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CHEMISTRY

9701/21

Paper 2 Structured Questions AS Core

May/June 2014

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

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Answer **all** the questions in the spaces provided.

- 1 (a) Explain what is meant by the term *ionisation energy*.

.....

.....

..... [3]

- (b) The first seven ionisation energies of an element, **A**, in kJ mol^{-1} , are

1012 1903 2912 4957 6274 21 269 25 398.

- (i) State the group of the Periodic Table to which **A** is most likely to belong. Explain your answer.

.....

.....

.....

..... [2]

- (ii) Complete the electronic configuration of the element in Period 2 that is in the same group as **A**.

$1s^2$ [1]

- (c) Another element, **Z**, in the same period of the Periodic Table as **A**, reacts with chlorine to form a compound with empirical formula ZCl_2 . The percentage composition by mass of ZCl_2 is **Z**, 31.13; **Cl**, 68.87.

- (i) Define the term *relative atomic mass*.

.....

.....

..... [2]

- (ii) Calculate the relative atomic mass, A_r , of **Z**.
Give your answer to **three** significant figures.

A_r of **Z** = ... [2]

(d) The chlorides of elements in Period 3 of the Periodic Table show different behaviours on addition to water, depending on their structure and bonding.

- (i) Write equations to show the behaviour of sodium chloride, NaCl , and silicon chloride, SiCl_4 , when separately added to an excess of water.

NaCl

SiCl_4

[2]

- (ii) State and explain the differences in behaviour of these two chlorides when added to water, in terms of their structure and the bonding found in the compounds.

.....

.....

.....

.....

.....

..... [4]

(e) Sulfur reacts with fluorine to form SF_6 . State the shape and bond angle of SF_6 .

shape of SF_6

bond angle of SF_6

[2]

[Total: 18]

- 2 The commonest form of iron(II) sulfate is the heptahydrate, $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$. On heating at 90°C this loses **some** of its water of crystallisation to form a different hydrated form of iron(II) sulfate, $\text{FeSO}_4 \cdot x\text{H}_2\text{O}$.

3.40 g of $\text{FeSO}_4 \cdot x\text{H}_2\text{O}$ was dissolved in water to form 250 cm^3 of solution.

A 25.0 cm^3 sample of this solution was acidified and titrated with $0.0200\text{ mol dm}^{-3}$ potassium manganate(VII).

In this titration 20.0 cm^3 of this potassium manganate(VII) solution was required to react fully with the Fe^{2+} ions present in the sample.

- (a) The MnO_4^- ions in the potassium manganate(VII) *oxidise* the Fe^{2+} ions in the acidified solution.

- (i) Explain, in terms of electron transfer, the meaning of the term *oxidise* in the sentence above.

.....
 [1]

- (ii) Complete and balance the ionic equation for the reaction between the manganate(VII) ions and the iron(II) ions.



- (b) (i) Calculate the number of moles of manganate(VII) used in the titration.

[1]

- (ii) Use the equation in (a)(ii) and your answer to (b)(i) to calculate the number of moles of Fe^{2+} present in the 25.0 cm^3 sample of solution used.

[1]

- (iii) Calculate the number of moles of $\text{FeSO}_4 \cdot x\text{H}_2\text{O}$ in 3.40 g of the compound.

[1]

- (iv) Calculate the relative formula mass of $\text{FeSO}_4 \cdot x\text{H}_2\text{O}$.

[1]

- (v) The relative formula mass of anhydrous iron(II) sulfate, FeSO_4 , is 151.8.

Calculate the value of x in $\text{FeSO}_4 \cdot x\text{H}_2\text{O}$.

[1]

[Total: 9]

- 3 (a) In this question, **K**, **L** and **M** refer to a halogen atom or halide ion.
For each part question, read the information and complete the answer lines below.

- (i) When concentrated sulfuric acid is added to solid **NaK**, white fumes are produced that turn damp blue litmus paper red. No other colour changes are observed.

identity of **K** = ...

equation for reaction

explanation of observation

..... [3]

- (ii) When silver nitrate solution is added to an aqueous solution of **NaL**, a precipitate forms that remains after the addition of concentrated ammonia solution.

identity of **L** = ...

colour of precipitate

equation for reaction [3]

- (iii) **M₂** is a liquid at room temperature with a boiling point higher than that of chlorine but lower than that of iodine.

identity of **M** = ...

explanation

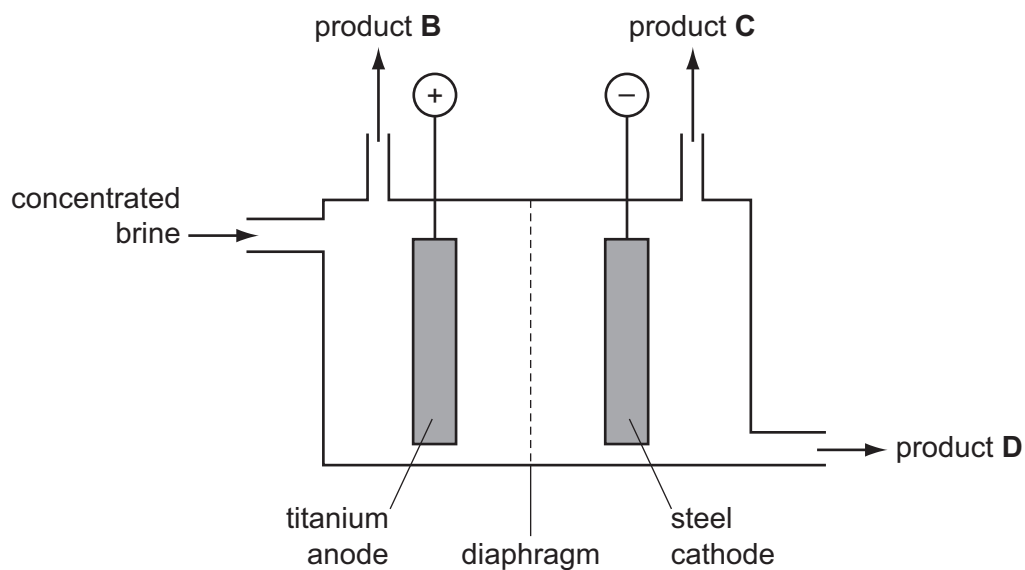
.....

.....

.....

..... [2]

(b) The diagram below is a simplified representation of a diaphragm cell.



(i) Identify each of the products.

B

C

D

[3]

(ii) Give the equations for the two electrode reactions.

anode

cathode

[2]

[Total: 13]

4 Alkanes and alkenes both react with bromine.

(a) Explain how and why bromine can be used to distinguish between an alkene and an alkane.

.....

 [2]

(b) The reaction of ethane with bromine forms a mixture of products.

(i) State the essential conditions for this reaction to occur.

..... [1]

(ii) Give the full name of the mechanism of this reaction.

..... [2]

(iii) Give the equation for a **termination** step that could occur, producing a **hydrocarbon**.

..... [1]

(iv) Give the equation for one **propagation** step involved in the formation of dibromoethane from bromoethane during this reaction.

..... [1]

(c) The reaction of ethene with bromine forms a single product.

(i) Give the full name of the mechanism of this reaction.

..... [2]

(ii) Complete the diagram below to illustrate this mechanism.
 Include all relevant charges, partial charges, curly arrows and lone pairs.

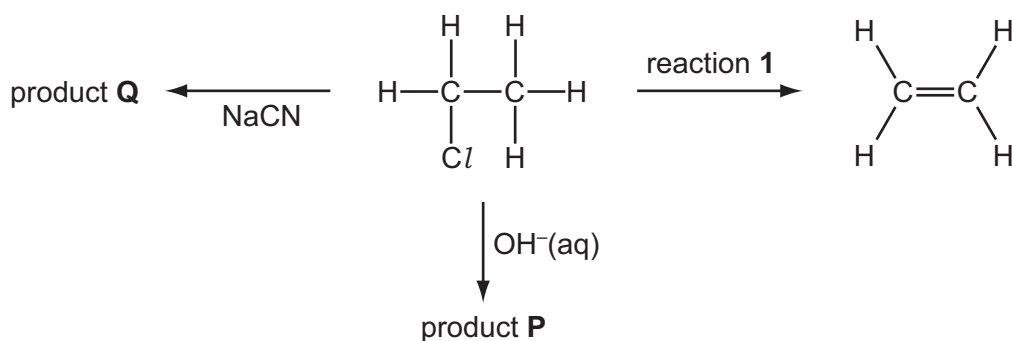


[4]

- (d) Chloroethene can be polymerised to form a polymer commonly known as PVC. Draw a diagram of the structure of PVC including **three** repeat units.

[2]

- (e) Chloroethane undergoes a series of reactions as shown in the diagram below.



- (i) Give the reagent and conditions necessary for reaction 1.

.....
 [2]

- (ii) Give the **skeletal** formula of product P.

[1]

- (iii) Give the **displayed** formula and the name of product Q.

..... [2]

[Total: 20]

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Answer **all** the questions in the spaces provided.

- 1 (a) Explain what is meant by the term *nucleon number*.

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

- (b) Bromine exists naturally as a mixture of two stable isotopes, ^{79}Br and ^{81}Br , with relative isotopic masses of 78.92 and 80.92 respectively.

- (i) Define the term *relative isotopic mass*.

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

- (ii) Using the relative atomic mass of bromine, 79.90, calculate the relative isotopic abundances of ^{79}Br and ^{81}Br .

[3]

- (c) Bromine reacts with the element **A** to form a compound with empirical formula ABr_3 . The percentage composition by mass of ABr_3 is **A**, 4.31; Br, 95.69.

Calculate the relative atomic mass, A_r , of **A**.
Give your answer to **three** significant figures.

A_r of **A** = ... [3]

(d) The elements in Period 3 of the Periodic Table show different behaviours in their reactions with oxygen.

- (i) Describe what you would **see** when separate samples of magnesium and sulfur are reacted with oxygen.

Write an equation for each reaction.

magnesium

.....

sulfur

.....

[4]

- (ii) Write equations for the reactions of aluminium oxide, Al_2O_3 , with

sodium hydroxide,

.....

hydrochloric acid.

.....

[2]

- (e) Phosphorus reacts with chlorine to form PCl_5 .

State the shape of and two different bond angles in a molecule of PCl_5 .

shape of PCl_5

bond angles in PCl_5

[2]

[Total: 17]

- 2 A 6.30 g sample of hydrated ethanedioic acid, $\text{H}_2\text{C}_2\text{O}_4 \cdot x\text{H}_2\text{O}$, was dissolved in water and the solution made up to 250 cm^3 .

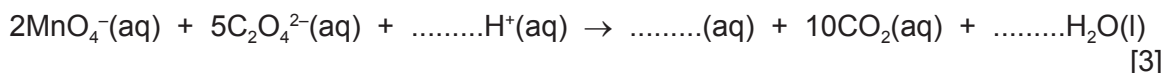
A 25.0 cm^3 sample of this solution was acidified and titrated with 0.100 mol dm^{-3} potassium manganate(VII) solution. 20.0 cm^3 of this potassium manganate(VII) solution was required to react fully with the ethanedioate ions, $\text{C}_2\text{O}_4^{2-}$, present in the sample.

(a) The MnO_4^- ions in the potassium manganate(VII) *oxidise* the ethanedioate ions.

- (i) Explain, in terms of electron transfer, the meaning of the term *oxidise* in the sentence above.

.....
 [1]

- (ii) Complete and balance the ionic equation for the reaction between the manganate(VII) ions and the ethanedioate ions.



- (b) (i) Calculate the number of moles of manganate(VII) used in the titration.

[1]

- (ii) Use the equation in (a)(ii) and your answer to (b)(i) to calculate the number of moles of $\text{C}_2\text{O}_4^{2-}$ present in the 25.0 cm^3 sample of solution used.

[1]

- (iii) Calculate the number of moles of $\text{H}_2\text{C}_2\text{O}_4 \cdot x\text{H}_2\text{O}$ in 6.30 g of the compound.

[1]

- (iv) Calculate the relative formula mass of $\text{H}_2\text{C}_2\text{O}_4 \cdot x\text{H}_2\text{O}$.

[1]

- (v) The relative formula mass of anhydrous ethanedioic acid, $\text{H}_2\text{C}_2\text{O}_4$, is 90.

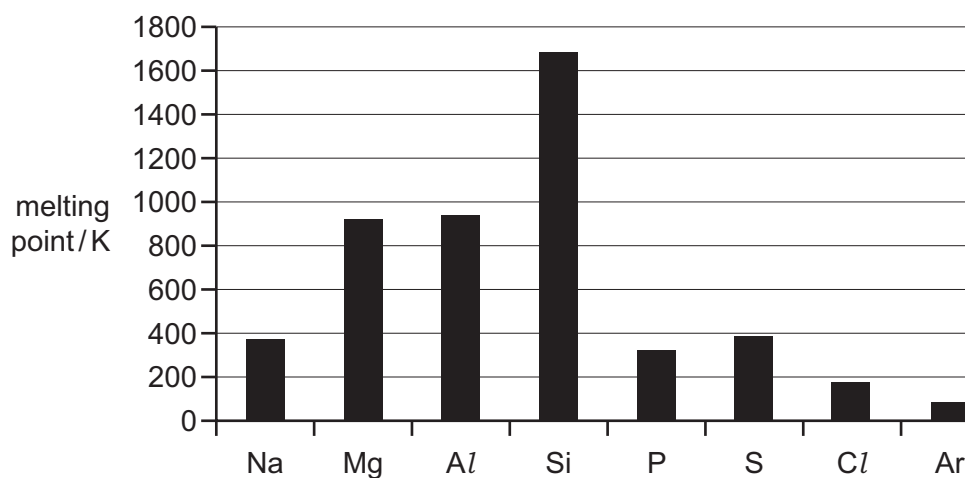
Calculate the value of x in $\text{H}_2\text{C}_2\text{O}_4 \cdot x\text{H}_2\text{O}$.

[1]

[Total: 9]

3 The elements in Period 3 of the Periodic Table show variations in their behaviour across the period.

(a) The bar chart below shows the variation of melting points of the elements across Period 3.



In each of the following parts of this question you should clearly identify the interactions involved and, where appropriate, explain their relative magnitudes.

(i) Explain the general increase in melting point from Na to Al.

.....

 [3]

(ii) Explain the variation of melting points from P to Ar.

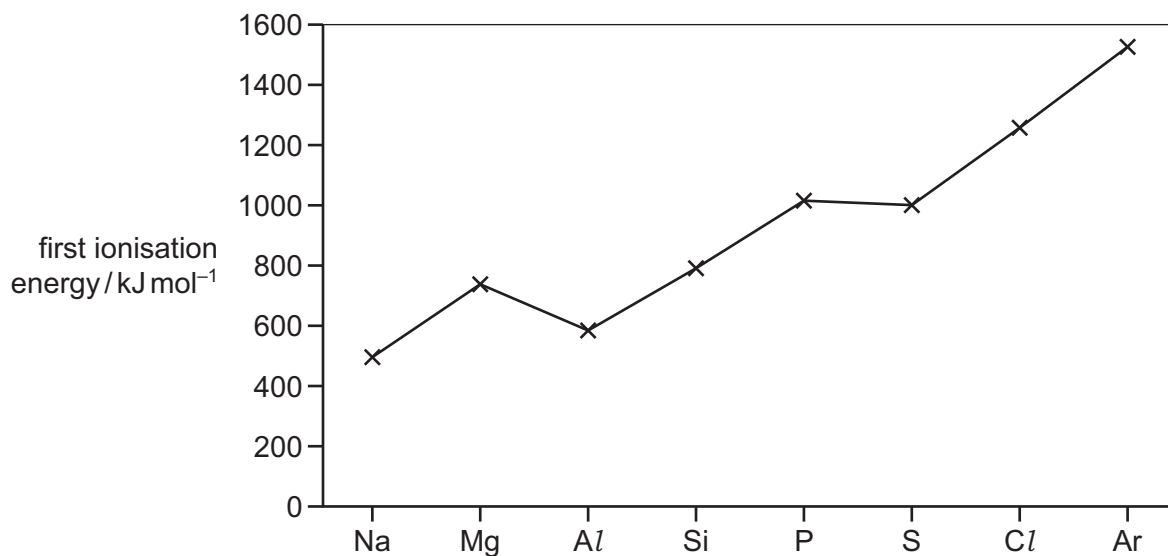
.....

 [3]

(iii) Explain why Si has a much higher melting point than any of the other elements in the period.

.....
 [1]

(b) The graph below shows the variation of the first ionisation energies across Period 3.



(i) Explain why the first ionisation energy of Ar is greater than that of Cl.

.....
 [1]

(ii) Explain why the first ionisation energy of Al is less than that of Mg.

.....
 [1]

(iii) Explain why the first ionisation energy of S is less than that of P.

.....
 [1]

[Total: 10]

4 Crude oil is processed to give a wide variety of hydrocarbons.

(a) Give the names of one physical process and one chemical process carried out during the processing of crude oil.

physical process

chemical process

[2]

(b) Alkanes and alkenes can both be obtained from crude oil.

(i) Explain why alkanes are unreactive.

.....

..... [2]

(ii) State the bond angles in a molecule of

ethane, ...

ethene.

[1]

(iii) State the shape of each molecule in terms of the arrangement of the atoms bonded to each carbon atom.

ethane ethene [1]

(iv) Explain why these molecules have different shapes in terms of the carbon-carbon bonds present.

.....

..... [1]

(c) (i) Use a series of equations to describe the mechanism of the reaction of ethane with chlorine to form chloroethane. Name the steps in this reaction.

.....

.....

.....

.....

..... [5]

(ii) Write an equation to show how butane could be produced as a by-product of this reaction.

..... [1]

[Total: 13]

- 5 A hydrocarbon, **P**, with the formula C_6H_{12} readily decolourises bromine.

On reaction with hot, concentrated, acidified potassium manganate(VII) solution a single organic product, **Q**, is obtained.

Q gives an orange precipitate when reacted with 2,4-dinitrophenylhydrazine, 2,4-DNPH reagent, but has no reaction with Tollens' reagent.

- (a) (i) Explain these observations.

.....

.....

.....

.....

.....

.....

.....

..... [4]

- (ii) Draw the skeletal formula of **P** and give its name.

name of **P** [2]

- (iii) Draw the skeletal formula of **Q** and give its name.

name of **Q** [2]

- (b) There are several structural isomers of **P** that also decolourise bromine, but only four of these structural isomers exhibit geometrical (cis-trans) isomerism.

Give the structures of any **three** structural isomers of **P** that exhibit geometrical (cis-trans) isomerism.

[3]

[Total: 11]

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- 1 (a) Define the term *mole*.

.....
 [1]

- (b) 10 cm³ of a gaseous hydrocarbon, C_xH_y, was reacted with 100 cm³ of oxygen gas, an excess.

The final volume of the gaseous mixture was 95 cm³.

This gaseous mixture was treated with concentrated, aqueous sodium hydroxide to absorb the carbon dioxide present. This reduced the gas volume to 75 cm³.

All gas volumes were measured at 298 K and 100 kPa.

- (i) Write an equation for the reaction between sodium hydroxide and carbon dioxide.

..... [1]

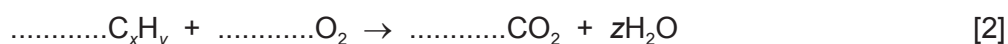
- (ii) Calculate the volume of carbon dioxide produced by the combustion of the hydrocarbon.

volume of CO₂ produced = ... cm³ [1]

- (iii) Calculate the volume of oxygen used up in the reaction with the hydrocarbon.

volume of O₂ used = ... cm³ [1]

- (iv) Use your answers to (b)(ii) and (b)(iii), together with the initial volume of hydrocarbon, to balance the equation below.



- (v) Deduce the values of x, y and z in the equation in (iv).

x = ...

y = ...

z = ...

[3]

- (c) Another hydrocarbon, **W**, with the formula C_4H_8 , reacts with hydrogen bromide, HBr , to give two products **X** and **Y**. **X** and **Y** are structural isomers of molecular formula C_4H_9Br .

Reaction of **X** with aqueous alkali produces an alcohol, **Z**, that has **no** reaction with acidified dichromate(VI).

- (i) Give the structures **and** names of the compounds **W**, **X**, **Y**, and **Z**

W

X

.....

.....

Y

Z

.....

.....

[4]

- (ii) When **W** reacts with hydrogen bromide, more **X** than **Y** is produced. Explain why.

.....

.....

.....

..... [2]

[Total: 15]

- 2** A sample of a hydrated double salt, $\text{Cu}(\text{NH}_4)_x(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}$, was boiled with an excess of sodium hydroxide. Ammonia was given off.

The ammonia produced was absorbed in 40.0 cm^3 of $0.400 \text{ mol dm}^{-3}$ hydrochloric acid. The resulting solution required 25 cm^3 of 0.12 mol dm^{-3} sodium hydroxide to neutralise the excess acid.

- (a)** Write the ionic equation for the reaction between ammonium ions and hydroxide ions.

..... [1]

- (b) (i)** Calculate the amount, in moles, of hydrochloric acid in 40.0 cm^3 of $0.400 \text{ mol dm}^{-3}$ solution.

[1]

- (ii)** Calculate the amount, in moles, of sodium hydroxide needed to neutralise the excess acid. This will be equal to the amount of hydrochloric acid left in excess.

[1]

- (iii)** Calculate the amount, in moles, of hydrochloric acid that reacted with ammonia.

[1]

- (iv)** Calculate the amount, in moles, of ammonium ions in the sample of the double salt.

[1]

- (v)** The sample contained 0.413 g of copper. Use this information and your answer to **(iv)** to calculate the value of x in $\text{Cu}(\text{NH}_4)_x(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}$.

[2]

- (vi)** Calculate the M_r of $\text{Cu}(\text{NH}_4)_x(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}$.

[1]

[Total: 8]

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3 Nitrogen dioxide, NO_2 , can enter the atmosphere in a variety of ways.

(a) (i) State one natural and one man-made source of atmospheric NO_2 .

natural

man-made

[1]

(ii) Write an equation to show how NO_2 leads to the formation of nitric acid in acid rain.

..... [1]

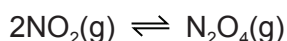
(iii) Use equations to illustrate the catalytic role of NO_2 in the formation of sulfuric acid in acid rain.

.....

.....

..... [3]

(b) Nitrogen dioxide exists in equilibrium with dinitrogen tetroxide, N_2O_4 .



2.00 mol of dinitrogen tetroxide was sealed in a container at 350 K. After equilibrium had been established the total pressure was 140 kPa and the mixture of gases contained 1.84 mol of dinitrogen tetroxide.

(i) Give the expression for the equilibrium constant, K_p , for this equilibrium.

$$K_p =$$

[1]

(ii) Calculate the number of moles of NO_2 present at equilibrium.

[1]

(iii) Calculate the total number of moles of gas present at equilibrium and hence the mole fraction of each gas present at equilibrium.

[2]

(iv) Calculate the partial pressure of each gas present at equilibrium.

[2]

(v) Calculate the value of the equilibrium constant, K_p , at 350 K.
Give your answer to **three** significant figures and include the units.

$K_p =$

units = ...

[2]

[Total: 13]

- 4 The halogens and their compounds have a wide variety of uses and the chemical and physical properties of the elements show regular patterns related to their positions in Group VII.

(a) Chlorine, bromine and iodine all react with hydrogen.

(i) State the trend in the reactivities of the halogens with hydrogen.

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

(ii) Explain this trend in terms of bond energies.

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

(b) In the laboratory it is not very convenient to prepare hydrogen halides from their elements.

Hydrogen halides can be prepared from their salts.

(i) Write an equation for the reaction of calcium chloride, CaCl_2 , with concentrated sulfuric acid.

..... [1]

(ii) Explain why hydrogen iodide is not prepared in this way.

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

(iii) When potassium bromide, KBr , reacts with concentrated sulfuric acid, sulfur dioxide, SO_2 , is produced. State what you would see and write an equation for this reaction.

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

- (c) (i) Give the structures of the four structural isomers of C_4H_9Br **and** identify each as primary, secondary or tertiary.

.....

.....

[4]

- (ii) Name the isomer of C_4H_9Br that contains a chiral centre and draw the three-dimensional structures of the two optical isomers.

name

structures

.....

[3]

- (d) Aqueous silver nitrate solution was added to separate tubes containing chloroethane, bromoethane and iodoethane. The tubes were heated in a water bath.

A yellow precipitate appeared first in the tube containing iodoethane, followed by a cream precipitate in the tube containing bromoethane and finally a white precipitate appeared in the tube containing chloroethane.

Explain these observations.

.....

.....

.....

.....

.....

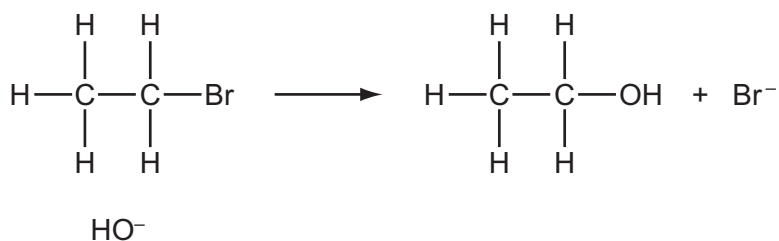
.....

..... [2]

- (e) (i) Give the full name of the mechanism for the reaction between aqueous sodium hydroxide and bromoethane.

..... [2]

- (ii) Complete the diagram below to represent this mechanism. Include all necessary curly arrows, partial charges and lone pairs.



[2]

- (f) In the past, CFCs such as CF_3Cl were widely used as refrigerants.

- (i) State a property of CFCs which makes them suitable for use as refrigerants.

..... [1]

- (ii) State the damaging effect of CFCs in the upper atmosphere.

.....

Explain your answer.

.....

.....

.....

[2]

[Total: 24]

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