, a spatula measure of hydrated magnesium sulfate was added and the crucible was reweighed.

Step 2 The crucible containing the hydrated magnesium sulfate was heated using the apparatus shown.



Step 3 After heating for two minutes, the crucible containing the magnesium sulfate was allowed to cool and was reweighed.

(i) Complete the table of results.

(1)

Measurement	Mass / g
Mass of empty crucible	21.21
Mass of crucible and hydrated magnesium sulfate before heating	26.71
Mass of crucible and magnesium sulfate after heating for two minutes	24.12
Mass of magnesium sulfate after heating for two minutes	
Mass of water lost	

(ii) Use these results to calculate the value of **x** in $MgSO_4 \bullet \mathbf{x}\ H_2O$.

Give your answer to the nearest whole number.

[A_r values: H = 1.0 O = 16.0 Mg = 24.3 S = 32.1]

(4)

(b) The correct value of **x** is greater than the value calculated in (a)(ii).

Suggest a way of improving the method to obtain a more accurate result, using the same apparatus.
Justify your answer.

(2)

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(Total for question = 7 marks)

Q4.

A sample of hydrated calcium sulfate, $CaSO_4.\mathbf{x}H_2O$, was heated to constant mass. 3.405 g of anhydrous calcium sulfate and 0.900 g of water were formed.

What is the value of **x**?

[Relative formula mass: $CaSO_4$ = 136.2]

(1)

☒ **A** 0.5

☒ **B** 2

☒ **C** 3

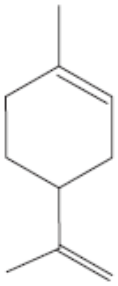
☒ **D** 4

(Total for question = 1 mark)

Q5.

Limonene is an oil extracted from the skin of citrus fruits such as oranges or lemons.
It is found in some cleaning products such as those used to remove chewing gum.

Limonene has the structure shown.



(a) Deduce the molecular formula of limonene.

(2)

.....

(b) (i) A few drops of acidified potassium manganate(VII) solution are mixed with a sample of limonene.

State the colour change.

(1)

From ..... to .....

(ii) Draw the skeletal formula of the structure of the **organic** product formed when the reaction in (b)(i) is carried out with **excess** acidified potassium manganate(VII).

(1)

(iii) Name the type of reaction that limonene undergoes in (b)(i).

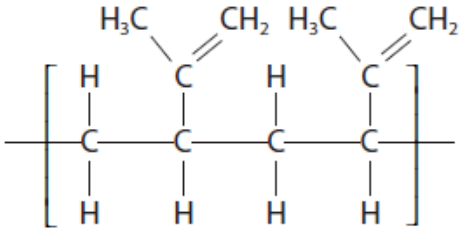
(1)

.....

(c) On heating, limonene reacts to form two molecules of a smaller hydrocarbon, **Q**.

Q can be polymerised to form **R**, a polymer used to improve the grip of car tyres.

A section of **R** is shown.



Section of polymer **R**

Draw the structure of **Q**.

(1)

(d) Give **two** ways in which chemists can help minimise problems caused by the disposal of polymers.

(2)

.....

.....

.....

.....

(e) Limonene is extracted from orange peel using a solvent.

Possible solvents are hexane and liquid carbon dioxide.

Liquid carbon dioxide can be obtained by allowing solid carbon dioxide to melt under high pressure.

(i) Suggest one advantage and one disadvantage of using liquid carbon dioxide rather than hexane to dissolve the limonene. Assume that the carbon dioxide does not escape into the atmosphere.

(2)

Advantage

.....

.....

Disadvantage

.....

.....

(ii) Orange peel contains 1.63 % of limonene by mass.

A chewing gum remover contains 30 cm^3 of limonene per bottle.

Calculate the mass of orange peel, in kg, needed to obtain 30 cm^3 of limonene.

[Density of limonene = 0.841 g cm^{-3}]

(3)

(Total for question = 13 marks)

Q6.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

In 1.31 g of a chloride of titanium, there is 0.528 g of titanium.

What is the empirical formula of this titanium chloride?

[A_r values: Ti = 47.9 Cl = 35.5]

☒ **A** TiCl

☒ **B** $TiCl_2$

☒ **C** $TiCl_3$

☒ **D** Ti_2Cl_4

(Total for question = 1 mark)

Q7.

Alkanes and alkenes are obtained from crude oil.

(a) Describe how a sample of octadecane can be obtained from a mixture of alkanes.

(2)

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.....

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(b) (i) Octadecane can be cracked to produce butene and **one** other product.

Complete the equation. State symbols are not required.

$$C_{18}H_{38} \rightarrow 2C_4H_8 +$$

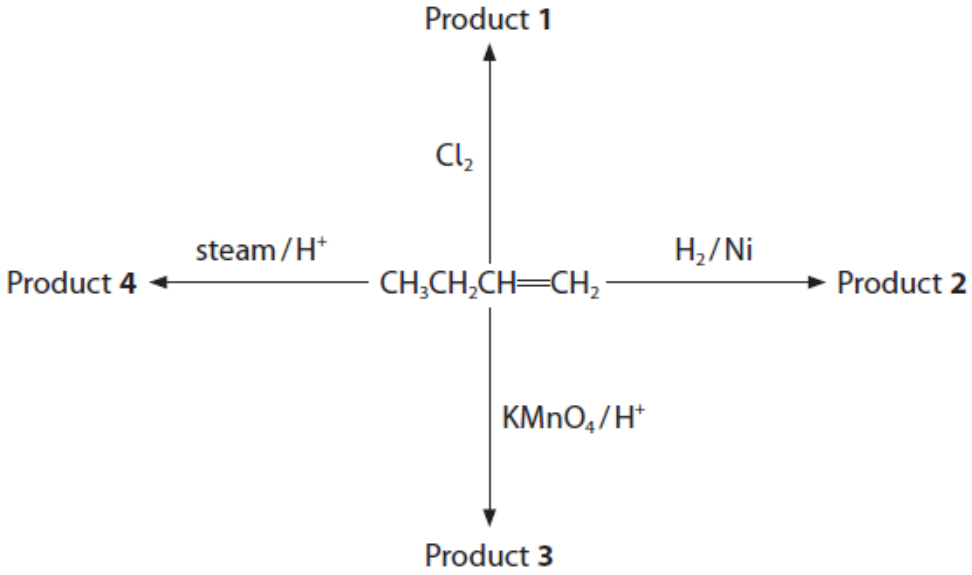
(1)

(ii) One of the products of this cracking reaction is but-1-ene.

Give the **skeletal** formulae for the other three **alkene** isomers of C_4H_8

(2)

(iii) Some reactions of but-1-ene are shown.



Give the name and **structural** formula of each of the products.

(4)

Product	Name	Structural formula
1		
2		
3		
4		

(c) Draw the displayed formula of poly(but-1-ene) showing two repeat units.

(2)

(d) State **one** advantage and **one** disadvantage of using incineration for the disposal of polymers, other than the effect on climate.

(2)

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.....

(e) (i) Butane is used as a fuel.

The equation for the complete combustion of butane is shown.

$$2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(l)$$

35.0 cm^3 butane is completely burned in 300 cm^3 oxygen.

Calculate the final total volume of gas in cm^3 .

All volumes are measured at the same temperature and pressure.

(3)

(ii) Explain the main hazard when using butane as a fuel in a portable heater in an enclosed space.

(2)

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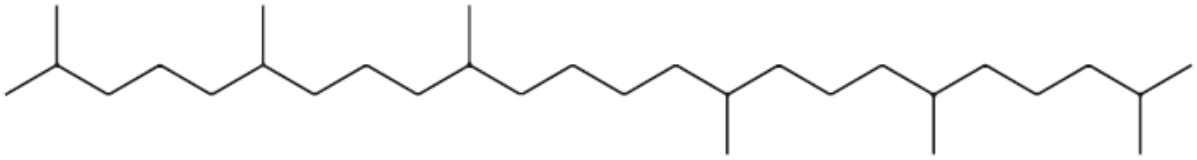
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(Total for question = 18 marks)

Q8.

This question is about the production of squalane, a liquid alkane which occurs naturally in human skin and is used in cosmetics.



squalane

(a) Suggest **two** properties that make squalane useful in cosmetics.

(2)

.....

.....

(b) Give the **molecular** formula of squalane.

(1)

.....

(c) Squalane can be produced from squalene, an alkene present in shark liver oil, by reaction with hydrogen gas in the presence of a suitable catalyst.

(i) Give the name of a suitable catalyst for the hydrogenation of squalene.

(1)

.....

(ii) Squalane used in cosmetic products must contain no more than 0.2 ppm by mass of catalyst.

Calculate the maximum permitted mass of catalyst in a product containing 50 g of squalane.

(1)

(iii) A reactor at 200°C contains 8500 mol of liquid squalene, and hydrogen gas at a pressure of 4.0×10^5 Pa.

Under these conditions, the complete hydrogenation of squalene requires 500 m^3 of hydrogen gas.

Calculate the number of C=C bonds in one molecule of squalene.

You **must** show your working.

[$pV = nRT$ $R = 8.31$ J mol^{-1} K^{-1}]

(4)

(iv) Write the equation, using molecular formulae, for the complete hydrogenation of squalene to squalane.
State symbols are **not** required.

(1)

(d) Globally, 2.8 million dm3 of squalene is used each year.
Traditionally squalene was obtained exclusively from shark liver oil, which is a mixture of liquids.

The liver of a shark yields 300 g of squalene.

(i) Suggest the name of a suitable technique to obtain squalene from shark liver oil.

(1)

.....

(ii) Calculate the minimum number of sharks that would be needed to produce 2.8 million dm^3 of squalene.

[Density of squalene = 0.86 g cm^{-3}]

(2)

(iii) Many large corporations now use squalane obtained entirely from plants.

Squalane can be obtained sustainably from corn starch with a yield of 23 % by mass.

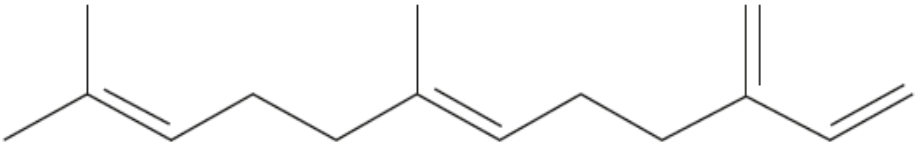
The production of 1 tonne of corn starch requires 0.093 hectares of land.

Calculate the area of land, **in km^2**, required to produce 2500 tonnes of squalane from corn starch.

[1 tonne = 1000kg 1 hectare = 0.01 km^2]

(3)

(e) The *E*-isomer of beta-farnesene can also be obtained from corn starch.



E-beta-farnesene

(i) Explain why beta-farnesene exhibits geometric isomerism and has only two geometric isomers.

You may label the structure and use this in your answer.

(2)

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(ii) Draw the **skeletal** formula of the geometric isomer of *E*-beta-farnesene, giving a reason why this is named the
Z-isomer.

(2)

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.....

(f) The compound alpha-farnesene, $C_{15}H_{24}$, is a structural isomer of beta-farnesene.

The structural formula of alpha-farnesene is

$$(CH_3)_2C=CHCH_2CH_2C(CH_3)=CHCH_2CH=C(CH_3)CH=CH_2$$

(i) State what is meant by the term **structural** isomers.

(2)

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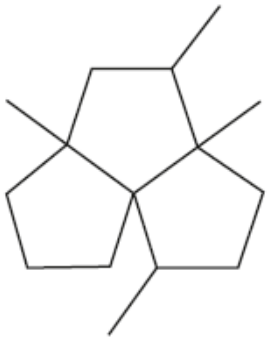
(ii) State the number of **geometric** isomers of alpha-farnesene.

(1)

.....

(iii) Complete the diagram to show another structural isomer of $C_{15}H_{24}$.

(1)



(Total for question = 24 marks)

Q9.

The partial oxidation of butane in the presence of a catalyst has been investigated as a possible source of hydrogen.

$$C_4H_{10}(g) + 2O_2(g) \rightarrow 4CO(g) + 5H_2(g)$$

(a) What is the most significant hazard associated with the pollutant CO(g)?

(1)

☒ **A** it is a major contributor to the formation of acid rain

☒ **B** it strongly absorbs infrared radiation

☒ **C** it is toxic at low concentrations

☒ **D** it is the main cause of ozone layer depletion

(b) A mixture of 40 cm^3 of butane and 20 cm^3 of oxygen reacts in a sealed system to form carbon monoxide and hydrogen.

What is the total volume of gas in the system at the end of the reaction, in cm^3?

(1)

☒ **A** 30

☒ **B** 60

☒ **C** 90

☒ **D** 120

(Total for question = 2 marks)

Use this space for any rough working. Anything you write in this space will gain no credit.

Q10.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Ammonium iron(II) sulfate, $(NH_4)_2Fe(SO_4)_2 \cdot 6H_2O$, is a double salt that is used as a source of iron(II) ions.

(a) What is the relative formula mass of the double salt?

[A_r values: H = 1.0 N = 14.0 O = 16.0 S = 32.1 Fe = 55.8]

(1)

☒ **A** 277.9

☒ **B** 284.0

☒ **C** 392.0

☒ **D** 447.8

(b) Ammonium sulfate is used in the preparation of the double salt.

What types of bond are present in ammonium sulfate?

(1)

☒ **A** ionic only

☒ **B** covalent and ionic only

☒ **C** dative covalent and ionic only

☒ **D** ionic, covalent and dative covalent

(c) What is the **total** number of ions present in 0.1 mol of the double salt?

[Avogadro constant (L) = 6.02×10^{23} mol^{-1}]

(1)

☒ **A** 1.80×10^{23}

☒ **B** 2.41×10^{23}

☒ **C** 3.01×10^{23}

☒ **D** 6.62×10^{23}

(Total for question = 3 marks)

Q11.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

What is the relative formula mass of hydrated sodium carbonate, $Na_2CO_3.\ 10H_2O$?

[A_r values: H = 1.0 C = 12.0 O = 16.0 Na = 23.0]

☒ **A** 106

☒ **B** 142

☒ **C** 263

☒ **D** 286

(Total for question = 1 mark)

Q12.

What is the relative formula mass of hydrated ammonium iron(II) sulfate, $(NH_4)_2Fe(SO_4)_2.6H_2O$?

[Relative atomic masses (A_r): H = 1.0 N = 14.0 O = 16.0 S = 32.1 Fe = 55.8]

(1)

☒ **A** 284

☒ **B** 302

☒ **C** 312

☒ **D** 392

(Total for question = 1 mark)

Q13.

This question is about silicon and carbon.

(a) Silicon is a semiconductor.

(i) Data obtained using the mass spectrum of silicon are shown.

Isotope mass number	Relative abundance
28	92.17
29	4.71
30	3.12

Calculate the relative atomic mass of silicon to **two** decimal places.

(2)

(ii) Suggest a reason why there is a small peak in the mass spectrum of silicon at $m/z = 14$

(1)

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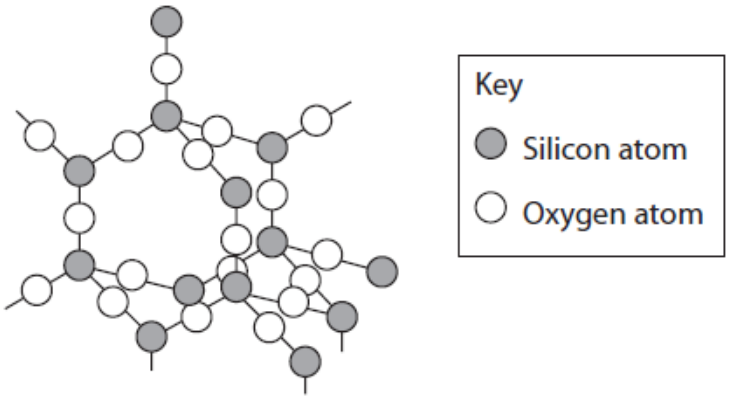
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(iii) Complete the table to show the number of protons and neutrons in each isotope of silicon.

Isotope	Number of protons	Number of neutrons
^{28}Si		
^{29}Si		
^{30}Si		

(1)

(b) Silicon dioxide, SiO_2, is the main constituent of sand and has a giant lattice structure similar to that of diamond.



Crystalline silicon dioxide is used on the surface of semiconductor devices to provide a heat-resistant, electrically insulating layer.

Explain how the structure and bonding of silicon dioxide make it useful for this application.

(3)

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(c) Calcium silicate is formed in the removal of silicon dioxide impurities in the extraction of iron from its ores. A sample of calcium silicate composed of calcium, silicon and oxygen was found to contain 12.0 g of calcium, 8.43 g of silicon and 14.47 g of oxygen.

Determine the empirical formula of calcium silicate.
You **must** show your working.

(3)

(d) Carbon dioxide is a gas at room temperature. A fizzy drink is canned at 5.0 °C and 1.3×10^5 Pa and contains approximately 3 g of carbon dioxide.

Calculate the volume, in cm^3, occupied by 3.00 g of carbon dioxide gas at 5.0 °C and 1.3×10^5 Pa.

[$pV = nRT$ $R = 8.31$ J mol^{-1} K^{-1}]

(4)

(Total for question = 14 marks)

Q14.

Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

There are 6.02×10^{23} atoms in 0.25 mol of

☒ **A** He

☒ **B** H_2O

☒ **C** BH_3

☒ **D** CH_4

(Total for question = 1 mark)

Q15.

Magnesium is a metal in Group 2 of the Periodic Table. It reacts with chlorine to form the salt magnesium chloride, $MgCl_2$.

(a) Draw a dot-and-cross diagram for magnesium chloride.

Show outer shell electrons only.

(1)

(b) Magnesium conducts electricity when it is in the solid state. Magnesium chloride conducts electricity when it is molten or dissolved in water but not when it is in the solid state.

Explain these observations.

(3)

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(c) Magnesium chloride can also be made by reacting magnesium oxide with dilute hydrochloric acid.

$$MgO(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l)$$

(i) Write the **ionic** equation, including state symbols, for this reaction.

(1)

(ii) Calculate the minimum volume of 2.00 mol dm^{-3} hydrochloric acid needed to completely react with 2.45 g of magnesium oxide.

(3)

Minimum volume of hydrochloric acid = ... cm^3

(d) A further method for making magnesium chloride is by reacting magnesium carbonate with dilute hydrochloric acid.

$$MgCO_3(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l) + CO_2(g)$$

Calculate the maximum mass of magnesium chloride that could be formed when 2.25 g of magnesium carbonate is added to excess dilute hydrochloric acid.

(2)

Maximum mass magnesium chloride = ... g

(e) Explain why the reaction to make magnesium chloride from magnesium oxide has a higher atom economy than the reaction using magnesium carbonate.

No calculation is required.

(2)

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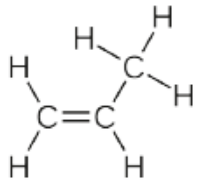
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(Total for question = 12 marks)

Q16.

This question is about the reactions of propene.



propene

(a) Write an equation for the incomplete combustion of **one mole** of propene to form carbon dioxide, carbon monoxide,
carbon and water as the only products. Include state symbols.

(2)

(b) State **one** similarity and **one** difference that would be **seen** when propene is mixed with separate samples of
acidified potassium manganate(VII) solution and of bromine water.

(2)

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(c) Propene reacts by addition polymerisation to form poly(propene).

Draw the structure of poly(propene), showing **two** repeat units.

(1)

(d) Propene reacts with bromine monochloride, BrCl, to form 1-bromo-2-chloropropane as the major product.

(i) Complete the diagram of bromine monochloride to show the dipole.

(1)

Br ——— Cl

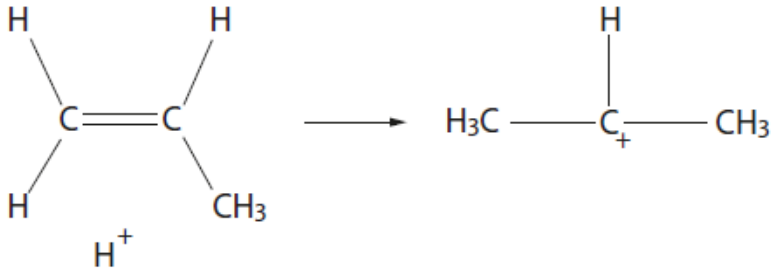
(ii) Draw the mechanism for the formation of 1-bromo-2-chloropropane in this reaction.
Include curly arrows, and relevant lone pairs.

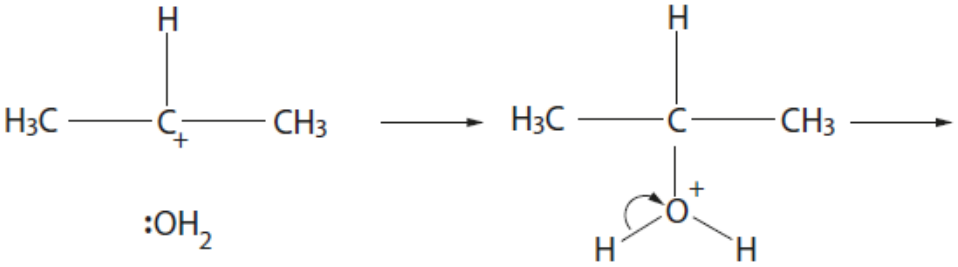
(3)

(e) Propene reacts with steam in the presence of an acid catalyst to form a mixture of the alcohols propan-1-ol and propan-2-ol.

Complete the mechanism for the formation of propan-2-ol, by adding curly arrows.
Include the species formed in the final step.

(3)





(Total for question = 12 marks)

Q17.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Propane burns completely in oxygen as shown.

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$$

100 cm^3 of propane was mixed with 600 cm^3 of oxygen and the mixture was ignited.

What is the **total** volume, in cm^3, of the gas mixture at the end of the reaction?
All gas volumes were measured at room temperature and pressure.

☒ **A** 300

☒ **B** 400

☒ **C** 700

☒ **D** 800

(Total for question = 1 mark)

Q18.

This question is about phosphorus and some of its compounds.

(a) The atomic number of phosphorus is 15.

(i) Complete the electronic configuration of a phosphorus atom using the electrons-in-boxes notation.

(1)



(ii) Explain why the first ionisation energy of phosphorus is greater than that of sulfur.

(2)

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(b) Phosphorus has a melting temperature of 44 °C.

Silicon has a melting temperature of 1410 °C.

Explain why the melting temperature of phosphorus is much lower than that of silicon.

(3)

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(c) Phosphorus(V) chloride, PCl_5 , exists as covalent molecules in the gaseous state.

(i) Complete the table for a PCl_5 molecule.

(3)

Number of bonding pairs of electrons on phosphorus		
Number of lone pairs of electrons on phosphorus		
Shape of molecule		
Cl—P—Cl bond **angles**		

(ii) In the solid state, phosphorus(V) chloride is ionic.

The cation and anion each have one phosphorus atom but a different number of chlorine atoms.

The cation is tetrahedral and the anion is octahedral.

Predict the formula of each ion. Include the charge on each ion.

(2)

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(d) In an experiment, 8.00 cm^3 of 0.250 mol dm^{-3} sodium hydroxide, NaOH, reacted completely with 10.0 cm^3 of 0.100 mol dm^{-3} phosphoric acid, H_3PO_4 .

Use these data to deduce the balanced equation for this reaction.
You **must** show your working.

(3)

(e) Hydrated magnesium phosphate has the formula $Mg_3(PO_4)_2.\mathbf{y}H_2O$.

A sample of this compound contains 78.5% by mass of anhydrous magnesium phosphate.

Deduce the value of **y**.

You **must** show your working.

[Molar mass of anhydrous magnesium phosphate, $Mg_3(PO_4)_2$ = 262.9 g mol^{-1}]

(2)

(Total for question = 16 marks)

Q19.

For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The concentration of nitrogen dioxide in a sample of air is 0.5 ppm.

What is the percentage of nitrogen dioxide molecules in this sample of air?

☐ **A** 0.5 %

☐ **B** 0.005 %

☒ **C** 0.00005 %

☒ **D** 0.0000005 %

(Total for question = 1 mark)

Q20.

Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

Which conversion has the **lowest** percentage atom economy (by mass) for the formation of $CaCl_2$?

☒ **A** $Ca + Cl_2 \rightarrow CaCl_2$

☒ **B** $Ca + 2HCl \rightarrow CaCl_2 + H_2$

☒ **C** $CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$

☒ **D** $CaCO_3 + 2NaCl \rightarrow CaCl_2 + Na_2CO_3$

(Total for question = 1 mark)

Q21.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

What is the percentage atom economy, by mass, for the production of hydrogen in the reaction shown?

$$CH_4 + H_2O \rightarrow CO + 3H_2$$

[A_r values: H = 1.00 C = 12.0 O = 16.0]

☒ **A** 8.8%

☒

B 17.6%

☒ **C** 21.4%

☒ **D** 82.4%

(Total for question = 1 mark)

Q22.

Organic waste may be disposed of by landfill or incineration.
Both processes produce gases.

(a) The main gases produced from a typical landfill are shown in the table.

Gas	Percentage by volume / %
methane	50
carbon dioxide	45
nitrogen	4
sulfur compounds	1

(i) Name the process that forms these gases in landfill.

(1)

.....

(ii) State the **main** environmental problem caused by landfill gases, identifying the gas or gases responsible.

(2)

.....

.....

(iii) One tonne of landfill waste produces approximately 12.5 dm^3 of landfill gases per day.

Calculate the mass of carbon dioxide produced in a year by a typical landfill site which contains 90 000 tonnes of waste.
Assume that the gas volume is measured at room temperature and pressure (r.t.p.).
[Molar volume of gas at r.t.p. = 24.0 dm^3 mol−1]

(3)

(b) Suggest **two** advantages of incineration over landfill.

(2)

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(c) Environmental groups prefer recycling to both landfill and incineration.

Suggest **one** advantage of recycling.

(1)

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(Total for question = 9 marks)

Q23.

Which pair of substances contains the same number of moles at room temperature and pressure (r.t.p.)?

[A_r values Ca = 40, Li = 7, Al = 27, Mg = 24. Molar volume of gas at r.t.p. = 24 dm^3 mol^{-1}]

(1)

☒ **A** 24 dm^3 of chlorine, Cl_2, and 20 g of calcium, Ca

☒ **B** 24 dm^3 of oxygen, O_2, and 14 g of lithium, Li

☒ **C** 1.2 dm^3 of hydrogen, H_2, and 2.7 g of aluminium, Al

☒ **D** 1.2 dm^3 of nitrogen, N_2, and 1.2 g of magnesium, Mg

(Total for question = 1 mark)

Q24.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

How many molecules are there in 44.0 g of carbon monoxide?

[Avogadro constant $L = 6.02 \times 10^{23}\,mol^{-1}$
A_r values: C = 12.0 O = 16.0]

☒ **A** 3.83×10^{23}

☒ **B** 6.02×10^{23}

☒ **C** 9.46×10^{23}

☒ **D** 1.89×10^{24}

(Total for question = 1 mark)

Q25.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A compound has M_r = 84 and its composition by mass is 71.4% carbon, 9.6% hydrogen and 19.0% oxygen.

What is the molecular formula of this compound?

[A_r values: H = 1.0 C = 12.0 O = 16.0]

☒ **A** $C_4H_3O_2$

☒ **B** $C_4H_4O_2$

☒ **C** C_5H_8O

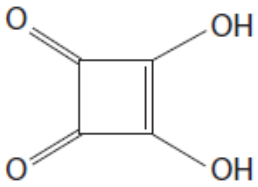
☒ **D** $C_6H_{10}O$

(Total for question = 1 mark)

Q26.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

What is the molecular formula of the compound shown?



☒ **A** C_2HO_2

☒ **B** $C_4H_2O_4$

☒ **C** $C_4H_4O_4$

☒ **D** $C_4H_6O_4$

(Total for question = 1 mark)

Q27.

A 0.210 g sample of a volatile organic liquid **C** is injected into a gas syringe and heated in an oven.
At 100 kPa and 358 K, the syringe contains 72.5 cm^3 of gas.

(a) Calculate the molar mass of **C**.

[$pV = nRT$ $R = 8.31$ J mol^{-1} K^{-1}]

(4)

(b) The organic liquid **C** is a hydrocarbon.

Give a possible name or formula for **C**, using your answer in (a).

(1)

(Total for question = 5 marks)

Q28.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which mixture results in a precipitation reaction?

☒ **A** dilute sulfuric acid and potassium hydroxide solution

☒ **B** iron and calcium chloride solution

☒ **C** chlorine water and potassium bromide solution

☒ **D** silver nitrate solution and potassium bromide solution

(Total for question = 1 mark)

Q29.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which mixture results in a displacement reaction?

☒ **A** iron and copper(II) sulfate solution

☒ **B** lead(II) nitrate solution and sodium iodide solution

☒

C dilute hydrochloric acid and sodium hydroxide solution

☒ **D** zinc and magnesium sulfate solution

(Total for question = 1 mark)

Q30.

Propene, C_3H_6, is produced in the dehydration of propanol.

$$C_3H_7OH \rightarrow C_3H_6 + H_2O$$

What is the mass, in g, of propene formed from 3.42 g of propanol when the yield is 85.2 % ?

[Relative molecular masses (M_r): $C_3H_7OH = 60$ $C_3H_6 = 42$]

(1)

☒ **A** 2.04

☒ **B** 2.39

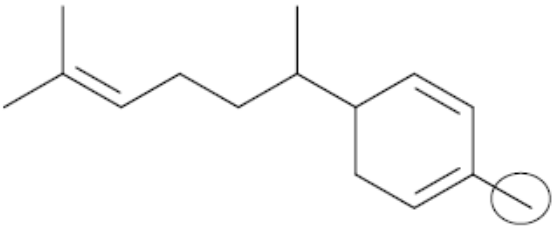
☒ **C** 2.91

☒ **D** 4.16

(Total for question = 1 mark)

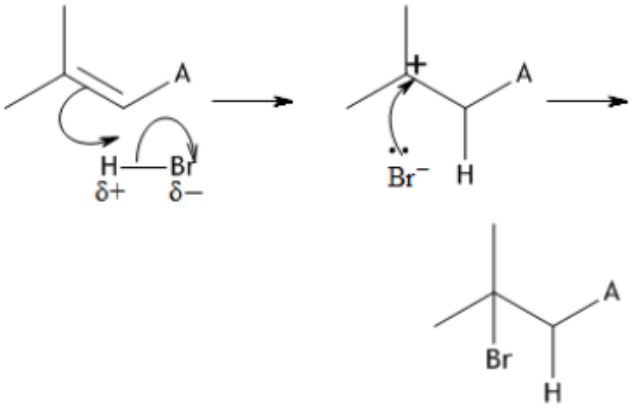
Mark Scheme

Q1.

Question number	Answer	Additional guidance	Mark
(a)	An answer that shows the following: • any indication of the methyl group on the right-hand side of the structure being selected	Example of diagram:  Allow inclusion of the "2" carbon within the circle Do not award more than one group circled or selected	1

Question number	Answer	Additional guidance	Mark
(b)	An answer that makes reference to the following: • C_{15} (1) • H_{24} (1)	Allow $H_{24}C_{15}$ / C15H24 No TE on incorrect number of carbon atoms	2

Question number	Answer	Additional guidance	Mark
(c)(i)	An answer that makes reference to the following: • electrophilic addition	Ignore 'heterolytic' Do not award 'free radical' Do not award substitution	1

Question number	Answer	Additional guidance	Mark
(c)(ii)	An answer that makes reference to the following: • curly arrow from H—Br bond to Br atom or just beyond **and** dipole on H–Br (1) • curly arrow from C=C to H or close by (1) • structure of tertiary carbocation intermediate (1) • curly arrow from **lone pair** on Br^- to positively charged carbon atom (1)	Example of mechanism shown below  Addition of Br–Br loses M1 only Allow secondary carbocation (should be based on structure from paper) Do not award $Br^{\delta-}$ Do not penalise an incorrect product Allow structural formulae etc. Ignore omission of added hydrogen Ignore omission of A or substitution of A at any stage Ignore connectivity of CH_3 groups Ignore other lone pairs	4

Question number	Answer	Additional guidance	Mark
(c)(iii)	An explanation that makes reference to the following points: • I is formed via a tertiary carbocation **and** II is formed via a secondary carbocation (1) • tertiary (carbocations) are more stable (than secondary) (1)	Assume "it" is I Must have carbocation at least once for M1 "It is a tertiary carbocation" does not score M1 Allow secondary are more stable than primary for M2 Allow tertiary is the most stable Allow reverse argument Marks are independent Ignore "tertiary cations have more alkyl groups' Allow "I is formed via a more stable intermediate" for M2 only	2

Question number	Answer	Additional guidance	Mark
(d)(i)	An answer that makes reference to the following: • nickel / Ni	Accept platinum / Pt / palladium / Pd	1

Question number	Answer	Additional guidance	Mark
(d)(ii)	• rearrangement of ideal gas equation to make volume the subject (1) • changing kPa to Pa **and** °C to K (1) • substitution of values into IGE (including 2 x 3 mol of H_2) (1) • calculation of volume of hydrogen with units (1)	Example of calculation $V = n \times R \times T \div p$ $p = 120 \times 1000 = 1.2\times 10^5$ (Pa) **and** $T = 150 + 273 = 423$ (K) $V = 6 \times 8.31\times 423 \div 1.2\times 10^5 =$ $= 0.17576\ m^3$ Accept 175.76 dm^3 / 175760 cm^3 TE at each stage Ignore SF except 1 SF Correct answer **and** units with some working scores (4) Penalise incorrect rounding once only	**4**

Q2.

Question number	Answer	Mark
(a)	**The only correct answer is B** (displacement) *A is incorrect because addition usually refers to organic reactions* *C is incorrect because no acids or bases are involved* *D is incorrect because substitution usually refers to organic reactions*	(1)

Question number	Answer	Mark
(b)	**The only correct answer is D** ($Zn \rightarrow Zn^{2+} + 2e^-$) *A is incorrect because Cu^+ is not formed* *B is incorrect because Cu^+ is not a reactant* *C is incorrect because Zn^+ is not formed*	(1)

Q3.

Question Number	Answer	Additional Guidance	Mark
(a)(i)	<table><tr><th>Measurement</th><th>Mass / g</th></tr><tr><td>Mass of empty crucible</td><td>21.21</td></tr><tr><td>Mass of crucible and magnesium sulfate before heating</td><td>26.71</td></tr><tr><td>Mass of crucible and magnesium sulfate after heating for 2 mins</td><td>24.12</td></tr><tr><td>Mass of magnesium sulfate</td><td>2.91</td></tr><tr><td>Mass of water</td><td>2.59</td></tr></table>	Both masses required	(1)

Question Number	Answer	Additional Guidance	Mark
(a)(ii)	• M1 M_r of $MgSO_4$ **(1)** • M2 moles of $MgSO_4$ **(1)** • M3 moles of H_2O **(1)** • M4 ratio of moles of water to moles of magnesium sulfate: to the nearest whole number **(1)**	<u>Example of calculation</u> $(24.3 + 32.1 + (4 \times 16)) = 120.4$ Allow 120 $(2.91 \div 120.4) = 0.024169$ / 2.4169×10^{-2} (mol) Ignore SF except 1 TE from wrong mass in (a)(i) $(2.59 \div 18) = 0.14389$ / 1.4389×10^{-1} (mol) Ignore SF except 1 TE from wrong mass in (a)(i) No TE on wrong M_r of H_2O Alternative method for M3 and M4 M_r of hydrate = 26.71-21.21/0.024169 = 227.56 mass of water = 227.56 – 120.4 = 107.16 moles of water = 107.16/18 = 5.9533 x = 6 $(0.1438889 \div 0.0241694) = 5.9533:1$ $(MgSO_4.6H_2O)$ x = 6 TE from M2 and M3 Correct answer with some **relevant** working scores (4) Ignore SF throughout	(4)

Question Number	Answer	Additional Guidance	Mark
(b)	An answer that makes reference to the following points: • heat to constant mass/ until mass does not change **(1)** • to ensure all the water is lost/ driven off **(1)**	Allow heat for longer Ignore any reference to repetition/ using a higher temperature/different flame/more magnesium sulfate/ any changes to the method Do not award heat under reflux for longer Allow more water is lost/given off Allow some water may have remained Allow all the water evaporated Ignore allow (reaction) to go to completion	**(2)**

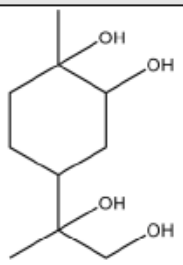
Q4.

Question number	Answer	Mark
	The only correct answer is B (2) *A is incorrect because the ratio of $CaSO_4$ to H_2O is the wrong way round* *C is incorrect because this is 3.405 x 0.900 to the nearest whole number and masses have not been converted to moles* *D is incorrect because this is 3.405 /0.900 to the nearest whole number and masses have not been converted to moles*	**(1)**

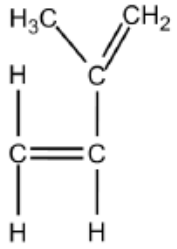
Q5.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)	An answer that makes reference to the following points: • C_{10} **(1)** • H_{16} **(1)**	Allow in either order Allow numerical values not shown as subscripts e.g. C10H16 scores both marks	2

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(i)	An answer that makes reference to the following points: • from purple to colourless	Do not award other colours Allow (pale) pink to colourless Ignore references to clear Ignore adjectives before purple e.g. deep purple	1

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(ii)		Allow displayed formula Ignore connectivity of OH group unless bond shown horizontally, and H connected directly to bond Ignore orientation of OH group	1

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(iii)	• oxidation	Allow electrophilic addition	1

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)		Allow skeletal, structural or displayed or any combination Ignore 'n' before or after structure Ignore connectivity of CH_3 and CH_2 groups	1

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)	An answer that makes reference to any **two** of the following points: • (help develop) biodegradable polymers / polymers from plant material / (polymers that can be) re-used / (polymers that can be easily) recycled (1) • remove (toxic) gases produced by incineration (of polymers) (1) • (develop processes to) convert polymers back into feedstock (for use in chemical industry) (1) • use of IR (spectroscopy) to separate polymers (for recycling) (1)	Allow the term 'plastic' for polymers Ignore biopolymers Ignore reduce use of polymers Allow monomers / smaller molecules / more reactive molecules / more useful molecules for 'feedstock'	2

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	Acceptable Answers	Additional Guidance	Mark
(e)(i)	An answer that makes reference to the following points: advantage of liquid CO_2 • non-flammable / non-toxic / readily available / CO_2 can be reused **(1)** disadvantage of liquid CO_2 • energy needed to generate (high) pressure / (high) pressure is expensive / risk of explosion under pressure / **(1)**	Allow reverse arguments for hexane Allow can be separated (from limonene) easily Allow hexane is non-renewable / finite Ignore 'removes CO_2 from atmosphere' Allow energy needed to maintain pressure Allow strength of vessel needed to withstand (high) pressure Ignore references to temperature Ignore just 'expensive' Do not award greenhouse gas / global warming	**2**

Question Number	Acceptable Answers	Additional Guidance	Mark
(e)(ii)	• calculation of mass of limonene required in 30 cm^3 of cleaning product **(1)** • calculation of mass of orange peel needed to produce 1 g of limonene **(1)** • calculation of mass of orange peel needed to produce enough limonene to make 30 cm^3 of cleaning product, in kg **(1)**	<u>Example of calculation</u> $0.841 \times 30 = 25.23$ (g) Ignore units in M1 1 g limonene needs $(100 \div 1.63)$ g of peel = 61.3497 (g) $(100 \div 1.63) \times 25.23 = 1547.9$ (g) = 1.55 (kg) Allow final answer in grams if units quoted Allow TE throughout M2 could be subsumed in M3 Ignore SF except 1 SF Correct answer with no working scores 3 NOTE : if ratio in M2 is inverted mass = 4.11×10^{-4} (kg) and scores M1 and M3	**3**

Q6.

Question Number	Answer	Mark
	The only correct answer is B ($TiCl_2$) **A** *is not correct because the mole ratio is 1:2 not 1:1* **C** *is not correct because the mole ratio is 1:2 not 1:3* **D** *is not correct because this is not an empirical formula*	**(1)**

Q7.

Question Number	Answer	Additional Guidance	Mark
(a)	An answer that makes reference to: • the mixture is boiled/ vapourised/ (fractionally) distilled **(1)** • distillate condensing at a suitable temperature (range) is collected **(1)**	Do not award cracking/reforming Allow correct references to collecting fractions at different heights/temperatures (in the fractionating column) Allow simple descriptions of fractional distillation e.g. separated by boiling point/ temperature Do not award references to molecular mass or to melting temperature.	**(2)**

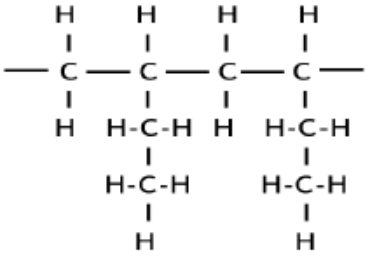
Question Number	Answer	Additional Guidance	Mark
(b)(i)	$(C_{18}H_{38} \rightarrow 2C_4H_8 +) C_{10}H_{22}$		**(1)**

Question Number	Answer	Additional Guidance	Mark
(b)(ii)	• cis **and** trans skeletal formulae **(1)** • 2-methylpropene **(1)**	 **and**   Allow 1 mark for three correct non-skeletal formulae Ignore bond lengths and angles	**(2)**

Question Number	Answer		Additional Guidance	Mark
(b)(iii)		(4)	8 correct points scores 4 marks 6 or 7 correct points scores 3 marks 4 or 5 correct points scores 2 marks 2 or 3 correct points scores 1 mark Allow displayed / skeletal formulae If two types of formula are shown **both** must be correct to score the point. Ignore punctuation errors , misplaced numbers e.g. 1,2-butan diol and connectivity of pendant -OH group.	(4)

Product	Name	Structural formula
1	1,2-dichlorobutane	$CH_3CH_2CHClCH_2Cl$
2	butane	$CH_3CH_2CH_2CH_3$
3	butan(e)-1,2-diol	$CH_3CH_2CHOHCH_2OH$
4	butan(e)-2-ol	$CH_3CH_2CHOHCH_3$

		Penalise omission of "an" in 3 and 4 once only Penalise wrong number of carbon atoms once only Award 1 **point** for butan-1-ol **and** correct formula in Product 4	

Question Number	Answer	Additional Guidance	Mark
(c)	• correct repeat unit **(1)** • two repeat units **and** continuation bonds **(1)** ALLOW C_2H_5, CH_2CH_3 as pendant group	 Ignore brackets and n Allow ethyl groups on C2 and C3 or C1 and C4 M2 depends on M1 or near miss e.g. attachment of pendant group or use of alternative 4-carbon monomer alkene producing a valid polymer i.e. poly(but-2-ene)/poly(methylpropene). Do not award a dimer	**(2)**

Question Number	Answer	Additional Guidance	Mark
(d)	• energy is produced /can be used to generate electricity or heat locally Or prevents polymers going to landfill/storage/taking up space **(1)** • toxic/harmful/corrosive gases/substances may be produced **(1)** Or particulates/soot may be produced	Allow production of hydrogen Ignore non-biodegradable, non-renewable, reduces polymer waste/pollution a named gas e.g. sulfur dioxide, hydrogen cyanide, dioxin without qualification is insufficient Do not award references to climate change	**(2)**

Question Number	Answer	Additional Guidance	Mark
(e)(i)	• volume CO_2 produced **(1)** • volume of oxygen used **(1)** • total volume of gas remaining **(1)** Alternative method • moles CO_2 produced **(1)** • moles oxygen remaining **(1)** • total volume remaining **(1)**	Example of calculation: 4 x 35 = 140 (cm^3) 6.5 x 35 = 227.5/228 (cm^3) 300-227.5 + 140 (cm^3) =212.5/213 (cm^3) Alternative method 35 / 24000 = 1.4583×10^{-3} / 1.458×10^{-3}/1.46×10^{-3} $1.4583 \times 10^{-3} \times 4 = 5.8333 \times 10^{-3}$ / 5.83×10^{-3} or 5.84×10^{-3} if rounded previously $300/24000 = 1.25 \times 10^{-2}$ $(1.46 \times 10^{-3}) \times 6.5 = 9.49 \times 10^{-3}$ moles $(1.25 \times 10^{-2}) - (9.49 \times 10^{-3}) = 3.01 \times 10^{-3}$ (mol) $[(5.83 \times 10^{-3}) + (3.01 \times 10^{-3})] \times 24000$ = 212.16/212 (cm^3) Allow TE throughout. Correct answer with no working scores 3 marks IGNORE SF except 1 SF	**(3)**

Question Number	Answer	Additional Guidance	Mark
(e)(ii)	• **carbon monoxide** may be produced (incomplete combustion may occur) **(1)** • which is toxic/combines(irreversibly) with haemoglobin/ **(1)**	Do not award particulates M2 depends on clear link to gas produced by burning butane Ignore references to flammability of butane/global warming/greenhouse gases If no other mark awarded allow 1 mark for carbon dioxide causes suffocation.	**(2)**

Q8.

Question Number	Answer	Additional guidance	Mark
(a)	Any **two** from the following: • chemically stable / inert / does not (easily) oxidise (1) • colourless (1) • odourless (1) • non-toxic / non-irritant (1) • hydrophobic / immiscible with water (1) • hypoallergenic (1)	Ignore any reference to: carbon chain length intermolecular forces melting/boiling temperature flammability/volatility liquid/moisturising/softening/lubricating/hydrating spreads easily/absorbed easily natural/in human skin cheap Allow unreactive / not very reactive / long shelf life / durable / does not breakdown (easily) Ignore just stable Ignore transparent/clear Allow not harmful / non-hazardous / non-corrosive Ignore safe Allow insoluble Ignore oily	2

Question Number	Answer	Additional guidance	Mark
(b)	• $C_{30}H_{62}$	Accept $H_{62}C_{30}$	1

Question Number	Answer	Additional guidance	Mark
(c)(i)	• nickel	Accept palladium or platinum Allow correct symbol	1

Question Number	Answer	Additional guidance	Mark
(c)(ii)	• 0.00001 / (1 ×) 10^{-5} (g)	Example of calculation: mass = $\frac{50}{10^6} \times 0.2 = 0.00001$ (g) Do not award incorrect unit Accept 10 μg / 0.01 mg Allow answer as fraction eg $\frac{1}{10^5}$ (g) Ignore SF Correct answer with no working scores (1)	1

Question Number	Answer	Additional guidance	Mark
(c)(iii)	• conversion of temperature to K (1) • rearrangement of ideal gas equation (1) • evaluation to give moles of hydrogen (1) • evaluation of mole ratio **and** number of C=C bonds per molecule of squalene (1)	Example of calculation: T = 200 + 273 (= 473 K) $n = \frac{pV}{RT}$ or $n = \frac{4.0 \times 10^5 \times 500}{8.31 \times 473}$ $n(H_2)$ = 50882.429 Ignore SF except 1 SF TE on temperature M3 dependent on correct use of ideal gas equation $n(H_2)$: n(squalene) 50882 : 8500 6 : 1 6 (× C=C bonds per molecule) TE on $n(H_2)$ provided $n(H_2)$ > than 8500 and answer is rounded to nearest integer 6 (× C=C bonds per molecule) with no working scores (1) 2 (× C=C bonds per molecule) from use of 24 dm^3 mol^{-1} as molar gas volume scores (2)	4

(c)(iii) cont	**Alternative route to M2, M3 and M4** • rearrangement of ideal gas equation (1) • evaluation to give volume of squalene (1) • evaluation of volume ratio **and** number of C=C bonds per molecule of squalene (1)	<u>Example of calculation:</u> $V = \frac{nRT}{p}$ or $V = \frac{8500 \times 8.31 \times 473}{4.0 \times 10^5}$ V(squalene) = 83.52589 (m^3) Ignore SF except 1 SF TE on temperature M3 dependent on correct use of ideal gas equation $V(H_2)$: V(squalene) 500 : 83.52589 6 : 1 6 (× C=C bonds per molecule) TE on V(squalene) provided V(squalene) < 500 (m^3) and answer is rounded to nearest integer	

Question Number	Answer	Additional guidance	Mark
(c)(iv)	• $C_{30}H_{50} + 6H_2 \rightarrow C_{30}H_{62}$	Ignore state symbols TE on (c)(iii) for any C_nH_{2n+2} product formula where $24 \leq n \leq 30$ If the number of C=C bonds is not stated in (c)(iii) then award (1) for an equation of the form: $C_nH_{2n-2y+2} + yH_2 \rightarrow C_nH_{2n+2}$ Where $24 \leq n \leq 30$ and $1 \leq y \leq 14$	1

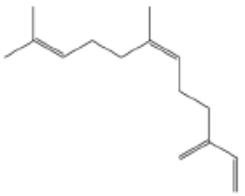
Question Number	Answer	Additional guidance	Mark
(d)(i)	• (fractional) distillation	Ignore solvent extraction Ignore filtration as part of the separation process Do not award just filtration Do not award chromatography	1

Question Number	Answer	Additional guidance	Mark
(d)(ii)	• calculation of mass of squalene in 2.8 million dm^3 **or** calculation of volume of squalene per shark (1)	Example of calculation: mass = $2.8 \times 10^9 \times 0.86 = 2.408 \times 10^9$ (g) **or** volume = $\frac{300}{0.86} = 348.8372$ (cm^3)	2
	• calculation of number of sharks required (1)	$\frac{2.408 \times 10^9}{300} = 8.0267 \times 10^6 = 8026666.667 / 8.0 \times 10^6$ TE on mass **or** $\frac{2.8 \times 10^9}{348.8372} = 8.0267 \times 10^6 = 8026666.667 / 8.0 \times 10^6$ TE on volume Ignore SF Penalise incorrect rounding once only Correct answer with no working scores (2)	

Question Number	Answer	Additional guidance	Mark
(d)(iii)	**Method 1** • calculation of mass of corn starch required (1) • calculation of required land area in hectares (1) • conversion of land area from hectares to km^2 (1) **Method 2** • conversion of land area from hectares to km^2 (1) • calculation of required land area in km^2 to produce 2500 tonnes of corn starch (1) • calculation of required land area in km^2 to produce 2500 tonnes of squalene (1)	Ignore SF and do not penalise correct premature rounding Penalise incorrect rounding once only Penalise incorrect units in final answer only mass = $\frac{2500}{23} \times 100 = 10869.57$ (tonnes) Allow conversion of mass of corn starch to kg / g land area = $10869.57 \times 0.093 = 1010.87$ (hectares) land area = $1010.87 \times 0.01 = 10.1087 = 10$ (km^2) $0.093 \times 0.01 = 0.00093 / 9.3 \times 10^{-4}$ (km^2) land area = $0.00093 \times 2500 = 2.325$ km^2 Allow conversion of mass of corn starch to kg / g land area = $\frac{2.325}{23} \times 100 = 10.1087 = 10$ (km^2)	3

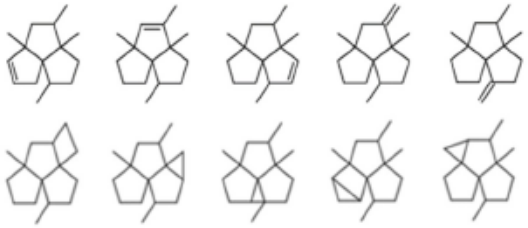
(d)(iii) cont	**Method 3** • calculation of required land area in hectares to produce 2500 tonnes of corn starch (1) • calculation of required land area in hectares to produce 2500 tonnes of squalene (1) • conversion of land area from hectares to km^2 (1)	land area = $2500 \times 0.093 = 232.5$ (hectares) Allow conversion of mass of corn starch to kg / g land area = $\frac{232.5}{23} \times 100 = 1010.87$ (hectares) land area = $1010.87 \times 0.01 = 10.1087 = 10$ (km^2) If no other mark awarded, 1 tonne corn starch yields 230 kg squalane scores (1)	

Question Number	Answer	Additional guidance	Mark
(e)(i)	An explanation that makes reference to the following points: • restricted rotation about/around C=C (1) • (only) central C=C has two different groups attached to each carbon of the C=C (1)	**Mark M1 and M2 independently** Accept pi-bond for C=C Allow just double bond for C=C Allow limited/no rotation about/around C=C Allow C=C restricts rotation Allow C=C cannot rotate Ignore just restricted rotation Do not award molecule cannot rotate Accept C=C from 6th carbon/6-ene for central C=C Allow (only) central C=C has four different groups Allow indication of central C=C on diagram Do not award if any other C=C bond identified as *E*/*Z*	2

Question Number	Answer	Additional guidance	Mark
(e)(ii)	• skeletal formula of *Z*-isomer (1) • (*Z* isomer has highest) priority groups on same side (of C=C) (1)	**Mark M1 and M2 independently** Examples of correct structure:  or  Ignore bond lengths and bond angles Ignore labelling of C=C bonds as *E*/*Z* Ignore any other type of formula Allow lowest priority groups on same side Allow identification of (highest) priority groups on diagram Allow ranking for priority Ignore preference for priority Ignore reference to mass/size of groups Allow top/bottom for same Ignore any reference to cis/trans	2

Question Number	Answer	Additional guidance	Mark
(f)(i)	• (compounds with the) same molecular formula (1) • different structural formula (1)	**Mark M1 and M2 independently** Ignore just same formula Ignore compounds with the same atoms Do not award same molecule Do not award same general formula Allow just different structure Allow different position of the C=C/double bonds Allow different displayed/skeletal formulae Ignore different arrangement of atoms (in space)	2

Question Number	Answer	Additional guidance	Mark
(f)(ii)	• four / 4	Ignore *E*/*Z*	1

Question Number	Answer	Additional guidance	Mark
(f)(iii)	• valid structure containing **one** C=C bond or • valid structure containing **one** bridging carbon-carbon bond	Examples of valid structure:  Ignore bond lengths and bond angles	1

Q9.

Question Number	Correct Answer	Mark
(a)	**The only correct answer is C** (it is toxic at low concentrations) *A is incorrect because CO does not form an acid in the atmosphere* *B is incorrect because CO does not strongly absorb infrared radiation* *D is incorrect because CO is not the main cause of ozone layer depletion*	1

Question Number	Correct Answer	Mark
(b)	**The only correct answer is D** (120) *A is incorrect because it is the volume of butane that has not reacted* *B is incorrect because it is the total volume of reactants* *C is incorrect because it is the total volume of products*	1

Q10.

Question Number	Answer	Mark
(a)	**The only correct answer is C** (392.0) ***A** is incorrect because the brackets have been ignored* ***B** is incorrect because the mass of water has been omitted* ***D** is incorrect because the iron has been doubled*	(1)

Question Number	Answer	Mark
(b)	**The only correct answer is D** (ionic, covalent and dative covalent) ***A** is incorrect because there are both dative covalent and covalent bonds within the ions* ***B** is incorrect because there are dative covalent bonds within the ions* ***C** is incorrect because there are covalent bonds within the ions*	(1)

Question Number	Answer	Mark
(c)	**The only correct answer is C** (3.01×10^{23}) ***A** is incorrect because only one ammonium, one iron and one sulfate ion have been included* ***B** is incorrect because the iron ions have not been included* ***D** is incorrect because the water molecules have been included*	(1)

Q11.

Q	Answer	Mark
	The only correct answer is D (286) ***A*** *is incorrect because this is the relative formula mass of anhydrous sodium carbonate, Na_2CO_3* ***B*** *is incorrect because this is the relative formula mass of $Na_2CO_3 + (20 \times 1) + 16$* ***C*** *is incorrect because this is the relative formula mass of $NaCO_3.10H_2O$*	**1**

Q12.

Question number	Answer	Mark
	The only correct answer is D (392) ***A*** *is incorrect because this does not include $6H_2O$* ***B*** *is incorrect because this only includes one H_2O* ***C*** *is incorrect because this includes $6H_2$ but only one O*	**(1)**

Q13.

Question Number	Answer	Additional Guidance	Mark
(a)(i)	• expression for calculation of RAM of silicon **(1)** • answer to two decimal places **(1)**	Example of calculation: $\frac{(28 \times 92.17) + (29 \times 4.71) + (30 \times 3.12)}{100}$ =28.1095 =28.11 Allow units g mol^{-1}/a.m.u only Correct answer scores 2 Allow TE from incorrect expression if answer lies between 28 and 30.	**(2)**

Question Number	Answer	Additional Guidance	Mark
(a)(ii)	Some silicon atoms (of mass 28) lose two electrons/have a charge of 2+	Allow (formation of) Si^{2+} Do not award "atoms of mass 14"	**(1)**

Question Number	Answer	Additional Guidance	Mark
(a)(iii)	^{28}Si 14 14 ^{29}Si 14 15 ^{30}Si 14 16		(1)

Question Number	Answer	Additional Guidance	Mark
(b)	• **all** atoms are joined together by covalent bonds/giant covalent(structure) (1) • these are strong / take a lot of energy to break (so melting temperature is very high) (1) • no electrons are free (to move)/ mobile/delocalised/ (so charge cannot be carried) (1)	Allow correct description of covalent bond Do not award intermolecular forces/ ionic bonds/ double covalent bonds. Ignore stoichiometry even if incorrect. Ignore high boiling temperature Ignore no free moving ions	(3)

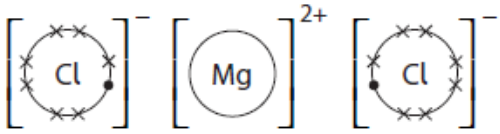
Question Number	Answer	Additional Guidance	Mark
(c)	• calculation of number of moles (1) • calculation of whole number mole ratio (1) • empirical formula	Example of calculation $\frac{12}{40.1}$ $\frac{8.43}{28.1}$ $\frac{14.47}{16}$ OR 0.299 : 0.30 : 0.904 1 : 1 : 3 $CaSiO_3$ Correct formula with no working scores 1 mark only TE on use of atomic numbers Incorrect symbol(s) in formula loses M3	(3)

Question Number	Answer	Additional Guidance	Mark
(d)	• calculation of moles carbon dioxide (1) • conversion of temperature to K (1) • rearrangement of expression (1) • evaluation of answer in cm^3	Example of calculation: 3÷44 = 0.06818 273 + 5 = 278 $V=\frac{0.06818 \times 8.31 \times 278}{1.3 \times 10^5}$ ($=1.2116 \times 10^{-3} m^3$) =1211.6/1212/1210/1200 (cm^3) TE throughout but do not award M4 for negative volume Ignore SF except 1 SF Correct answer with no working scores 4 marks	(4)

Q14.

Question number	Answer	Mark
	The only correct answer is C (BH_3) **A** *is incorrect because there are* 1.51×10^{23} *atoms* **B** *is incorrect because there are* 4.52×10^{23} *atoms* **D** *is incorrect because there are* 7.53×10^{23} *atoms*	1

Q15.

Question number	Answer	Additional guidance	Mark
(a)	• dot-and-cross diagram, including charges	Example of diagram:  Allow no electrons or 8 electrons on outer shell of Mg Allow any combination of dots or crosses for electrons Ignore missing square brackets	1

Question number	Answer	Additional guidance	Mark
(b)	An explanation that makes reference to the following points: • identification of charge carriers: magnesium - electrons **and** magnesium chloride - ions (1) • magnesium conducts electricity when solid because delocalised electrons can flow through (1) • magnesium chloride does not conduct when solid because the ions cannot move **and** it does conduct electricity when molten or dissolved in water as the ions can move. (1)		3

Question number	Answer	Additional guidance	Mark
(c)(i)	• correct balanced ionic equation with state symbols	Examples of equation: $MgO(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2O(l)$ or $MgO(s) + 2H_3O^+(aq) \rightarrow Mg^{2+}(aq) + 2H_2O(l)$	1

Question number	Answer	Additional guidance	Mark
(c)(ii)	• calculation of moles of MgO (1) • calculation of moles of HCl (1) • calculation of volume of HCl (1)	Example of calculation: moles MgO = $\frac{2.45}{40.3}$ = 0.060794 moles HCl = 2 × 0.060794 = 0.121588 volume HCl = 0.121588 × $\frac{1000}{2.00}$ = 60.794 cm^3 Ignore SF except 1 SF Allow use of A_r(Mg) = 24 (61.25 cm^3) Correct answer with no working scores full marks	3

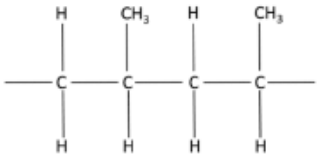
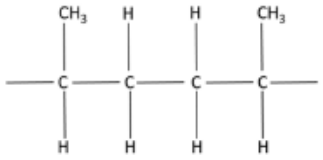
Question number	Answer	Additional guidance	Mark
(d)	Either • calculation of moles of $MgCO_3$ (1) • calculation of mass of $MgCl_2$ (1) or • use of both molar masses (1) • calculation of mass of $MgCl_2$ (1)	Example of calculation: moles $MgCO_3$ = $\frac{2.25}{84.3}$ = 0.02669 mass $MgCl_2$ = 0.02669 × 95.3 = 2.5436 (g) or 84.3 g $MgCO_3$ makes 95.3 g $MgCl_2$ so 2.25 g $MgCO_3$ makes $\frac{95.3}{84.3}$ × 2.25 = 2.5436 (g) $MgCl_2$ Ignore SF except 1 SF Allow use of A_r(Mg) = 24 (2.5446 g) Correct answer with no working scores full marks	2

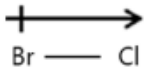
Question number	Answer		Additional guidance	Mark
(e)	An explanation that makes reference to the following points: • (in the reaction with magnesium oxide) there are fewer waste products/no carbon dioxide is released/water is the only waste product • so the molar mass of all products is lower/the denominator of the equation for atom economy is lower or • 1 mol of magnesium compound produces 1 mol of magnesium chloride • but the M_r of magnesium carbonate is greater than the M_r of magnesium oxide/carbon dioxide is an additional waste product from magnesium carbonate.	(1) (1) (1) (1)	Ignore calculations Allow reverse arguments	2

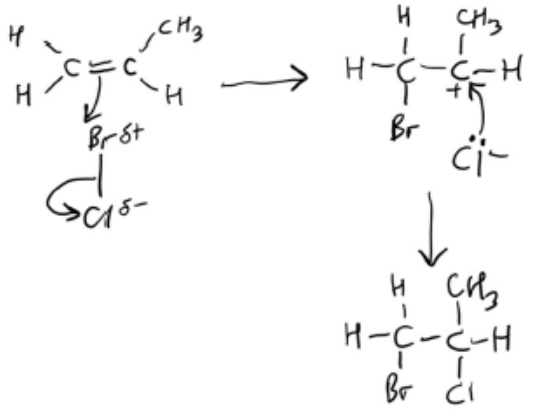
Q16.

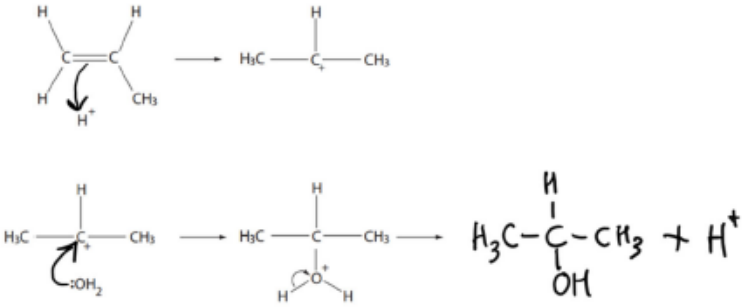
Question Number	Answer	Additional guidance	Mark
(a)	• balanced equation with **1 mol** C_3H_6 and correct products (1) • state symbols (1)	Example of equation: $C_3H_6(g) + 3O_2(g) \rightarrow CO_2(g) + CO(g) + C(s) + 3H_2O(l)$ Allow structural, displayed or skeletal formulae Allow $H_2O(g)$ Do not award $H_2O(aq)$ M2 dependent on correct species for the incomplete combustion of any C_nH_{2n} / C_nH_{2n+2} hydrocarbon forming $CO_2(g)$, $CO(g)$, $C(s)$ and $H_2O(l)/(g)$ If no other mark awarded, a correctly balanced equation, with correct state symbols, for the incomplete combustion of propene scores (1) eg $C_3H_6(g) + 3O_2(g) \rightarrow 3CO(g) + 3H_2O(l)/(g)$ eg $2C_3H_6(g) + 7O_2(g) \rightarrow 2CO_2(g) + 4CO(g) + 6H_2O(l)/(g)$	2

Question Number	Answer	Additional guidance	Mark
(b)	• both solutions decolourise / turn colourless (1) • from purple with (potassium) manganate((VII))/$KMnO_4$/MnO_4^- **and** from orange with (aqueous) bromine/Br_2 (1)	Ignore any reference to breaking of the C=C bond / type of reaction Ignore any reference to layers / effervescence Ignore any reference to reaction products / formation of solids Ignore turn clear / change colour Allow pink for purple or any combination of purple/pink Allow yellow or brown for orange or any combination of orange/yellow/brown Do not award any mention of red (eg red-brown) If neither M1 nor M2 awarded, either of the following scores (1): (potassium) manganate((VII))/$KMnO_4$/MnO_4^- decolourises from purple/pink or bromine decolourises from orange/yellow/brown	2

Question Number	Answer	Additional guidance	Mark
(c)	• poly(propene) structure containing two repeat units with extension bonds	Example of diagram:  Accept CH_3 groups on same or opposite sides Allow head-to-head and tail-to-tail configurations eg  Allow displayed, structural, skeletal formulae or any combination of these Ignore connectivity of vertical C–CH_3 bond Ignore brackets and 'n'	1

Question Number	Answer	Additional guidance	Mark
(d)(i)	• correct dipole	Example of correct diagram: δ+ δ– Br —— Cl Allow correct indication of net dipole moment:  Br —— Cl Ignore horizontal arrow from Br to Cl, on or above the bond Ignore bond pair electrons on diagram Ignore lone pairs on Br/Cl Ignore electron density map Ignore double-headed curly arrow from bond to Cl Do not award full charges	1

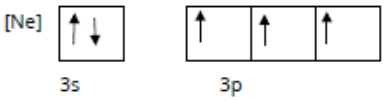
Question Number	Answer	Additional guidance	Mark
(d)(ii)	A mechanism showing:	Example of mechanism:  Allow displayed, structural, skeletal formulae or any combination of these	3
	• curly arrow from C=C bond to (δ+)halogen **and** curly arrow from Br–Cl bond to (δ–)halogen or just beyond (1)	Penalise incorrect propene structure once only Penalise half-headed curly arrows once only	
	• secondary carbocation (1)	Allow primary carbocation for mechanism involving ethene only	
	• curly arrow from lone pair on halide ion to $C^{(+)}$ **and** correct product (1)	Allow curly arrow from lone pair to positive charge Do not award δ– on halide ion	

Question Number	Answer	Additional guidance	Mark
(e)	A mechanism showing: • curly arrow from C=C bond to H^+ (1) • curly arrow from lone pair on water to C^+ (1) • correct structure for propan-2-ol **and** H^+ (catalyst regenerated) (1)	Example of correct mechanism:  Do not award any additional curly arrows from/to/on propene/H^+ Allow curly arrow from lone pair to positive charge Do not award any additional curly arrows shown in this step Allow any combination of displayed/structural/skeletal formulae Ignore atom connectivity except displayed C–H–O Ignore any additional curly arrows added to the central intermediate	3

Q17.

Q	Answer	Mark
	The only correct answer is B (400 cm^3) ***A*** *is incorrect because this is the volume of carbon dioxide produced and there is 100 cm^3 of oxygen left* ***C*** *is incorrect because this is the volume of carbon dioxide and water produced if water was a gas* ***D*** *is incorrect because this is the volume of carbon dioxide and water produced if water was a gas plus 100 cm^3 of oxygen that remains*	1

Q18.

Question number	Answer	Additional guidance	Mark
(a)(i)	• correct electronic configuration	Example of electronic configuration:  Allow half-arrow heads Allow three arrows pointing downwards in 3p orbitals Ignore numbers in the boxes e.g. 2	(1)

Question number	Answer	Additional guidance	Mark
(a)(ii)	An explanation that makes reference to the following points: **Phosphorus** • phosphorus has a half-filled p (sub)shell / one electron in each p orbital / the p orbitals are singly occupied (1) • more energy is required to remove an unpaired electron (than a paired electron) **or** an unpaired electron / electron removed has a lower energy (1) OR **Sulfur** • the outermost / 3p electron or the electron being removed in sulfur is paired (1) • less energy is required to remove a paired electron (than an unpaired electron) **or** repulsion between paired electrons (reduces the ionisation energy needed to remove it) **or** the paired electron has a higher energy (1)	**Both marks must come from the same pair** Allow 'electrons-in-boxes' / $3p_x3p_y3p_z$ to show electronic configurations Allow 'box' for orbital as this is in (i) Ignore references to shielding / nuclear charge / lone pairs Penalise 3 or more electrons in a p **orbital** once only Allow '(electron removed is from) a half-filled p orbital' Do not award just $3p^3$ Allow a half-filled subshell is (more) stable Allow sulfur is $3p^4$ Allow sulfur forms a half-filled p (sub)shell when it loses 1 electron Note – paired only needs to be mentioned once in M1 or M2 Do not award M2 if answer states more energy needed to remove electron in sulfur	(2)

Question number	Answer	Additional guidance	Mark
(b)	An explanation that makes reference to the following points: • there are intermolecular forces between P_4 / phosphorus (molecules) **or** phosphorus is made up of small molecules / discrete molecules / is simple molecular (1) • there are covalent bonds between the silicon atoms **or** silicon is a giant (covalent) structure / giant lattice (1) • (much) more energy is needed to break the (covalent) bonds in silicon than overcome the intermolecular forces in phosphorus **or** the (covalent) bonds in silicon are (much) stronger than the (intermolecular) forces in phosphorus (1)	Allow London / dispersion / van der Waals' forces for intermolecular forces Allow macromolecular / giant molecule Do not award ionic / metallic Do not award breaking bonds between phosphorus **atoms**	(3)

Question number	Answer	Additional guidance	Mark
(c)(I)	• number of bonding pairs **and** number of lone pairs (1) • shape (1) • **both** bond angles (1)	Example of table: <table><tr><td>Number of bonding pairs of electrons on phosphorus</td><td colspan="2">5</td></tr><tr><td>Number of lone pairs on electrons on phosphorus</td><td colspan="2">0</td></tr><tr><td>Shape of molecule</td><td colspan="2">trigonal bipyramidal</td></tr><tr><td>Cl-P-Cl bond angles</td><td>90°</td><td>120°</td></tr></table> Mark independently Allow bond angles in either order Ignore 180°	(3)

Question number	Answer	Additional guidance	Mark
(c)(II)	• PCl_4^+ (1) • PCl_6^- (1)	Ions can be in any order If no charges are shown or charges are incorrect, allow (1) for PCl_4 and PCl_6	(2)

Question number	Answer	Additional guidance	Mark
(d)	• calculation of mol of H_3PO_4 **and** calculation of mol of NaOH (1) • mol ratio (1) • balanced equation (1)	Example of calculation: mol H_3PO_4 = $\frac{10.0 \times 0.100}{1000}$ = 0.00100 / 1.00×10^{-3} **and** mol NaOH = $\frac{8.0 \times 0.250}{1000}$ = 0.00200 / 2.00×10^{-3} mol ratio H_3PO_4 : NaOH = 1 : 2 Mol ratio mark can be awarded from equation TE on mol H_3PO_4 and NaOH Do not award M2 if the mol ratio in the balanced equation contradicts the mol ratio from the mol calculations $H_3PO_4 + 2NaOH \rightarrow Na_2HPO_4 + 2H_2O$ Allow HNa_2PO_4 Allow $H_3PO_4 + 2OH^- \rightarrow HPO_4^{2-} + 2H_2O$ Allow multiples Ignore state symbols, even if incorrect Equation TE on mol ratio provided it is 1:1 or 1:3 $H_3PO_4 + NaOH \rightarrow NaH_2PO_4 + H_2O$ $H_3PO_4 + 3NaOH \rightarrow Na_3PO_4 + 3H_2O$	(3)

Question number	Answer	Additional guidance	Mark
(e)	• calculation of molar mass of hydrated magnesium phosphate (1) • calculation of **y** (1)	Examples of calculation: **Method 1** molar mass = 262.9 x $\frac{100}{78.5}$ = 334.9 (g) mass of water = 334.9 – 262.9 = 72 moles of water = $\frac{72}{18}$ = 4 so **y** = 4 Allow alternative methods, for example **Method 2** in 100 g of salt: mol $Mg_3(PO_4)_2$ = $\frac{78.5}{262.9}$ = 0.29859 (mol) **and** mol H_2O = $\frac{21.5}{18}$ = 1.1944(mol) (1) ratio $Mg_3(PO_4)_2$: H_2O = 0.29859 : 1.1944 = 1 : 4 so **y** = 4 (1) This could also be done using 0.785 g and 0.215 g **Method 3** $\frac{262.9}{262.9 + 18y}$ = 0.785 or $\frac{262.9}{262.9 + 18y}$ x 100 = 78.5(1) 262.9 = 206.4 + 14.13 **y** so **y** = 4 (1) Correct answer with no working or working that does not involve A_r or M_r or moles scores (0) Allow TE for **y** from correct working but an incorrect number used for one of the values	(2)

Q19.

Question Number	Answer	Mark
	The only correct answer is C (0.00005%) **A** *is not correct because the answer shows the percentage equal to ppm* **B** *is not correct because the answer shows the ppm divided by 100* **D** *is not correct because the correct answer has been divided by 100*	(1)

Q20.

Question number	Answer	Mark
	The only correct answer is D ($CaCO_3 + 2NaCl \rightarrow CaCl_2 + Na_2CO_3$) ***A*** *is incorrect because there are no waste products* ***B*** *is incorrect because H_2 has a lower M_r than Na_2CO_3* ***C*** *is incorrect because the combined M_r of H_2O and CO_2 is lower than Na_2CO_3*	1

Q21.

Question number	Answer	Mark
	The only correct answer is B (17.6%) *A is incorrect because the mass of hydrogen has been divided by the total mass of reactants and products* *C is incorrect because the mass of hydrogen has been divided by the mass of carbon monoxide* *D is incorrect because this is the atom economy for carbon monoxide*	(1)

Q22.

Question number	Answer	Additional guidance	Mark
(a)(i)	An answer that makes reference to one of the following: • biodegradation / putrefaction / decomposition • fermentation • anaerobic respiration	Ignore decay Allow any indication of a biological process e.g. 'bacterial action' Do not award "**thermal** decomposition"	1

Question number	Answer	Additional guidance	Mark
(a)(ii)	An answer that makes reference to the following points: • climate change / global temperature (1) • methane / CH_4 **and** (1) carbon dioxide / CO_2	 Allow global warming Ignore greenhouse effect / increase in temperature Do not award ozone depletion / acid rain Do not award ammonia/NO_x/SO_x/H_2S	2

Question number	Answer	Additional guidance	Mark
(a)(iii)	• calculation of annual volume of carbon dioxide (1) • calculation of moles of carbon dioxide (1) • calculation of mass of carbon dioxide (1)	Example of calculation = (45 ÷ 100) × 365 × 90000 × 12.5 = = 1.8478×10^8 (dm^3) = $1.8478 \times 10^8 \div 24(.0) = 7.6992 \times 10^6$ (mol) = $7.6992 \times 10^6 \times 44 = 3.3877 \times 10^8$ (g) / 3.3877×10^2 tonnes / 338.77 tonnes Answers not in grams must have units for M3 TE at each stage Allow 365.25 / 366 days Ignore SF except 1 SF Correct answer with some working scores (3)	3

Question number	Answer	Additional guidance	Mark
(b)	An answer that makes reference to any **two** of the following points: • decreases quantity of waste / less space is needed (1) • can be used (more easily) to generate electricity / produce heat (energy) (1) • pollutants can be trapped more easily (1) • transport costs lower (because sites can be sited near urban centres) (1) • prevents release of **methane** into the atmosphere (1) • high temperatures eliminate harmful bacteria / fungi (1) • residue can be used in construction products (1) • can deal with polymers/plastics/wastes that do not biodegrade (1) • reduced risk of water / soil pollution (by leaching) (1)	Allow less land needed Allow no land needed **for waste** Ignore no waste products Do not award generate energy Allow is a source of power Do not award incineration is less polluting / produces less CO_2 without referring to capture Allow residue can be used as fertiliser Ignore "reduces pollution" Ignore cost, appearance, time and contaminants	2

Question number	Answer	Additional guidance	Mark
(c)	An answer that makes reference to **one** of the following points: • resources conserved (1) (by recycling) • less energy is used (in recycling) (1)	Allow reverse arguments Allow produces **less** toxic or greenhouse gases Do not award answers relating to cost Ignore renewable / sustainable	1

Q23.

Question number	Answer	Mark
	D 1.2 dm^3 of nitrogen, N_2, and 1.2 g of magnesium, Mg	1

Q24.

Question number	Answer	Mark
	The only correct answer is C (9.46×10^{23}) *A is incorrect because the M_r has been divided by the mass* *B is incorrect because this would be correct for CO_2* *D is incorrect because this is the number of atoms*	(1)

Q25.

Question number	Answer	Mark
	The only correct answer is C (C_5H_8O) *A is incorrect because the M_r is 83* *B is incorrect because the ratio of C and H is not the same* *D is incorrect because this is rounding number of moles to 1 SF*	(1)

Q26.

Question number	Answer	Mark
	The only correct answer is B ($C_4H_2O_4$) *A is incorrect because this is the empirical formula* *C is incorrect because there are two extra hydrogens in the formula* *D is incorrect because there are four extra hydrogens in the formula*	(1)

Q27.

Question Number	Answer	Additional Guidance	Mark
(a)	• M1 conversion of volume to m^3 (1) • M2 rearrangement of Ideal Gas Equation (1) • M3 conversion of pressure and evaluation to give number of moles (1) • M4 calculation of molar mass (1)	Example of calculation $72.5 \times 10^{-6} = 7.25 \times 10^{-5} / 0.0000725\ (m^3)$ $n = \frac{pV}{RT}$ $\frac{100000 \times 7.25 \times 10^{-5}}{8.31 \times 358} =$ $2.4370 \times 10^{-3} / 0.002437 (mol)$ Allow TE on volume from M1 $\frac{0.210}{2.4370 \times 10^{-3}} = 86.172 = 86\ (g\ mol^{-1})$ Allow TE on moles from M3 Ignore SF except 1SF Ignore units even if incorrect	(4)

Question Number	Answer	Additional Guidance	Mark
(b)	• hexane or any alkane with the molecular formula of C_6H_{14}	Allow name or structural/displayed/skeletal formula Allow TE on sensible mass from (a) If no mass allow hexane If both name and formula/structure given they must match The name or formula must match the mass in (a)	(1)

Q28.

Question Number	Correct Answer	Mark
	The only correct answer is D (silver nitrate solution and potassium bromide solution) *A is incorrect because the reaction is a neutralisation* *B is incorrect because there is no reaction* *C is incorrect because the reaction is a displacement*	1

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Q29.

Question Number	Correct Answer	Mark
	The only correct answer is A (iron and copper(II) sulfate solution) *B is incorrect because the reaction is a precipitation* *C is incorrect because the reaction is a neutralisation* *D is incorrect because there is no reaction*	1

Q30.

Question number	Answer	Mark
	The only correct answer is A (2.04 (g)) *B is incorrect because this is the mass when the yield is 100%* *C is incorrect because this is just the masses expressed as a percentage without converting them into moles* *D is incorrect because this is the mass of propene formed with the molar masses reversed*	**(1)**