



Oxford Cambridge and RSA

Thursday 23 May 2019 – Morning

AS Level Chemistry B (Salters)

H033/02 Chemistry in depth

Time allowed: 1 hour 30 minutes



You must have:

- the Data Sheet for Chemistry B (Salters)
(sent with general stationery)

You may use:

- a scientific or graphical calculator



Please write clearly in black ink. **Do not write in the barcodes.**

Centre number

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Candidate number

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First name(s)

Last name

StemUp Model Solution

INSTRUCTIONS

- Use black ink. HB pencil may be used for graphs and diagrams only.
- Answer **all** the questions.
- Where appropriate, your answers should be supported with working. Marks may be given for a correct method even if the answer is incorrect.
- Write your answer to each question in the space provided. If additional space is required, use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.

INFORMATION

- The total mark for this paper is **70**.
- The marks for each question are shown in brackets [].
- Quality of extended responses will be assessed in questions marked with an asterisk (*).
- This document consists of **20** pages.

Answer **all** the questions.

- 1 Catalytic cracking of hydrocarbons is carried out in the petrochemical industry. Hot vaporised hydrocarbons and a powdered catalyst are fed into the bottom of a tube and forced upwards by steam.

- (a) (i) Decane, $C_{10}H_{22}$, can be cracked to give an **alkene** with four carbon atoms and another alkane.

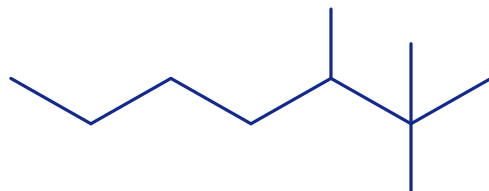
Write a chemical equation for this reaction using **molecular** formulae.



[1]

- (ii) 2,2,3-Trimethylheptane is an isomer of decane.

Draw the **skeletal formula** of 2,2,3-trimethylheptane.



[1]

- (b) A student wishes to crack a sample of liquid decane in the laboratory and collect the gaseous products.

Fig. 1.1 shows the apparatus that a student drew before doing this.

What modifications would be required for this apparatus to work?

Explain your answers.

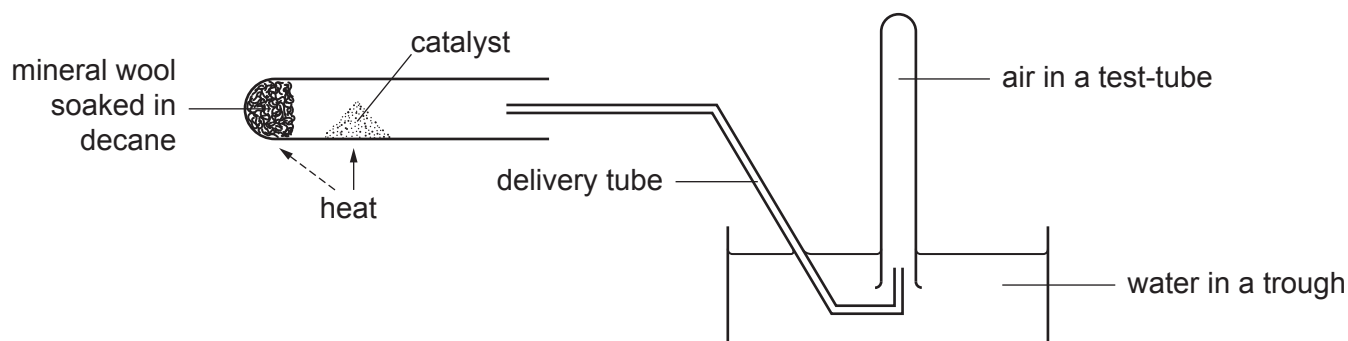


Fig. 1.1

The test-tube must be completely full of water (inverted in the trough), not full of air, otherwise the gaseous products will not collect in the tube (displacing water).

A bung is needed in the heated tube to hold the delivery tube, otherwise the gaseous products will escape into the atmosphere instead of going through the delivery tube.

Also, the delivery tube must be removed from the water before heating stops to prevent suck-back. [4]

- (c) Small alkenes produced in cracking can be used for making polymers.

The structure of a polymer chain is shown in **Fig. 1.2**.

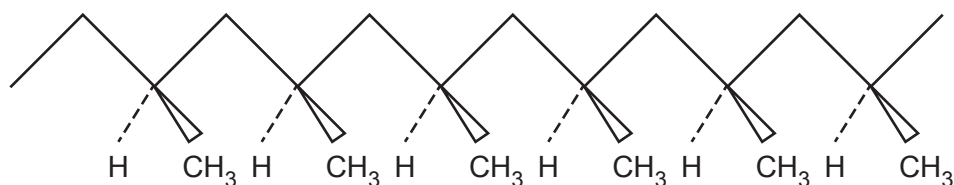


Fig. 1.2

Give the **name** of the monomer that forms the polymer in **Fig. 1.2**.

propene (propylene), $\text{CH}_2=\text{CHCH}_3$ [1]

- (d) Another alkene that can be polymerised is but-2-ene, $\text{CH}_3\text{CH}=\text{CHCH}_3$.

Explain why stereoisomerism can occur in but-2-ene.

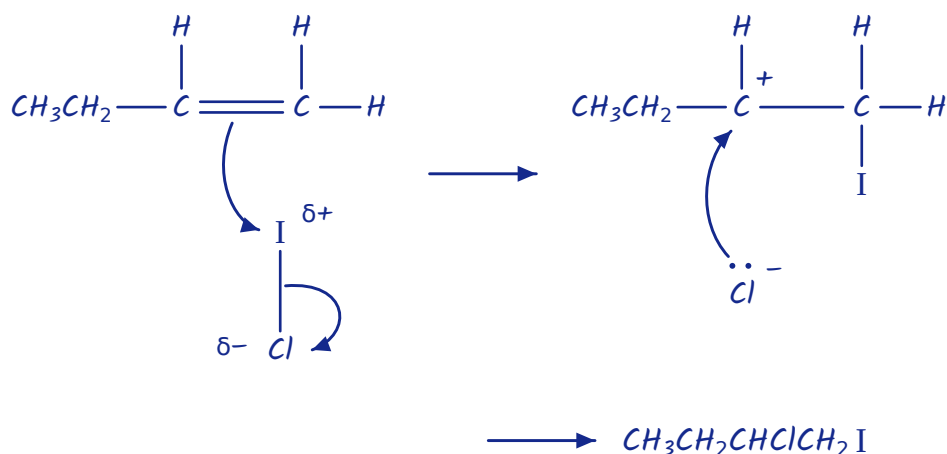
There is no (restricted) rotation about the $\text{C}=\text{C}$ double bond.
 Each carbon atom of the $\text{C}=\text{C}$ has two different groups attached (a CH_3
 and an H), so *E* and *Z* isomers exist.

[2]

- (e) When but-1-ene, $\text{CH}_3\text{CH}_2\text{CH}=\text{CH}_2$, reacts with ICl the main product is 1-iodo-2-chlorobutane, $\text{CH}_3\text{CH}_2\text{CHClCH}_2\text{I}$.

Suggest a mechanism for this reaction.

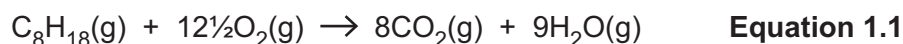
Show full and partial charges and 'curly arrows'.



[3]

- (f) Petrol contains hydrocarbons like octane, C_8H_{18} .

Equation 1.1 shows the complete combustion of octane.



3.42 g of octane are burned per second in a vehicle engine.

The exhaust gases are produced at a temperature of 550°C and a pressure of $1.50 \times 10^5 \text{ Pa}$.

Calculate the volume of exhaust gases, in dm^3 , produced per second.

Assume that carbon dioxide and water vapour are the only gases present in the exhaust.

$$M_r C_8H_{18} = 8(12.0) + 18(1.0) = 114.0$$

$$n(C_8H_{18}) = 3.42 \div 114.0 = 0.0300 \text{ mol per second}$$

$$n(\text{gases}) = (8 + 9) \times 0.0300 = 0.510 \text{ mol}$$

$$pV = nRT, \text{ so } V = nRT \div p$$

$$T = 550 + 273 = 823 \text{ K}$$

$$V = (0.510 \times 8.314 \times 823) \div (1.50 \times 10^5)$$

$$V = 2.33 \times 10^{-2} \text{ m}^3$$

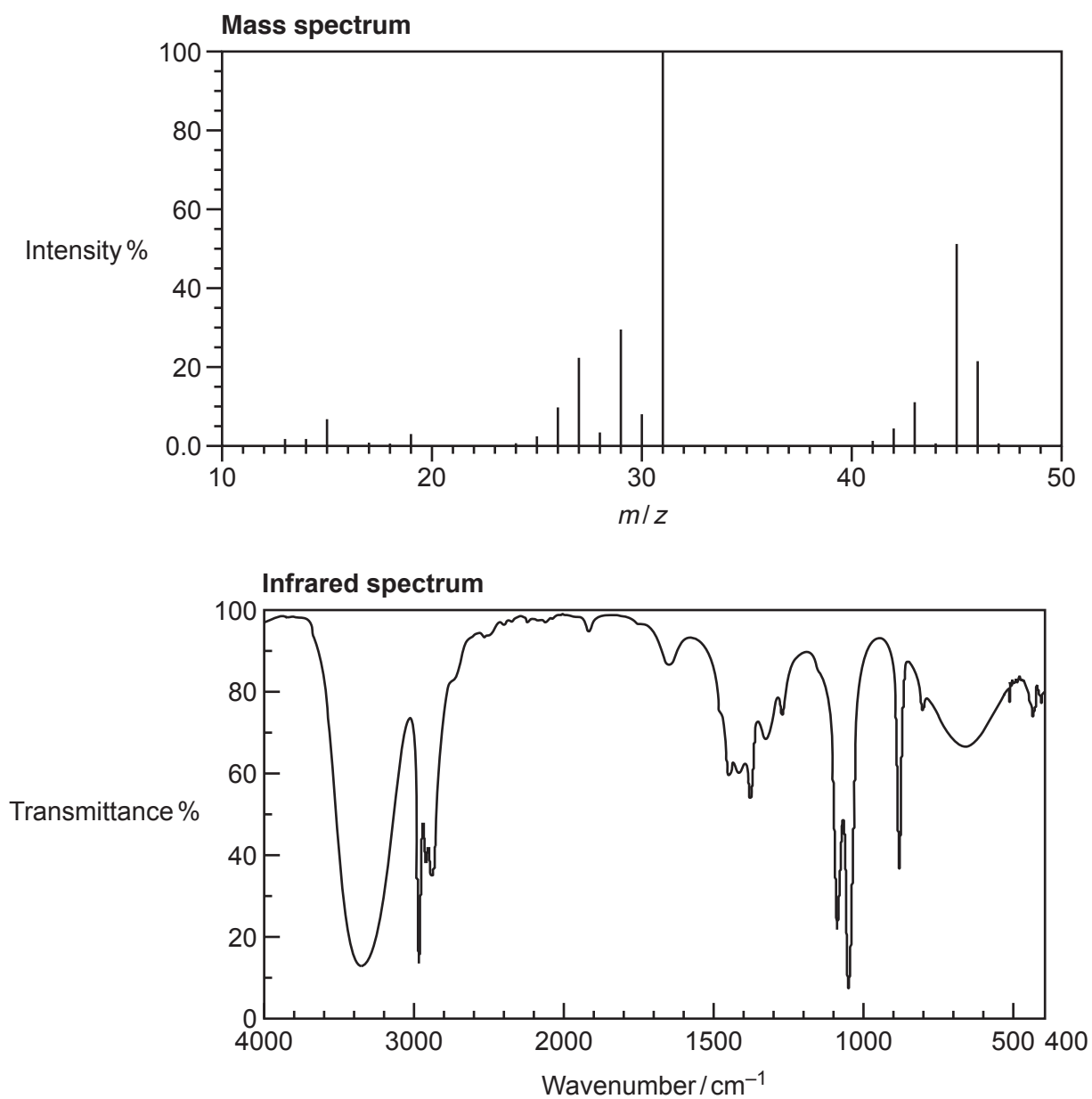
$$V = 2.33 \times 10^{-2} \times 1000 = 23.3 \text{ dm}^3$$

volume of exhaust gases = ...23.3..... dm^3 [4]

(g) Biofuels are increasingly providing alternatives to petrol.

One of the compounds in a biofuel has the following mass spectrum and infrared spectrum.

The biofuel contains carbon, hydrogen and oxygen only.



(i) Identify the biofuel given by the mass spectrum and infrared spectrum.

ethanol, CH₃CH₂OH

[1]

- (ii) Give **one** piece of evidence from the mass spectrum to support your answer to (g)(i).

*The molecular ion peak is at $m/z = 46$, which matches M_r of ethanol
(46.0).* [1]

- (iii) Give **one** piece of evidence from the infrared spectrum to support your answer to (g)(i).

A broad absorption at about 3350 cm^{-1} , due to O-H (alcohol). [1]

- (h)* Discuss the advantages and disadvantages of using biofuels as fuels for cars compared with fossil fuels. [6]

Advantages: biofuels are renewable and sustainable, as crops can be regrown, while fossil fuels are finite. They are (almost) carbon neutral: the CO_2 released when they burn was absorbed by the plants during photosynthesis, so there is less net greenhouse gas and less global warming. They can be made from waste that would otherwise go to landfill. Biofuels contain virtually no sulfur, so less SO_2 and less acid rain. They also give fewer particulates (less lung damage), less CO (poisonous) and fewer unburnt hydrocarbons, so less photochemical smog. Biodiesel is biodegradable if spilled and can directly replace diesel.

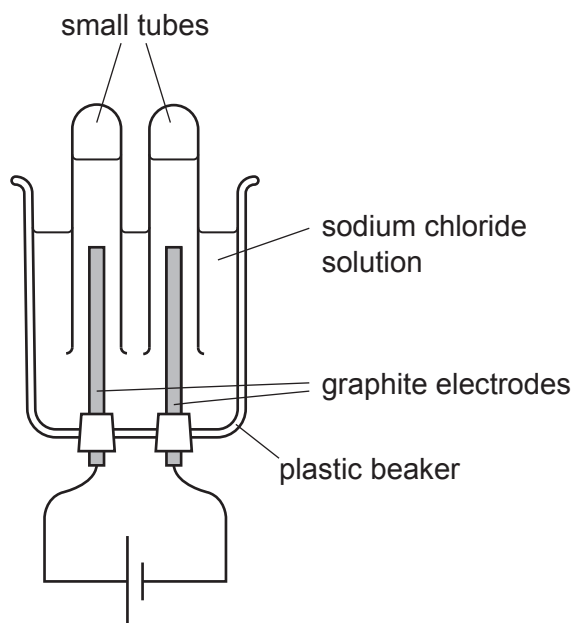
Disadvantages: they are not a straight replacement for petrol, so car engines must be modified to use high ethanol fuels. Land used to grow fuel crops cannot grow food. They are not fully carbon neutral, as CO_2 is still released when the crops are farmed and the fuel is produced and transported. They can produce more NO_x , which leads to more tropospheric ozone and respiratory problems.

Additional answer space if required

Overall, biofuels reduce net CO_2 and pollution but need modified engines and land.

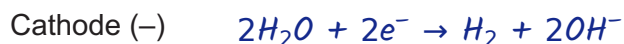
2 Chlorine is obtained by the electrolysis of aqueous sodium chloride.

- (a) A student investigates the electrolysis of aqueous sodium chloride in the laboratory using the apparatus shown below.



The student observes bubbles of gas at both the anode (+) and the cathode (–).

Write half-equations for the reactions occurring at each electrode.

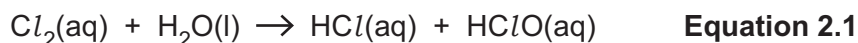


[2]

- (b) One use of chlorine is in water treatment.

Chlorine reacts with water to form chloric(I) acid, HClO , as in **equation 2.1**.

The HClO kills the bacteria that can cause diseases like cholera.



- (i) Explain what is meant by the (I) in chloric(I) acid.

It is the oxidation state of chlorine in HClO , which is +1. [1]

- (ii) Chloric(I) acid can also be produced by adding solid calcium chlorate(I) to water.

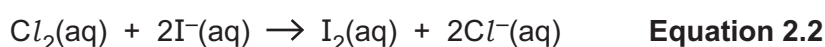
Suggest a reason why it may be preferable to use calcium chlorate(I) rather than chlorine for treating drinking water.

*Calcium chlorate(I) is a solid but chlorine is a toxic gas, so it is easier
and safer to transport, store and handle.* [2]

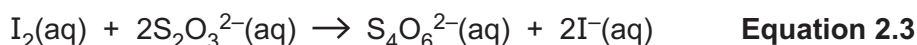
- (c) (i) Chlorine is also used to sterilise swimming pool water.

An analytical chemist uses a titration to find out the amount of chlorine in a sample of swimming pool water.

The chemist takes a 25.0 cm^3 sample of water and treats it with an excess of potassium iodide solution. The equation for this reaction is shown in **equation 2.2**.



The chemist then titrates the treated sample with $0.000100\text{ mol dm}^{-3}$ sodium thiosulfate solution to find out how much iodine has formed. The equation for this reaction is shown in **equation 2.3**.



The chemist obtains a mean titre of 12.4 cm^3 .

Use this information to calculate the concentration of Cl_2 , in mol dm^{-3} , in the sample of swimming pool water.

Give your answer to an **appropriate** number of significant figures.

Assume Cl_2 is the only substance in the water that oxidises iodide ions.

$$n(\text{S}_2\text{O}_3^{2-}) = (12.4 \div 1000) \times 0.000100 = 1.24 \times 10^{-6} \text{ mol}$$

$$n(\text{I}_2) = n(\text{Cl}_2) = 1.24 \times 10^{-6} \div 2 = 6.20 \times 10^{-7} \text{ mol}$$

$$\begin{aligned} [\text{Cl}_2] &= 6.20 \times 10^{-7} \div (25.0 \div 1000) \\ &= 2.48 \times 10^{-5} \text{ mol dm}^{-3} \text{ (3 s.f., as the data are to 3 s.f.)} \end{aligned}$$

$$\text{concentration of } \text{Cl}_2 = \dots\dots\dots 2.48 \times 10^{-5} \dots\dots\dots \text{ mol dm}^{-3} \text{ [4]}$$

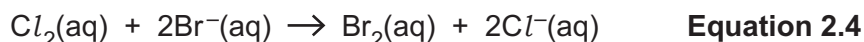
- (ii) A student is asked to write a detailed plan for the titration carried out by the chemist. The student writes:

- 1 Use a measuring cylinder to transfer 25 cm^3 of swimming pool water to a 250 cm^3 conical flask.
- 2 Rinse out a burette with de-ionised water and fill it with the $0.000100\text{ mol dm}^{-3}$ solution of sodium thiosulfate, and ensure that the space below the tap is filled.
- 3 Record the initial burette reading to the nearest 0.1 cm^3 .
- 4 Add excess potassium iodide solution to the solution in the conical flask.
- 5 Add a few drops of starch indicator.
- 6 Titrate until the blue-black colour of the starch indicator just disappears.
- 7 Repeat until titres agree within 0.1 cm^3 .

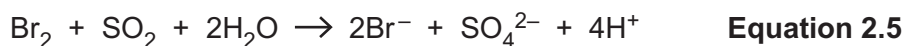
Identify and correct the mistakes that the student has made.

- Step 1: use a 25.0 cm^3 (volumetric) pipette, not a measuring cylinder.*
- Step 2: rinse the burette with the sodium thiosulfate solution, not water.*
- Step 3: read the burette to the nearest 0.05 cm^3 , not 0.1 cm^3 .*
- Step 5: add starch only when the iodine colour has faded to pale yellow (straw) near the end point.* [3]

- (d) Bromine can be extracted from seawater. One method of making bromine involves reacting chlorine gas with acidified seawater that contains bromide ions.



The bromine that is produced is then reacted with sulfur dioxide and water.
The reaction that occurs is a redox process.



Give the formula of the reducing agent in the reaction shown in **equation 2.5**.

Explain your answer in terms of oxidation states.

Reducing agent*SO₂*.....

Explanation ..*the oxidation state of S increases from +4 (in SO₂) to +6 (in SO₄²⁻)*..... [1]

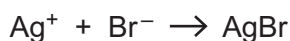
- (e) The solution containing bromide ions is then treated with chlorine and steam before the bromine produced is separated by fractional distillation.

Describe the state and appearance at room temperature of the bromine that is collected at the end of this process.

..*a dark red-brown liquid*..... [1]

- (f) (i) A student is given a solution of bromide ions.

The student adds acidified silver nitrate to the solution of bromide ions.



Describe what the student sees.

..*a cream precipitate forms*..... [1]

- (ii) A solution of sodium bromide has a concentration of $0.0260 \text{ mol dm}^{-3}$.
 25.0 cm^3 of this solution are mixed with an excess of silver nitrate solution.
 0.118 g of silver bromide is obtained.

Calculate the percentage yield of silver bromide.

$$n(\text{Br}^-) = (25.0 \div 1000) \times 0.0260 = 6.50 \times 10^{-4} \text{ mol} = n(\text{AgBr})$$

$$M(\text{AgBr}) = 107.9 + 79.9 = 187.8 \text{ g mol}^{-1}$$

$$\text{maximum mass of AgBr} = 6.50 \times 10^{-4} \times 187.8 = 0.122 \text{ g}$$

$$\% \text{ yield} = (0.118 \div 0.122) \times 100 = 96.7 \%$$

percentage yield of AgBr = ...*96.7*..... % [3]

3 Many of the chemical elements found on Earth were produced in nuclear fusion reactions in stars.

- (a) Write a nuclear equation to show the fusion of the nuclei of two hydrogen-2 atoms to give a single atom.



[1]

- (b) The presence of different elements in stars is shown by absorption or emission atomic spectra.

The diagrams below represent parts of an absorption spectrum and an emission spectrum.

absorption spectrum



frequency →

emission spectrum



frequency →

A student says that the absorption and emission spectra are for the same element.

Discuss whether the student is correct, giving the chemical theory.

The student is correct: the dark absorption lines are at exactly the same frequencies as the bright emission lines.
Electrons absorb photons and are excited to higher levels, or fall back and emit photons: the energy transitions are the same ($\Delta E = h\nu$).
Each element has unique, quantised energy levels, so it is the same element. [3]

- (c) The element indium was discovered in 1863 from an emission spectrum.

Indium has two naturally occurring isotopes as shown in the table.

Isotope	Isotopic mass
^{113}In	112.90
^{115}In	114.90

The relative atomic mass, A_r , of indium is 114.82.

Calculate the percentage abundances of the two isotopes.

$$\text{let } x = \% \text{ abundance of } ^{113}\text{In}, \text{ so } ^{115}\text{In} = 100 - x$$

$$[112.90x + 114.90(100 - x)] \div 100 = 114.82$$

$$112.90x + 11490 - 114.90x = 11482$$

$$-2.00x = -8, \text{ so } x = 4$$

$$^{113}\text{In} = 4 \%, ^{115}\text{In} = 100 - 4 = 96 \%$$

$$^{113}\text{In} \dots\dots 4 \dots\dots \%; ^{115}\text{In} \dots\dots 96 \dots\dots \% \quad [2]$$

- (d) Indium is in Group 13 of the periodic table, the same group as aluminium.

- (i) Complete the electronic configuration of indium.

$$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 5s^2 \dots\dots 5p^1 \dots\dots \quad [1]$$

- (ii) Indium has the same structure and bonding as aluminium.

Explain why indium conducts electricity.

*Indium has delocalised electrons, which can move through the structure
and carry charge.* [1]

- (iii) Indium forms an oxide that has a melting point of 1910 °C and conducts electricity in the molten state.

Explain this high melting point in terms of the structure and bonding in the compound.

*It is a giant ionic lattice with strong attractions between oppositely
charged ions, which need a lot of energy to overcome.* [1]

- (e) A student is asked to predict and explain the shape of an InH_3 molecule.

The student writes, 'Since the formula, InH_3 , is similar to ammonia, NH_3 , the shape must be the same, so it is trigonal pyramidal with bond angles of about 107° '.

Discuss the student's statements about InH_3 .

Give the supporting chemistry.

The student is incorrect about InH_3 .
In is in Group 13 with 3 outer electrons, so InH_3 has only 3 bond pairs
and no lone pair. The 3 bond pairs repel equally, so it is trigonal planar
with bond angles of 120° .
 NH_3 is different: N has 3 bond pairs and 1 lone pair, which repels more,
so NH_3 is pyramidal (107°).

[3]

4 Halons are halogenated organic compounds.

Halons have been particularly useful in aircraft fire extinguishers.

One halon is Halon-1211, CBrClF_2 .

In the high temperature of a fire one of the bonds in CBrClF_2 breaks and radicals are formed.

- (a) A student states that it is a C–F bond that breaks because C–F is the most polar of the three carbon-halogen bonds.

The student's statement is partially correct.

- (i) Explain, chemically, the correct part of the statement.

The C–F bond is the most polar ($\text{C–F} > \text{C–Cl} > \text{C–Br}$), because fluorine is the most electronegative of the three halogens ($\text{F} > \text{Cl} > \text{Br}$), so the bonding electrons are pulled most towards F.

[2]

- (ii) Correct the incorrect part of the statement, giving a reason for the correction.

It is the C–Br bond that breaks, not C–F. C–Br is the weakest bond, with the lowest bond enthalpy ($\text{C–F} > \text{C–Cl} > \text{C–Br}$), so it needs the least energy to break.

[2]

- (b) An alternative halon that is also used in fire extinguishers has the following composition by mass.

C	Br	F
9.2%	61.5%	29.3%

The M_r of this halon is 259.8.

Deduce the molecular formula of this halon.

$$C : Br : F = 9.2/12.0 : 61.5/79.9 : 29.3/19.0$$

$$= 0.767 : 0.770 : 1.54$$

$$= 1 : 1 : 2, \text{ so empirical formula} = CBrF_2$$

$$\text{empirical formula mass} = 12.0 + 79.9 + 2(19.0) = 129.9$$

$$259.8 \div 129.9 = 2, \text{ so molecular formula} = 2 \times CBrF_2$$

molecular formula of halon = ... $C_2Br_2F_4$ [2]

- (c) When halons get into the stratosphere, C–Cl bonds can be broken by UV radiation from the Sun.

The minimum frequency of radiation needed to break one C–Cl bond is 8.67×10^{14} Hz.

Calculate the bond enthalpy of the C–Cl bond, in kJ mol^{-1} .

$$\text{energy to break one C-Cl bond: } E = h\nu$$

$$E = 6.63 \times 10^{-34} \times 8.67 \times 10^{14} = 5.75 \times 10^{-19} \text{ J}$$

$$\text{energy per mole} = 5.75 \times 10^{-19} \times 6.02 \times 10^{23}$$

$$= 346\,000 \text{ J mol}^{-1} = 346 \text{ kJ mol}^{-1}$$

bond enthalpy = ... $+346$ kJ mol^{-1} [3]

(d)* Ozone and nitrogen dioxide are present in both the troposphere and the stratosphere.

Describe the advantages and disadvantages of the presence of ozone and how it can be affected by the presence of nitrogen dioxide in the troposphere and stratosphere.

Give equations where appropriate.

[6]

Troposphere: ozone is a disadvantage. It is toxic and is a component of photochemical smog, causing respiratory problems and damage to crops. NO_2 from car engines makes this worse: in sunlight $\text{NO}_2 \rightarrow \text{NO} + \text{O}$, then $\text{O} + \text{O}_2 \rightarrow \text{O}_3$, so NO_2 and O_3 together form photochemical smog.

Stratosphere: ozone is an advantage. It absorbs harmful high energy UV radiation, $\text{O}_3 + h\nu \rightarrow \text{O}_2 + \text{O}$, which protects us from UV that causes sunburn, skin cancer, DNA damage and eye damage, and harms crops.

In the stratosphere NO_2 catalyses ozone breakdown. UV splits it into radicals: $\text{NO}_2 + h\nu \rightarrow \text{NO} + \text{O}$. Then:

$\text{NO} + \text{O}_3 \rightarrow \text{NO}_2 + \text{O}_2$

$\text{NO}_2 + \text{O} \rightarrow \text{NO} + \text{O}_2$

overall: $\text{O}_3 + \text{O} \rightarrow 2\text{O}_2$

The NO radical is regenerated, so it acts as a catalyst: one NO can destroy many O_3 molecules, which depletes the ozone layer and lets more UV reach the Earth.

Additional answer space if required

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END OF QUESTION PAPER

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