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CHEMISTRY (PRINCIPAL)

Paper 2 Part A Written

9791/02

May/June 2017

2 hours 15 minutes

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
DO NOT WRITE IN ANY BARCODES.

Answer **all** questions.

Electronic calculators may be used.

You may lose marks if you do not show your working, if you do not use appropriate units or if you do not give your answer to appropriate significant figures.

A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [] at the end of each question or part question.

For Examiner's Use	
1	
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Total	

The syllabus is approved for use in England, Wales and Northern Ireland as a Cambridge International Level 3 Pre-U Certificate.

This document consists of **21** printed pages and **3** blank pages.

1 Sulfur forms a range of different fluorides.

- (a) (i) Draw the 3D shape of sulfur hexafluoride, SF₆. Use hashed and wedged bonds where necessary.

[1]

- (ii) State the shape of the SF₆ molecule and the bond angle between adjacent S–F bonds.

shape bond angle [1]

- (iii) Explain why SF₆ has this shape.

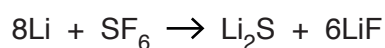
.....

 [2]

- (iv) Explain why SF₆ molecules are non-polar.

.....
 [1]

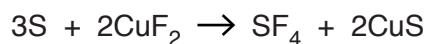
- (b) SF₆ reacts with lithium metal as shown in the equation.



Calculate the mass, in g, of lithium needed to react with 10.0 g of sulfur hexafluoride.

mass = g [2]

- (c) Copper(II) fluoride reacts with sulfur to form sulfur tetrafluoride and copper(II) sulfide.



State the relevant oxidation numbers and explain why this is a disproportionation reaction.

.....
.....
..... [2]

- (d) Sulfur chloride pentafluoride, SF_5Cl , readily undergoes addition reactions with alkenes. A $\text{C}-\text{Cl}$ bond forms in the reaction.

Give the structures of the **two** possible products from the reaction of propene with SF_5Cl .

product 1

product 2

[2]

[Total: 11]

2 Nitrogen is an unreactive gas but it can form a number of different hydrides and oxides.

(a) Explain why nitrogen gas is unreactive.

.....
 [1]

(b) Compound **X** is a hydride of nitrogen.

(i) **X** contains 12.5% of hydrogen by mass. Calculate the empirical formula of **X**.

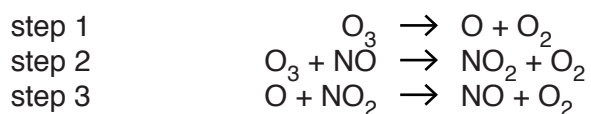
empirical formula [1]

(ii) On heating, **X** vaporises and then decomposes into its elements. On decomposition, 25 cm³ of gaseous **X** forms 75 cm³ of gaseous products at room temperature and pressure.

Deduce the molecular formula of **X**.

molecular formula [1]

(c) One oxide of nitrogen is nitrogen(II) oxide, NO. This oxide is involved in the breakdown of ozone in the stratosphere by the mechanism shown.



(i) It is thought that this process involves homolytic fission.

What is meant by the term *homolytic fission*?

.....
 [1]

(ii) NO is acting as a catalyst. Explain, by reference to the relevant steps, how this is evident from the mechanism shown.

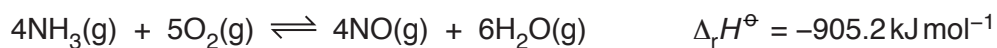
.....
 [1]

- (d) Another oxide of nitrogen is nitrogen(V) oxide, N_2O_5 . Molecules of N_2O_5 contain no nitrogen to nitrogen, or oxygen to oxygen bonds.

Draw a dot-cross diagram to suggest the bonding in N_2O_5 .

[3]

- (e) The first stage in the industrial production of nitric acid from ammonia can be represented by the equation shown.



Standard enthalpy of formation data is given in the table.

compound	$\Delta_f H^\ominus / \text{kJ mol}^{-1}$
$\text{NH}_3(\text{g})$	-46.1
$\text{H}_2\text{O}(\text{g})$	-241.8

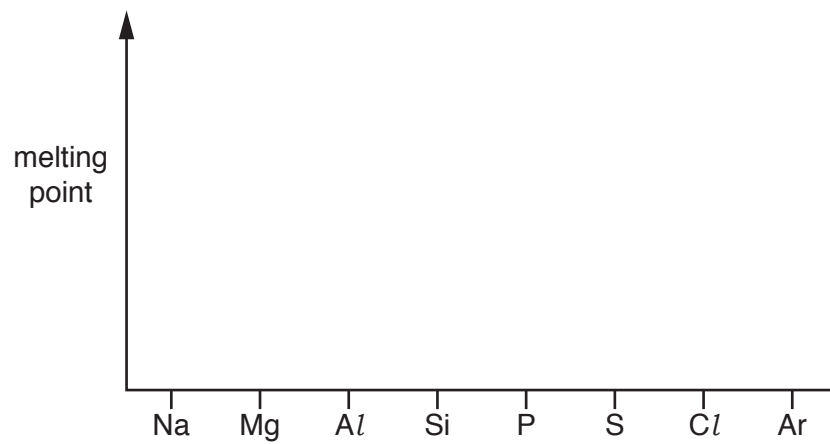
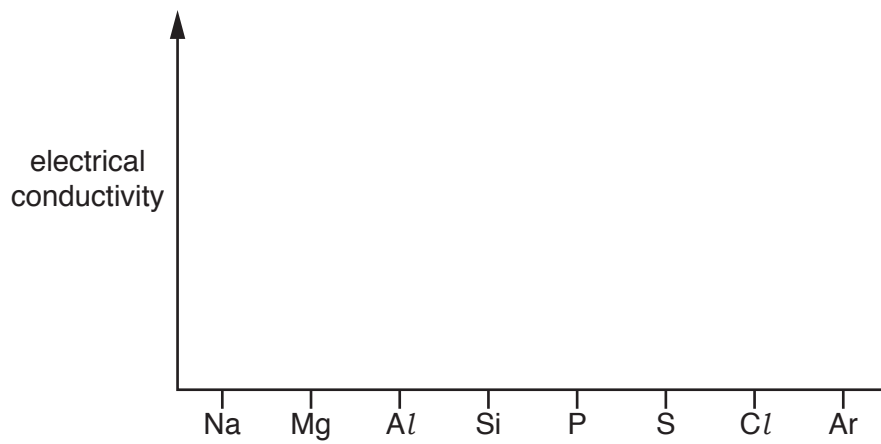
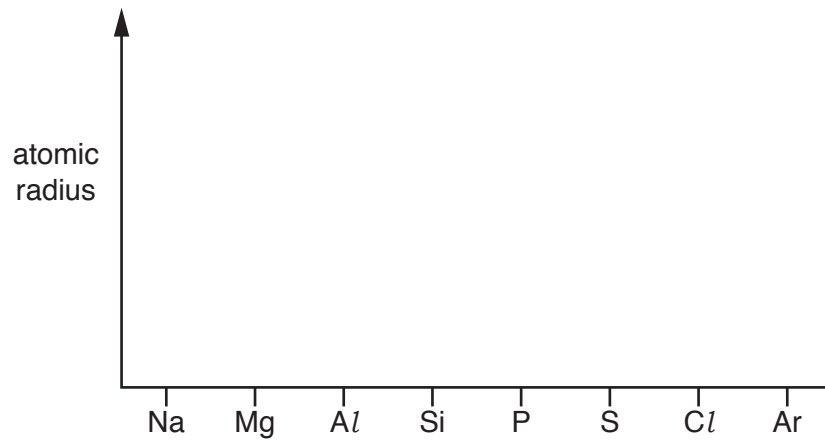
Calculate the standard enthalpy change of formation, $\Delta_f H^\ominus$, of $\text{NO}(\text{g})$.

You are advised to show your working. Include a sign in your answer.

$$\Delta_f H^\ominus = \dots\dots\dots \text{ kJ mol}^{-1} \quad [3]$$

[Total: 11]

- 3 (a) On the axes, draw a sketch graph to show how each property varies across Period 3 (Na to Ar).



[3]

- (b) The melting points of two Period 3 chlorides are shown.

sodium chloride, NaCl	silicon(IV) chloride, SiCl_4
1074 K	203 K

In terms of structure and bonding, explain why the melting points of these two chlorides differ.

.....

.....

.....

.....

..... [3]

- (c) Describe what would be observed if concentrated sulfuric acid is added to separate solid samples of NaCl , NaBr and NaI .

Include any relevant equations in your answer.

NaCl

.....

.....

.....

NaBr

.....

.....

.....

NaI

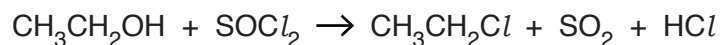
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[6]

- (d) Thionyl dichloride, SOCl_2 , is a useful reagent in organic synthesis, substituting $-\text{OH}$ groups with $-\text{Cl}$ groups.



Write the equation for the reaction of SOCl_2 with water.

..... [1]

- (e) Coal-fired power stations can release large amounts of sulfur dioxide, SO_2 , and carbon dioxide, CO_2 , into the atmosphere.

- (i) Describe, with the aid of an equation, how sulfur dioxide can be removed from power station emissions.

.....

 [2]

- (ii) The bond angle in CO_2 is 180° . The bond angle in SO_2 is approximately 120° .

Explain why SO_2 has a smaller bond angle than CO_2 .

.....

 [1]

- (iii) CO_2 and SO_2 both absorb infra-red radiation.

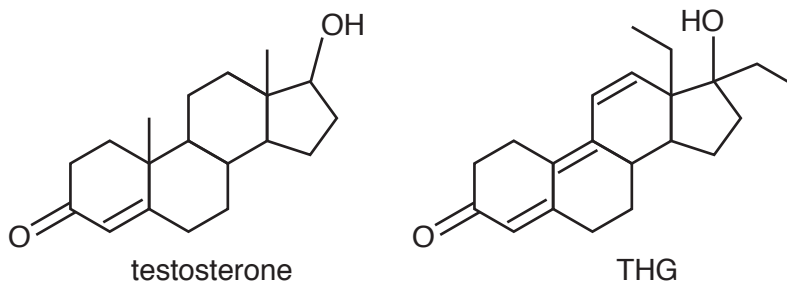
What effect does absorption of infra-red radiation have on molecules?

.....
 [1]

[Total: 17]

PLEASE TURN OVER.

- 4 A number of athletes have been disqualified for misuse of drugs such as anabolic steroids. THG is an anabolic steroid that mimics the effects of natural hormones such as testosterone.



- (a) (i) Complete the molecular formula for testosterone by showing the number of hydrogen atoms.



- (ii) How many chiral centres are there in testosterone?

..... [1]

- (b) Describe a chemical test to distinguish between testosterone and THG.

.....

 [2]

- (c) Testosterone and THG both contain C=C and C=O bonds.

- (i) Describe, in terms of atomic and molecular orbitals, how C=O bonds are formed.

You are advised to draw a diagram.

.....

 [2]

- (ii) C=O groups are readily attacked by nucleophilic reagents; C=C groups are not.

Explain why these double-bonded groups behave differently.

.....

.....

.....

..... [2]

- (d) THG can be reduced using aqueous NaBH₄.

State

- what type of bond is broken,
- which bonds are made,
- how the functional group level of the relevant carbon changes.

.....

.....

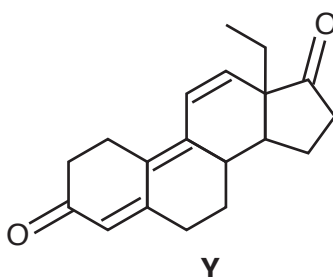
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..... [2]

- (e) In 1912, Victor Grignard reported on a new class of versatile reagents now called Grignard reagents, RMgX. These reagents can be used in organic synthesis to form carbon-carbon bonds.

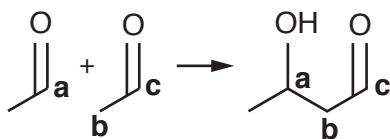
Compound **Y** can be converted into THG using a Grignard reagent.



Identify the Grignard reagent that can convert **Y** into THG.

..... [1]

- (f) The aldol reaction links two carbonyl compounds. The carbonyl carbon, **a**, of one molecule forms a covalent bond with a carbon atom, **b**, which is bonded to the carbonyl carbon, **c**, of the other molecule.



- (i) What type of reaction is the aldol reaction?

..... [1]

- (ii) When different carbonyl compounds are used in an aldol reaction, a mixture of structural isomers is formed.

Suggest **three** of the possible structural isomers formed if a mixture of propanone, CH_3COCH_3 , and propanal, $\text{CH}_3\text{CH}_2\text{CHO}$, is used.

[3]

[Total: 15]

5 Selenium, Se, is an essential micronutrient for humans and it is used extensively as a semi-conductor in photocells for solar panels.

(a) (i) Complete the electronic configuration of a selenium atom.

1s² [1]

(ii) A sample of selenium was discovered in Asia after an earthquake. The sample was found to contain the isotopes with the percentage abundances shown in the table.

isotope	percentage abundance
⁷⁶ Se	9.91
⁷⁸ Se	23.52
⁸⁰ Se	56.40
⁸² Se	10.17

Calculate the relative atomic mass of selenium in this sample.

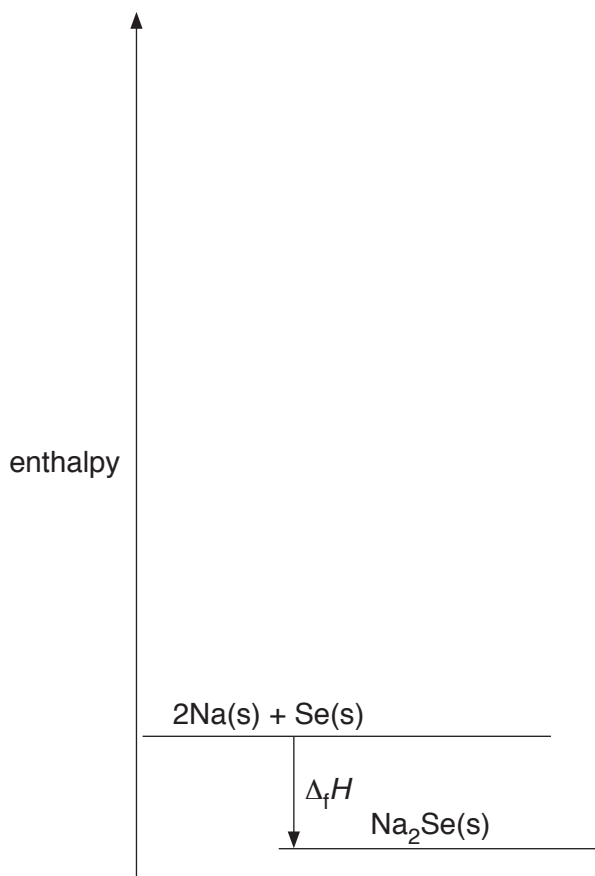
Give your answer to three significant figures.

$A_r =$ [2]

(b) The lattice enthalpy of an ionic compound can be determined from a Born-Haber cycle.

Complete the Born-Haber cycle for sodium selenide, Na_2Se .

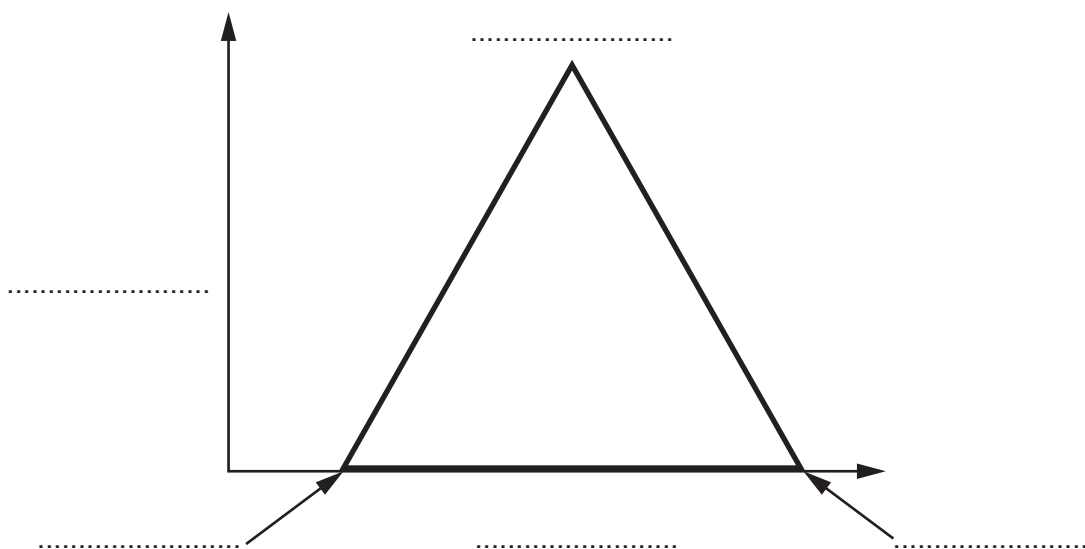
Label each enthalpy change and include state symbols.



[5]

(c) The type of bonding present in a compound can be predicted using a van Arkel triangle.

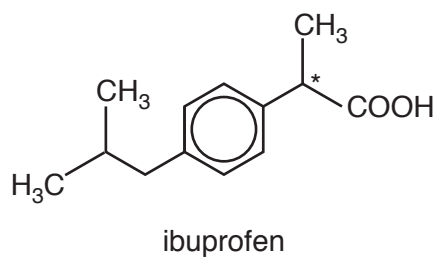
Label the diagram.



[2]

[Total: 10]

- 6 (a) Ibuprofen is an anti-inflammatory drug. The chiral carbon is indicated by *.



- (i) Draw the stereoisomers of ibuprofen.

[2]

- (ii) Ethanoic acid is a by-product of the manufacture of ibuprofen.

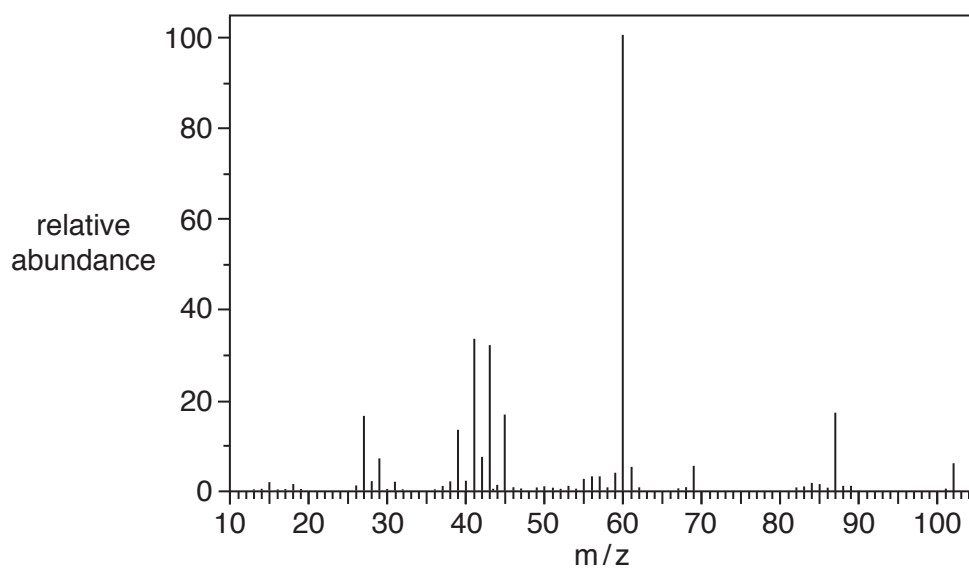
Ethanoic acid can exist as a dimer containing two hydrogen bonds.

Draw the structure of this dimer, showing relevant lone pairs and labelling clearly all relevant dipoles and hydrogen bonds.

[3]

- (b) (i) A different organic compound, **Z**, also contains carbon, hydrogen and oxygen only. Elemental analysis of **Z** shows that it contains 31.4% oxygen by mass.

The mass spectrum of **Z** is shown.



Show that the information from **both** the elemental analysis and mass spectrum is consistent with the molecular formula of **Z** being $C_5H_{10}O_2$.

[2]

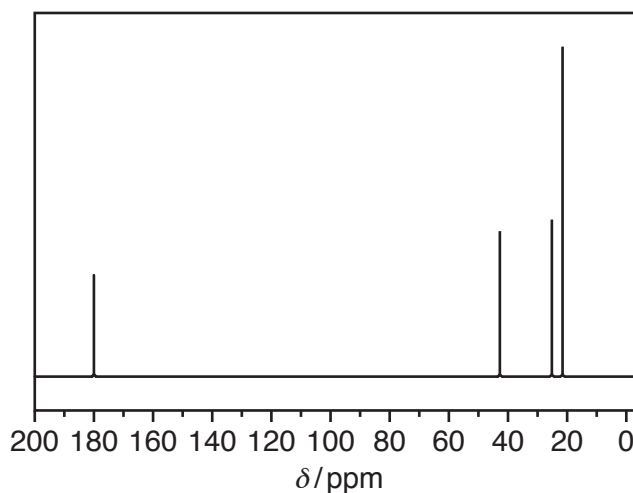
- (ii) There are **three** possible isomers of $C_5H_{10}O_2$ that are **branched** saturated carboxylic acids.

Give the structure and name of each isomer.

	isomer 1	isomer 2	isomer 3
structure			
name			

[3]

(iii) A ^{13}C NMR spectrum of one of the isomers is shown.



Use this information to deduce which of your isomers in (ii) gave this spectrum.

In your answer, you should make clear how you eliminated the other possible isomers by suggesting how their spectra would differ.

Assign the peak at 180 ppm.

.....

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.....

peak at 180 ppm

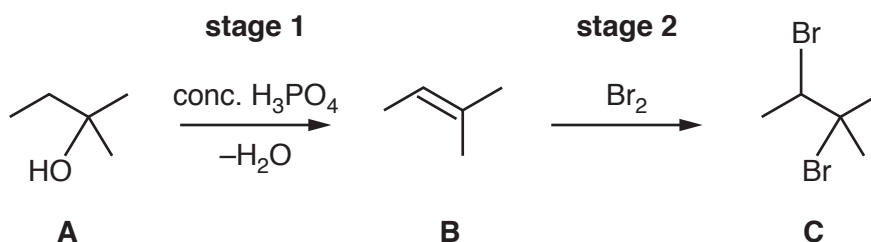
[4]

[Total: 14]

- 7 A student devises an experiment to convert an alcohol to a dibromoalkane in two stages, as shown in the scheme below.

In **stage 1**, alcohol **A** is dehydrated to alkene **B**.

In **stage 2**, **B** is converted to dibromoalkane **C**.



Physical properties and hazards of the materials are given in the table. You may need to refer to this table throughout this question.

substance	boiling point /°C	density /g cm ⁻³	hazards
alcohol A	102	0.81	moderate hazard, flammable, corrosive
alkene B	38	0.66	health hazard, flammable, hazardous to the aquatic environment
dibromoalkane C	(decomposes)	1.67	acutely toxic, hazardous to the aquatic environment
concentrated phosphoric acid	158	1.69	corrosive
bromine	59	3.10	acutely toxic, corrosive, hazardous to the aquatic environment

- (a) **B** is the major product of the reaction in **stage 1**. Give the structure of the minor product.

[1]

- (b) Hot, concentrated phosphoric acid is a dehydrating agent; hot, concentrated sulfuric acid is also a dehydrating agent. Both acids are corrosive, readily available and affordable.

Suggest why the student avoids using concentrated sulfuric acid.

.....
 [1]

- (c) The student needs 12g of alkene **B** to be prepared in **stage 1**. **Stage 1** has a yield of 85%.

Calculate the volume of **A** needed to produce 12g of **B**.

volume of **A** = cm³ [5]

- (d) In **stage 1**, alcohol **A** is mixed with 6cm³ of concentrated phosphoric acid. The mixture is heated and the product, alkene **B**, collected by fractional distillation. The vessel that receives **B** sits in an ice bath.

- (i) Why must **B** be collected using an ice bath?

.....
 [1]

- (ii) The experiment is carried out in a fume cupboard. The student wears a lab coat and eye protection. What additional safety precaution is required when handling concentrated phosphoric acid?

.....
 [1]

- (iii) Anhydrous calcium chloride granules, CaCl₂, are added to the distillate. Explain why.

..... [1]

- (iv) The alkene is separated from the CaCl₂ granules and purified by distillation. What is the safest method of heating the alkene for this distillation?

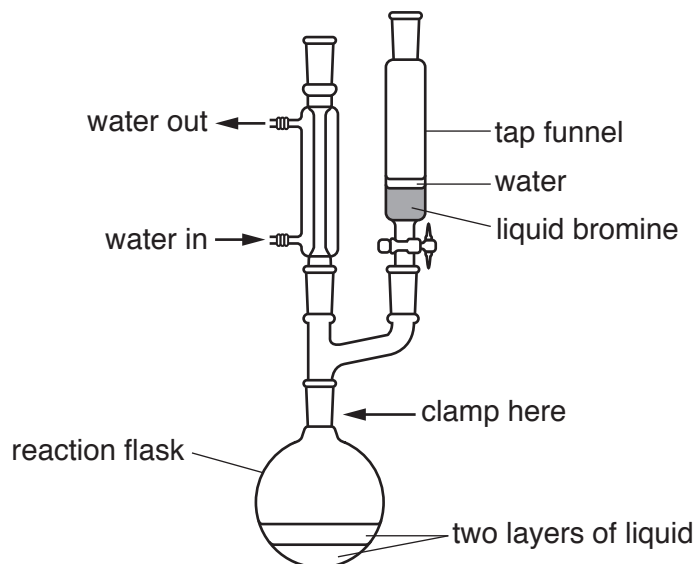
.....
 [1]

- (v) The student considers a similar scheme to make 1,2-dibromopropane. What practical difficulty would arise when collecting the intermediate alkene?

.....
 [1]

- (e) In **stage 2**, the apparatus is set up as in the diagram. 12 g of alkene **B** (from **stage 1**) and 20 cm³ of water are placed in the reaction flask. These exist as two layers within the reaction flask.

11 cm³ of bromine is placed in the tap funnel and covered with a layer of water. The bromine is then added to the reaction flask at a rate of one drop per second.



The bromine reacts on contact with the alkene. Part-way through adding the bromine, (with **B**, **C** and water present) the organic layer in the reaction flask changes from the upper layer to the lower layer.

- (i) Explain the purpose of the layer of water on top of the bromine in the tap funnel.

.....
 [1]

- (ii) Give **two** reasons why the water forms a layer above the bromine.

.....

 [2]

- (iii) Suggest why the bromine is added at such a slow rate.

.....
..... [1]

- (iv) Explain why the organic layer in the reaction flask changes from the upper layer to the lower layer when adding the bromine.

.....
.....
.....
.....
..... [3]

- (f) When most of the bromine has been added in **stage 2**, as the aqueous layer in the reaction flask becomes coloured, the mixture is boiled under reflux. Bromine continues to be added until the aqueous layer is permanently coloured. The colour is discharged with a few drops of ammonia solution.

The reaction mixture is then distilled. Product **C** distils over with water at about 100 °C. The distillate forms two layers. It is transferred to a separating funnel to run off the lower layer into a conical flask.

- (i) Suggest the permanent colour seen in the aqueous layer on adding bromine to the reaction vessel.

..... [1]

- (ii) Suggest why it is desirable for water to be present during the final distillation.

.....
.....
..... [1]

- (iii) What final stage remains to be done to isolate pure product **C**?

.....
..... [1]

[Total: 22]

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