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9701/51

October/November 2018

**1 hour 15 minutes**

Candidates answer on the Question Paper.

No Additional Materials are required.

**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 or if you do not use appropriate units.

Use of a Data Booklet is unnecessary.

At the end of the examination, fasten all your work securely together.

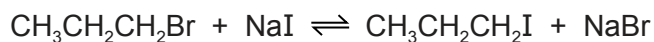
The number of marks is given in brackets [ ] at the end of each question or part question.

This document consists of **11** printed pages and **1** blank page.

## 2

- 1 The Finkelstein reaction is a nucleophilic substitution reaction in which a halogen atom in a halogenoalkane is replaced by another halogen atom. The reaction is carried out using dry propanone as a solvent.

One example of the Finkelstein reaction is given.



- (a) (i) Explain why it is important for **dry** propanone to be used as a solvent for this reaction.

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

- (ii) The solubilities of NaBr and NaI in propanone are shown.

| compound | solubility at 25 °C<br>in g / 100 g of propanone |
|----------|--------------------------------------------------|
| NaBr     | 0.00841                                          |
| NaI      | 39.9                                             |

Use this information to explain why, although the reaction between  $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}$  and NaI is reversible, the reaction produces a very high yield.

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

3

(b) Some safety information for the organic compounds used in this reaction is shown.

- 1-bromopropane is **highly flammable** and **moderate health hazard**. It is irritating to eyes, the respiratory system and skin.
- 1-iodopropane is **flammable** and **moderate health hazard**. It is irritating to eyes, the respiratory system and skin.
- Propanone is **highly flammable** and **moderate health hazard**. It is irritating to eyes, and may cause dizziness and drowsiness.

Identify **two** different precautions, other than using protective equipment such as gloves, a lab coat or eye protection, that should be taken when carrying out this experiment. Explain each answer.

1 precaution .....

.....

explanation .....

.....

2 precaution .....

.....

explanation .....

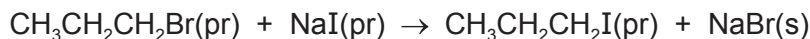
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[2]

4

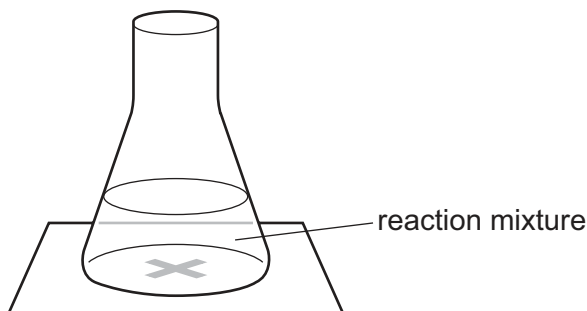
- (c) A student plans an experiment to show that the rate of the reaction is proportional to the concentration of NaI.

Propanone is used as the solvent in this reaction.



(pr) = substance is dissolved in propanone

The student plans to record the time it takes for the solid formed to obscure a cross on a piece of paper below the conical flask, as shown.



To carry out this experiment, the following materials are available.

- $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}(\text{l})$
- $\text{NaI}(\text{s})$
- dry propanone,  $\text{CH}_3\text{COCH}_3(\text{l})$
- usual laboratory apparatus

- (i) Calculate the masses of  $\text{NaI}(\text{s})$  and  $\text{CH}_3\text{COCH}_3(\text{l})$  that would be needed to make  $150\text{ cm}^3$  of  $0.50\text{ mol dm}^{-3}$   $\text{NaI}(\text{pr})$ . Assume  $150\text{ cm}^3$  of propanone are required. Give your answers to **one decimal place**.

The density of  $\text{CH}_3\text{COCH}_3(\text{l})$  is  $0.79\text{ g cm}^{-3}$ .

[ $A_r$ : Na, 23.0; I, 126.9]

mass of  $\text{NaI}(\text{s}) = \dots\dots\dots \text{ g}$

mass of  $\text{CH}_3\text{COCH}_3(\text{l}) = \dots\dots\dots \text{ g}$   
[2]

5

(ii) Part of the table the student used to record data is given.

Complete the table with appropriate volumes that the student could have used in four further experiments.

| volume of<br>$0.50 \text{ mol dm}^{-3}$<br>$\text{NaI}(\text{pr})/\text{cm}^3$ | volume of<br>$\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}(\text{l})$<br>$/\text{cm}^3$ | volume of<br>$\text{CH}_3\text{COCH}_3(\text{l})$<br>$/\text{cm}^3$ | total volume<br>$/\text{cm}^3$ | time<br>$/\text{s}$ |
|--------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|---------------------------------------------------------------------|--------------------------------|---------------------|
| 10.0                                                                           | 2.0                                                                                   | 30.0                                                                | 42.0                           |                     |
|                                                                                |                                                                                       |                                                                     |                                |                     |
|                                                                                |                                                                                       |                                                                     |                                |                     |
|                                                                                |                                                                                       |                                                                     |                                |                     |
|                                                                                |                                                                                       |                                                                     |                                |                     |

[2]

(iii) The student uses the same experimental set-up each time.

In this experiment, identify the dependent variable.

..... [1]

(iv) Write an expression to show how the student could calculate the rate of the reaction.

[1]

(v) Identify the major source of inaccuracy of measurement in this reaction.

Suggest an improvement to the experiment to make it more accurate.

inaccuracy .....

.....

improvement .....

.....

[2]

## 6

(d) The reaction between  $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}$  and  $\text{NaI}$  proceeds via an  $\text{S}_{\text{N}}2$  mechanism.

The student repeated the experiment in (c) using an isomer of  $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}$  that reacts via both  $\text{S}_{\text{N}}1$  and  $\text{S}_{\text{N}}2$  mechanisms.

State and explain whether the student will be able to show that the rate of this reaction is proportional to the concentration of  $\text{NaI}$ .

.....

.....

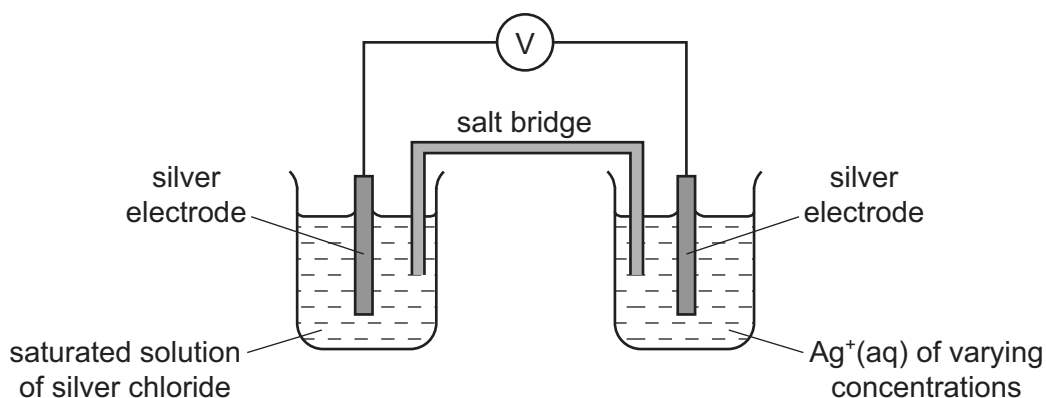
.....

..... [1]

[Total: 14]

- 2 The solubility product,  $K_{sp}$ , of a sparingly soluble salt can be determined by measuring the cell potential of a cell known as a *concentration cell*. One of the half-cells uses a saturated solution of the salt as the electrolyte.

The  $K_{sp}$  of silver chloride,  $\text{AgCl}$ , can be measured using the apparatus shown.



The silver electrodes of the two half-cells were connected via a voltmeter, reading to three decimal places. This measured the cell potential of the concentration cell.

The half-cells were kept at a temperature of  $40^\circ\text{C}$ . Under these conditions, the relationship between cell potential,  $E_{\text{cell}}$ , and  $[\text{Ag}^+(\text{aq})]$  is

$$16.1E_{\text{cell}} = \log C_{\text{sat}} - \log [\text{Ag}^+(\text{aq})]$$

$C_{\text{sat}}$  is the concentration of the saturated solution of silver chloride

- (a) (i) The solutions in the half-cells need to be kept at  $40^\circ\text{C}$ .

Explain how you would do this.

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

- (ii) If the temperature was maintained at  $40^\circ\text{C}$ , over time the reading on the voltmeter would change.

Suggest **one** reason why.

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

8

The cell potential was measured for various concentrations of  $\text{Ag}^+(\text{aq})$  and the results obtained are shown in the table.

(b) Complete the fourth and fifth columns of the table.

Give each answer to **two decimal places**.

| experiment | $[\text{Ag}^+(\text{aq})]$<br>/ $\text{mol dm}^{-3}$ | $E_{\text{cell}}/\text{V}$ | $-\log [\text{Ag}^+(\text{aq})]$ | $16.1E_{\text{cell}}/\text{V}$ |
|------------|------------------------------------------------------|----------------------------|----------------------------------|--------------------------------|
| 1          | 0.00100                                              | -0.097                     |                                  |                                |
| 2          | 0.00500                                              | -0.140                     |                                  |                                |
| 3          | 0.0100                                               | -0.159                     |                                  |                                |
| 4          | 0.0250                                               | -0.171                     |                                  |                                |
| 5          | 0.0500                                               | -0.202                     |                                  |                                |
| 6          | 0.100                                                | -0.221                     |                                  |                                |
| 7          | 0.200                                                | -0.239                     |                                  |                                |
| 8          | 0.500                                                | -0.264                     |                                  |                                |
| 9          | 1.50                                                 | -0.294                     |                                  |                                |

[2]

(c) (i) On the grid on page 9, plot a graph of  $16.1E_{\text{cell}}$  against  $-\log [\text{Ag}^+(\text{aq})]$ .

Draw a line of best fit.

[2]

(ii) Circle the single most anomalous point on the graph.

The temperature of the half-cells was maintained at  $40^\circ\text{C}$ . Suggest what error in the experimental set-up may have caused the anomaly.

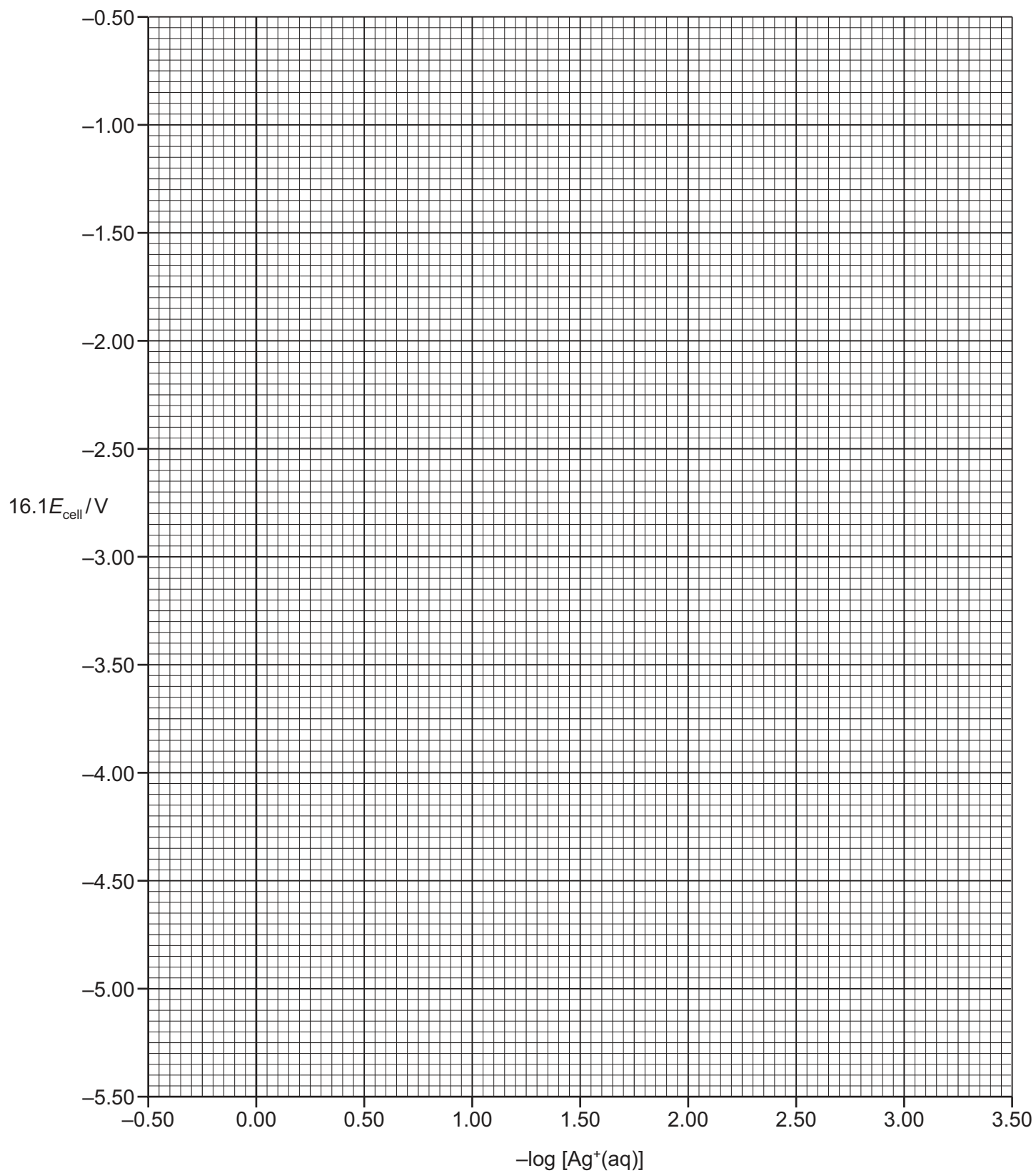
.....  
 .....  
 ..... [2]

(iii) Use your graph and the equation to determine a value for  $\log C_{\text{sat}}$ .

$$16.1E_{\text{cell}} = \log C_{\text{sat}} - \log [\text{Ag}^+(\text{aq})]$$

$$\log C_{\text{sat}} = \dots\dots\dots [1]$$

9



(d) To carry out these experiments,  $\text{Ag}^+(\text{aq})$  of concentration  $2.0 \text{ mol dm}^{-3}$  was prepared.

- (i) For experiment 6, calculate the volume of  $2.0 \text{ mol dm}^{-3} \text{ Ag}^+(\text{aq})$  needed to prepare exactly  $250.0 \text{ cm}^3$  of  $\text{Ag}^+(\text{aq})$  in a  $250.0 \text{ cm}^3$  volumetric flask.

volume = .....  $\text{cm}^3$  [1]

- (ii) Name a suitable piece of apparatus which could be used to measure the volume calculated in (i).

..... [1]

- (e) (i) The relationship between the solubility product,  $K_{\text{sp}}$ , and the concentration of the saturated solution of silver chloride,  $C_{\text{sat}}$ , is shown.

$$K_{\text{sp}} = C_{\text{sat}}^2$$

Use this equation and your answer to (c)(iii) to calculate a value for  $K_{\text{sp}}$ .

Give your answer to **three significant figures**.

(If you have no answer for (c)(iii), use a value of  $-4.20$  but this is **not** the true value.)

$K_{\text{sp}} =$  ..... [2]

11

- (ii) The solubility of  $\text{AgCl}$  increases with temperature.

Using the axes below, sketch a graph to show how the  $K_{\text{sp}}$  of  $\text{AgCl}$  varies with temperature.

Label both axes.



[1]

- (f) The salt bridge in a concentration cell commonly contains a solution of one of the following compounds.

potassium chloride      potassium nitrate      sodium chloride

Identify which, if any, of these compounds would **not** be suitable for use in the salt bridge in this experiment.

Explain your answer.

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

[Total: 16]

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