# SERANGOON JUNIOR COLLEGE
## General Certificate of Education Advanced Level
## Higher 2

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|---|---|
| **CANDIDATE NAME** | |
| **CLASS** | |

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## CHEMISTRY **9647/02**

Preliminary Examination **22 August 2014**
Paper 2 Structured Questions (SPA) **2 hours**

Candidates answer on the Question Paper.
Additional Materials: Data Booklet.

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**READ THESE INSTRUCTIONS FIRST**

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough work.

Answer **all** questions in the space provided.
You are advised to spend **30 minutes** on question 1.

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

| **For Examiner's Use** | |
|---|---|
| **P1** | /40 |
| **P2** | /72 |
| **P3** | /80 |
| **GRAND TOTAL** | /192 |
| **%** | |
| **GRADE** | |

| **For Examiner's Use** | |
|---|---|
| **1(P)** | /12 |
| **2** | /20 |
| **3** | /13 |
| **4** | /12 |
| **5** | /15 |
| **TOTAL P2** | /72 |

This document consists of **19** printed pages and **1** blank page

## Answer all questions in the space provided

**1** **Planning (P)**

Borax, also known as sodium tetraborate decahydrate, $Na_2B_4O_5(OH)_4.10H_2O$, is a controlled poison in Singapore and cannot be bought off the shelf.

Borax dissolves slightly in water to form an alkaline solution:

$$Na_2B_4O_5(OH)_4(s) \rightleftharpoons 2Na^+(aq) + [B_4O_5(OH)_4]^{2-}(aq)$$

$$[B_4O_5(OH)_4]^{2-}(aq) + 5H_2O(l) \rightleftharpoons 4H_3BO_3(aq) + 2OH^-(aq)$$

The solubility product of borax at 30°C can be determined via volumetric analysis using hydrochloric acid solution.

**(a)** Assuming that ***a*** $cm^3$ of 0.500 mol $dm^{-3}$ HC*l* is required for titrating 25.0 $cm^3$ of borax solution at 30°C, calculate the solubility product of borax (excluding units) in terms of ***a***.

**[3]**

**(b)** Deduce the sign for ∆S for the dissolution of borax. Hence, predict whether this process will be more or less feasible at a higher temperature, given that ∆H is endothermic.

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**[2]**

The solubility of borax can also be defined as 30 g of solid that will dissolve in 100 g of water at 60°C.

**(c)** Other than volumetric analysis, write a plan to validate the above information.

Your plan should also include

- steps to prepare a saturated solution
- steps to maintain the temperature throughout the experiment

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**[6]**

**(d)** Identify one potential safety hazard in either experiment **(a)** or **(c)** and state how you would minimise this risk.

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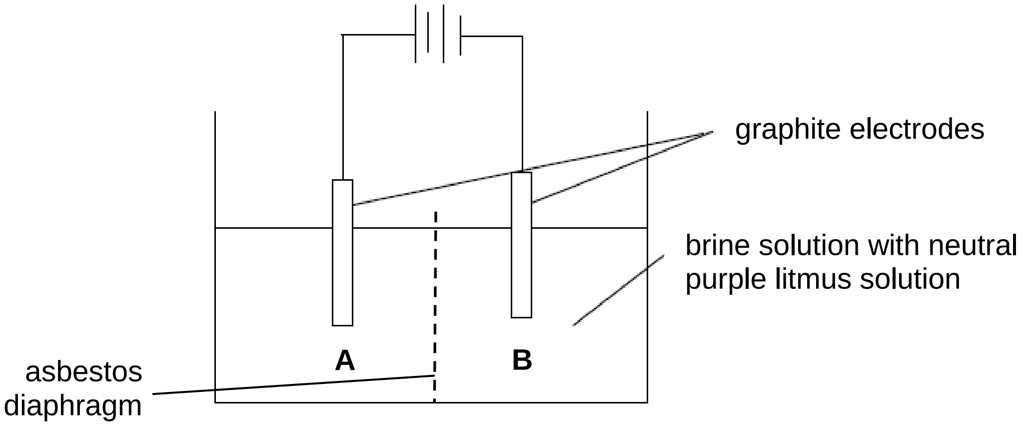
**[1]**

**[Total: 12]**

**2** Sodium and chlorine are two common elements on Earth. Elemental chlorine is commercially produced from brine, also known as concentrated sodium chloride, by electrolysis.

The electrolysis of brine solution containing neutral litmus solution is carried out in the following apparatus using graphite electrodes. The colour changes of the litmus solutions around regions **A** and **B** were observed during the process.



**(a)** **(i)** With the aid of the *Data Booklet*, account for the colours changes observed around regions **A** and **B**. Include balanced equations where appropriate.

| Region | Observations | Reason |
|---|---|---|
| **A** | Litmus solution first turned red, and then turned colourless | |
| **B** | Litmus solution turned blue | |

For Examiner's Use

**(ii)** The asbestos diaphragm is a porous material that prevents the products from electrolysis from mixing.

Write an equation to illustrate the reaction that will occur at room temperature when the diaphragm was removed after the electrolysis.

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**(iii)** Useful chlorine-containing products such as sodium chlorate(V) and chlorine dioxide may be obtained from further processing of the products in **(a)(ii)**.

By considering the numbers of bonding and non–bonding electron pairs, draw diagrams in the boxes below to show the likely shape of $ClO_3^-$ and $ClO_2$.

In your diagrams, state the shape and clearly indicate the respective bond angle values.

| **chlorate(V) ion , $ClO_3^-$** | **chlorine dioxide, $ClO_2$** |
|---|---|
| Shape: …………………………<br>Bond angle: …………………… | Shape: …………………………<br>Bond angle: …………………… |

**[9]**

**(b)** Chlorine dioxide is an unstable gas which decomposes into chlorine gas and oxygen gas readily.

**(i)** Write a balanced equation for this decomposition.

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**(ii)** At a pressure of 1 atm and decomposition temperature of 40°C, calculate the volume of chlorine gas formed when 150.0 g of chlo decomposed.

**(iii)** Comparing between chlorine and chlorine dioxide gas, state and explain which gas deviates more from ideal gas behaviour.

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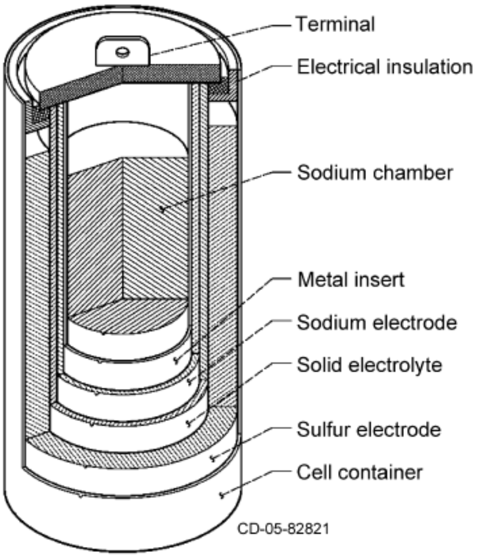
**[6]**

**(c)** Molten sodium salts are used in batteries to run industrial plants due to its high energy density and efficiency.



Sodium sulfur battery schematic

A typical sodium-sulfur battery is as shown above. During the discharge phase, molten elemental sodium at the core serves as the anode. The sodium ions produced at the anode then migrates to the sulfur electrode. The discharge process of one such cell producing 2.00 V is represented as follows:

$$2Na + 4S \rightarrow Na_2S_4$$

**(i)** Using the information above, write the equation to represent the reaction taking place at the sulfur cathode.

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**(ii)** With reference to the *Data Booklet*, determine a value for the $E^\theta$ of the reaction at the cathode. State any assumptions you make.

**(iii)** Using your answer in **(c)(ii)**, suggest a replacement half-cell for sodium metal to generate a higher voltage reading than 2.00 V.

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**(iv)** Suggest one precaution to take in storing the sodium-sulfur battery.

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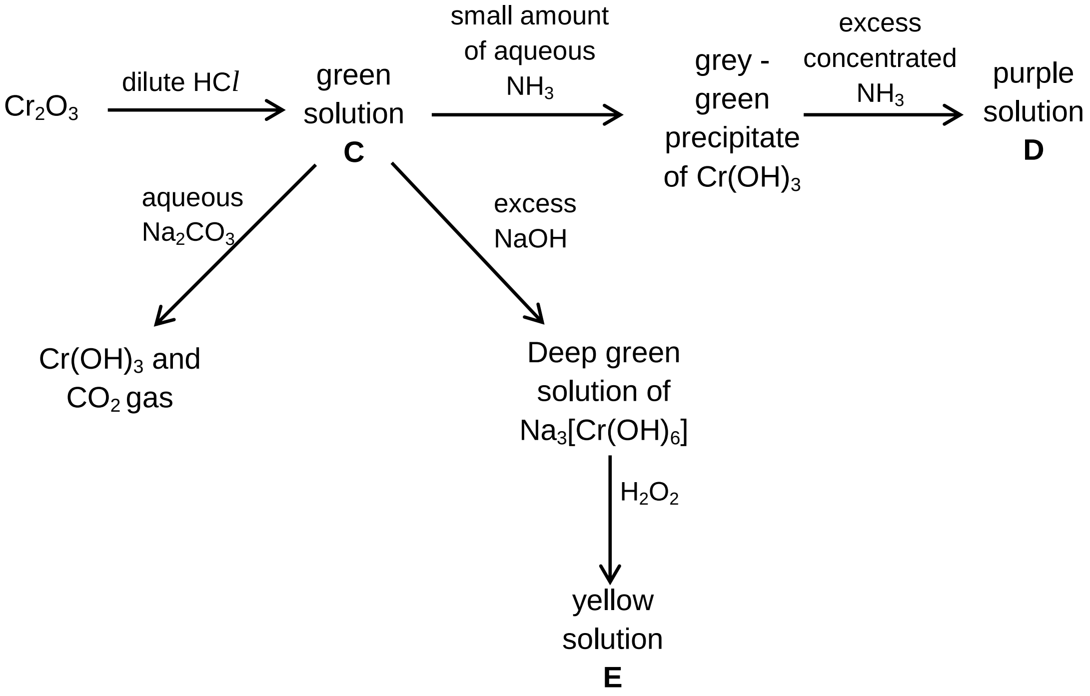
**[5]**

**[Total: 20]**

*For Examiner's Use*

**3** **(a)** Chromium(III) oxide was used by the Chinese in the Qin dynasty over 2,000 years ago to coat metal weapons found with the Terracotta Army. Chromium oxide is amphoteric. Although insoluble in water, it dissolves in acid.

The following shows a reaction scheme involving chromium oxide:



**(i)** Identify the chromium containing species in **C**, **D** and **E**.

**C**: ......................................

**D**: ......................................

**E**: ......................................

**(ii)** Explain, with the aid of equations, why the green precipitate of $Cr(OH)_3$ dissolved in excess concentrated ammonia to form the purple solution **D**.

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**(iii)** Construct an equation for the reaction of $Na_3[Cr(OH)_6]$ with hydrogen peroxide to form the yellow solution **E**.

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**(iv)** Explain why $Cr(OH)_3$ and not $Cr_2(CO_3)_3$ is formed when aqueous sodium carbonate is added to solution **C**.

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**[8]**

**(b)** Two chromium(III) complexes with the formula $Cr(H_2O)_6Cl_3$ can be prepared under various conditions. Each complex contains a cation in which the coordination number of chromium is 6. The amount of lead(II) chloride precipitated when aqueous lead(II) nitrate is added is shown in the table below:

| **Complex** | **Colour** | **Amount (in mol) of $PbCl_2$ precipitated per mole of complex** | **Presence of dipole moment** |
|---|---|---|---|
| **F** | dark green | 0.5 | yes |
| **G** | dark green | 0.5 | no |

**(i)** Using the results of the reaction with lead(II) nitrate, suggest the structural formula for the cation present in **F** and **G**.

Structural formula: ……………………………………….

**(ii)** Explain the presence or absence of a dipole moment for complexes **F** and **G** respectively.

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**[2]**

**(c)** Chromium, together with calcium and magnesium, are key mineral nutrients with nutritional influences on blood sugar.

**(i)** Explain why the atomic radius of calcium is larger than that of magnesium.

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**(ii)** Explain why the reaction of calcium with hydrochloric acid is more vigorous than the reaction of magnesium with hydrochloric acid.

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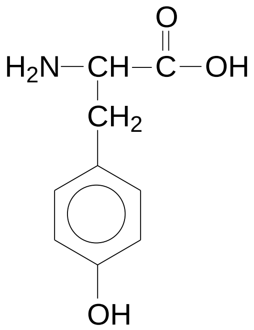
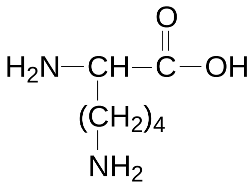
**[3]**

**[Total: 13]**

**4** The amino acids tyrosine, lysine and glycine are constituents of many proteins.

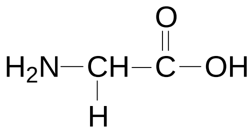


**Tyrosine**



$H_2N-CH((CH_2)_4NH_2)-C(=O)-OH$

**Lysine**



$H_2N-CH(H)-C(=O)-OH$

**Glycine**

**(a)** State the reagents and conditions you could use to break proteins into amino acids.

Reagents and conditions: …………………………………………………………

**[1]**

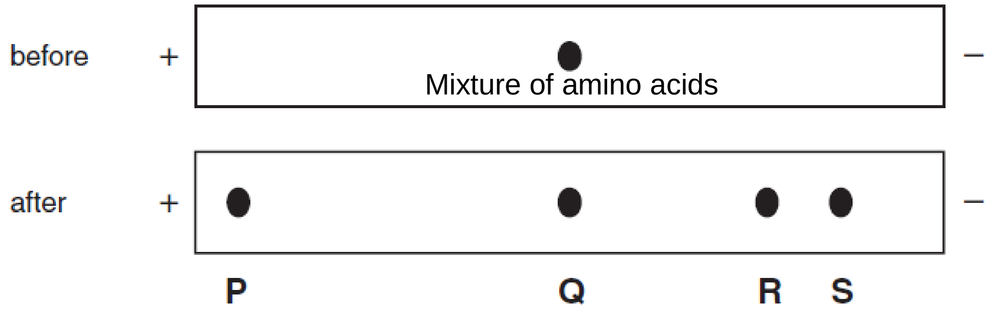
**(b)** Electrophoresis can be used to separate amino acids.

Using glycine (isoelectric point = 5.97) as an example, fill in the following table to explain why the result of electrophoresis depends on pH.

| | **pH < 5.97** | **pH = 5.97** | **pH > 5.97** |
|---|---|---|---|
| **Structural formula** | | | |
| **Direction of movement** | | | |

**[3]**

**(c)** The diagram below shows the results of electrophoresis in neutral solution. At the start of the experiment, a spot of solution containing a mixture of amino acids **P, Q, R** and **S** was placed in the middle of the plate.



Assuming amino acids **R** and **S** carry the same charge when in this buffer solution, which is likely to be the larger molecule? Explain your answer.

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**[2]**

**(d)** Gastrin is a hormone produced by the stomach which stimulates the release of gastric acid. It is a heptadecapeptide (17 amino acids) hormone. The digestion of gastrin by two enzymes are given below:

Enzyme **T**:
Glu-Glu-Glu-Glu
Ala-Ala-Tyr-Trp-Met
Asp-Phe
Glu-Gly-Pro-Gly-Trp-Leu

Enzyme **U:**
Glu-Gly-Pro-Gly-Trp
Ala-Tyr-Trp
Met-Asp-Phe
Leu-Glu-Glu-Glu-Glu-Ala

State a possible primary structure of gastrin based on the information given above.

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**[2]**

**(e)** Enzymes are large protein molecules that adopt a highly specific three-dimensional structure.

**(i)** With reference to the R group interactions, explain how enzymes lose their catalytic effectiveness above 40 $^{0}$C.

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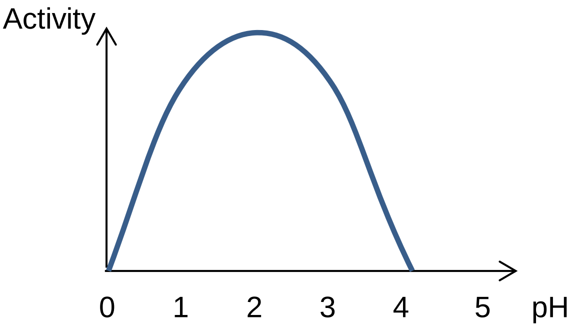
**(ii)** When food enters our stomach, gastric juice containing hydrochloric acid and pepsin are released to aid in the digestion of proteins into short polypeptides. The graph below shows the variation of pepsin activity with pH:



Explain the shape of the graph as fully as you can.

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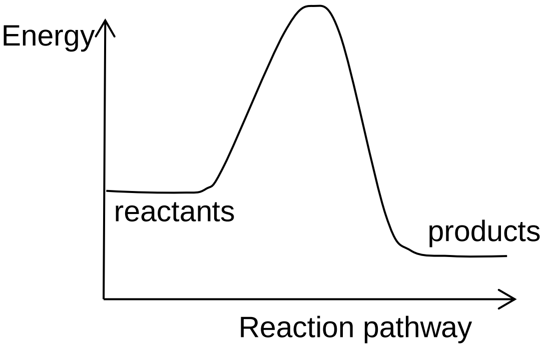
**(iii)** The diagram below shows the reaction pathway of an enzyme-catalysed reaction. On the diagram, sketch the pathway if the enzyme was denatured.



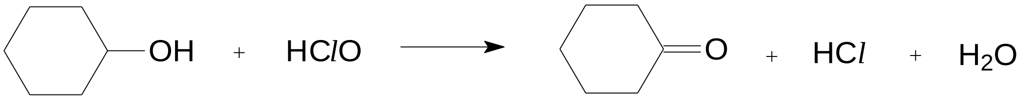
**[4]**

**[Total: 12]**

**5** Hypochlorous acid, HC*l*O is a readily available and safe oxidising agent as compared to dichromates. It can be formed by treating household bleach, which contains sodium hypochlorite, NaC*l*O, with acetic acid.

$$NaClO + CH_3COOH \rightarrow HClO + CH_3COO^-Na^+$$

Cyclohexanone can be prepared by the hypochlorite oxidation of cyclohexanol.



Data about some compounds in the preparation are given in the table.

| Compound | Boiling point / °C | Density / g cm$^{-3}$ | $M_r$ | Solubility in water |
|---|---|---|---|---|
| Cyclohexanol | 161.5 | 0.96 | 100 | slightly soluble |
| Cyclohexanone | 155 | 0.947 | 98 | slightly soluble |
| Acetic acid | 118 | 1.05 | 60 | soluble |
| Diethyl ether | 34.6 | 0.714 | 74 | insoluble |
| Water | 100 | 1.00 | 18 | - |

**Preparation of impure cyclohexanone**

1 Place 8 cm$^3$ of cyclohexanol and 4.0 cm$^3$ of acetic acid into a 250 cm$^3$ conical flask.

2 Slowly add 115 cm$^3$ of bleach into the flask over a course of about 15 minutes. After the addition is complete, continue stirring for 20 minutes. Monitor the temperature.

3 Test for excess hypochlorite ion in the reaction mixture using starch-iodide paper.

4 Add aqueous NaOH with stirring to the reaction mixture.

5 Transfer the mixture into a round-bottomed flask and collect the crude product by distillation.

**(a)** In step 2, the temperature of the mixture must be kept within 40 – 50°C.

Suggest a reason why the temperature cannot go below 40°C.

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**[1]**

**(b)** In step 3, a dark blue colour on the starch-iodide paper indicates the presence of hypochlorite ions.

Construct relevant half equations and hence, write a balanced equation to account for this observation.

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**[2]**

**(c)** What is the purpose of adding sodium hydroxide in step 4.

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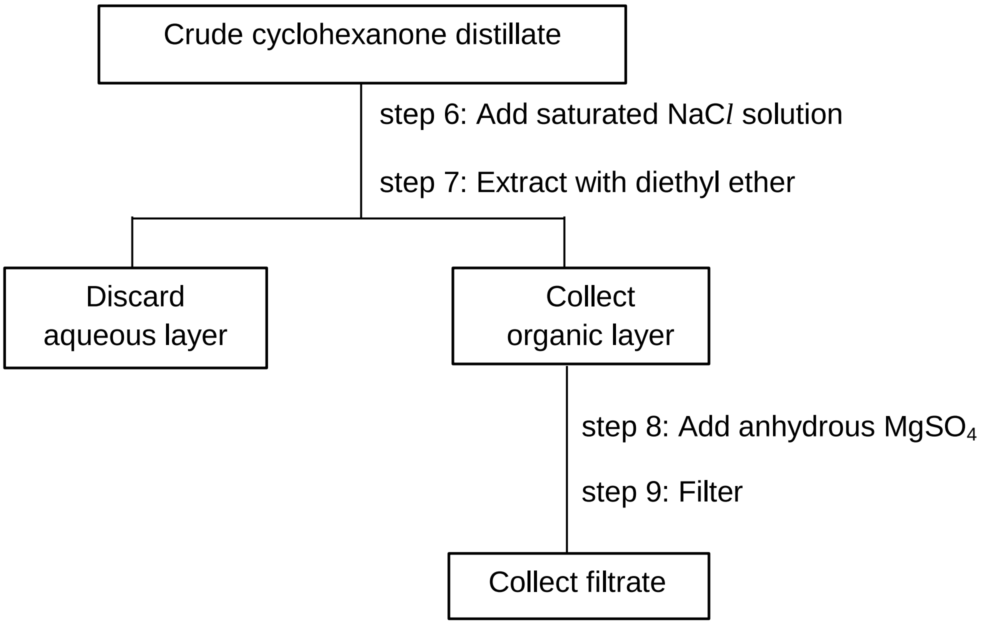
**[1]**

The flowchart below shows the purification process of crude cyclohexanone collected in step 5.



**(d)** **(i)** Identify the other organic compound present in the distillate collected in step 5.

Organic compound: ………………………

**(ii)** The compound from **(d)(i)** can be separated from cyclohexanone after filtration in step 9. Suggest a method for this separation.

Method: …………………………………………..

**[2]**

The following data are repeated from page 16.

| **Compound** | **Boiling point / °C** | **Density / g cm$^{-3}$** | **M$_r$** | **Solubility in water** |
|---|---|---|---|---|
| Cyclohexanol | 161.5 | 0.96 | 100 | slightly soluble |
| Cyclohexanone | 155 | 0.947 | 98 | slightly soluble |
| Acetic acid | 118 | 1.05 | 60 | soluble |
| Diethyl ether | 34.6 | 0.714 | 74 | insoluble |
| Water | 100 | 1.00 | 18 | - |

**(e)** **(i)** Explain why cyclohexanone is slightly soluble in water.

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**(ii)** In step 7, diethyl ether was added to extract the organic compound from the aqueous layer. Explain why cyclohexanone is more soluble in diethyl ether than in water.

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**[2]**

**(f)** In the separation process in step 7, cyclohexanone was distributed between both the organic phase as well as the aqueous phase.

$$\text{Cyclohexanone (in water)} \rightleftharpoons \text{Cyclohexanone (in organic solvent)}$$

The ratio of the concentrations of the solute in the two solvents at equilibrium is a constant value called the *partition coefficient*, *K*.

$$K = \frac{[cyclohexanone\ in\ organic\ solvent]}{[cyclohexanone\ in\ water]}$$

The *K* of cyclohexanone between diethyl ether and water is 38.6 at room temperature.

**(i)** A solution containing 5.00 g of cyclohexanone in 1 dm$^3$ of water was shaken with 20 cm$^3$ of diethyl ether. The mass of cyclohexanone extracted in diethyl ether at equilibrium is ***b*** g.

Express the concentration of cyclohexanone (in g dm$^{-3}$) left in the aqueous layer in terms of ***b***.

**(ii)** Hence, calculate the value of ***b***, given *K* = 38.6.

**(iii)** If the extraction is done using two successive portions of 10 $cm^3$ diethyl ether instead, 2.40 g of cyclohexanone will be extracted.

Hence, state whether it is more efficient to use one 20 $cm^3$ portion of diethyl ether or two successive portions of 10 $cm^3$ diethyl ether for extraction.

………………………………………………………………………………………

**[3]**

**(g)** Anhydrous magnesium sulfate was used to remove an impurity in step 8. Identify the impurity and explain how it was removed.

Impurity: ………………………………

Explanation:

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**[2]**

**(h)** Describe one simple test-tube reaction you could carry out to distinguish cyclohexanol from cyclohexanone.

Test:

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Observations:

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**[2]**

**[Total: 15]**

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