

1 (a) Solutions of Group 2 hydrogencarbonates, $M(\text{HCO}_3)_2$, decompose on heating to give the corresponding metal carbonate, carbon dioxide and water.

(i) Write an equation for the decomposition of strontium hydrogencarbonate, $\text{Sr}(\text{HCO}_3)_2$.

..... [1]

(ii) The thermal stability of Group 2 carbonates increases down the group.

Explain this trend.

.....

 [2]

(b) The hydroxides and fluorides of Group 2 elements show similar trends in solubility.

Describe the trend in the solubility of the fluorides of calcium, strontium and barium.

Explain your answer.

.....
 least soluble most soluble

explanation

 [4]

(c) (i) Define enthalpy change of hydration, ΔH_{hyd} .

.....

.....

..... [1]

(ii) State the main factors that affect the magnitude of enthalpy change of hydration.

Explain your answer.

.....

.....

.....

..... [2]

(d) Table 1.1 shows various energy changes.

Table 1.1

energy change	value / kJ mol^{-1}
lattice energy of MgF_2	−2957
enthalpy change of hydration, ΔH_{hyd} , of Mg^{2+}	−1926
enthalpy change of hydration, ΔH_{hyd} , of F^-	−505

Use data from Table 1.1 to calculate the enthalpy change of solution, ΔH_{sol} , for $\text{MgF}_2(\text{s})$.

It may be helpful to draw a labelled energy cycle. Show your working.

$$\Delta H_{\text{sol}} \text{ of } \text{MgF}_2(\text{s}) = \dots\dots\dots \text{ kJ mol}^{-1} [2]$$

(e) Mercury(I) fluoride, Hg_2F_2 , is sparingly soluble in water.

The cation in Hg_2F_2 exists as the diatomic ion Hg_2^{2+} with a covalent Hg–Hg bond.

(i) Write the expression for the solubility product, K_{sp} , of Hg_2F_2 . Include the units.

$$K_{\text{sp}} =$$

units
[2]

(ii) The solubility of Hg_2F_2 is $9.20 \times 10^{-3} \text{ mol dm}^{-3}$ at 298 K.

Calculate the value of K_{sp} of Hg_2F_2 at 298 K.

$$K_{\text{sp}} = \dots\dots\dots [1]$$

[Total: 15]

3 (a) (i) Define conjugate acid–base pair.

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

(ii) Give the formulas of the conjugate acid and the conjugate base of the hydrogen phosphate ion, HPO_4^{2-} .

conjugate acid of HPO_4^{2-}

conjugate base of HPO_4^{2-} [1]

(b) The K_a of propanoic acid, $\text{CH}_3\text{CH}_2\text{COOH}$, is $1.35 \times 10^{-5} \text{ mol dm}^{-3}$ at 298 K.

Solution **C** is a solution of $\text{CH}_3\text{CH}_2\text{COOH}$ with a pH of 3.60 at 298 K.

(i) Calculate the concentration of $\text{CH}_3\text{CH}_2\text{COOH}$ in solution **C**.

$[\text{CH}_3\text{CH}_2\text{COOH}] = \dots\dots\dots \text{mol dm}^{-3}$ [2]

(ii) Calculate the concentration of hydroxide ions in solution **C**.

$[\text{OH}^-] = \dots\dots\dots \text{mol dm}^{-3}$ [1]

(iii) Calculate the concentration of a solution of hydrochloric acid with the same pH as solution **C**.

concentration = $\dots\dots\dots \text{mol dm}^{-3}$ [1]

(iv) Table 3.1 shows three possible values of the K_a of dimethylpropanoic acid, $(\text{CH}_3)_3\text{CCOOH}$.

Place a tick in Table 3.1 to show the correct value. Explain your answer.

Table 3.1

value of K_a / mol dm^{-3}	place one tick (✓) in this column
9.33×10^{-6}	
1.35×10^{-5}	
3.35×10^{-5}	

explanation

.....

.....

.....

..... [3]

(c) Solution **D** is made by mixing 100 cm^3 of 0.100 mol dm^{-3} $\text{CH}_3\text{CH}_2\text{COOH}$ and 100 cm^3 of 0.100 mol dm^{-3} NaCl .

The pH of solution **D** is measured as small amounts of $\text{H}_2\text{SO}_4(\text{aq})$ are added to it, and when small amounts of $\text{NaOH}(\text{aq})$ are added to it.

Solution **D** only acts as a buffer solution when **one** of these solutions is added to it.

(i) Complete the sentence and write an equation for the reaction that occurs.

Solution **D** acts as a buffer when is added to it.

equation [1]

(ii) Complete the sentence and explain why solution **D** does **not** act as a buffer when the other solution is added.

Solution **D** does **not** act as a buffer when is added to it.

explanation

..... [1]

(d) Manganese(II) hydroxide, $\text{Mn}(\text{OH})_2$, is only slightly soluble in water.

The solubility of $\text{Mn}(\text{OH})_2$ in water is $3.28 \times 10^{-3} \text{ g dm}^{-3}$ at 298 K.

(i) Calculate the concentration of a saturated solution of $\text{Mn}(\text{OH})_2$ at 298 K.

$$[\text{Mn}(\text{OH})_2] = \dots\dots\dots \text{mol dm}^{-3} \quad [1]$$

(ii) Write an expression for the K_{sp} of $\text{Mn}(\text{OH})_2$. Give the units of K_{sp} .

$$K_{\text{sp}} =$$

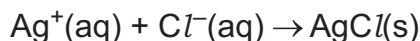
$$\text{units} = \dots\dots\dots [2]$$

(iii) Use your answers to **(d)(i)** and **(d)(ii)** to calculate the value of K_{sp} of $\text{Mn}(\text{OH})_2$ at 298 K.

$$K_{\text{sp}} = \dots\dots\dots [1]$$

[Total: 15]

- 1 The concentration of aqueous chloride ions can be found by titration with aqueous silver nitrate, $\text{AgNO}_3(\text{aq})$.



The indicator used is aqueous potassium chromate(VI), $\text{K}_2\text{CrO}_4(\text{aq})$.

As $\text{AgNO}_3(\text{aq})$ is added to aqueous chloride ions, a white precipitate of $\text{AgCl}(\text{s})$ is formed.

When all the chloride ions have reacted, further addition of $\text{AgNO}_3(\text{aq})$ leads to the formation of a red precipitate of silver chromate(VI), $\text{Ag}_2\text{CrO}_4(\text{s})$. The first appearance of the red precipitate shows the end-point of the titration.

A student carries out an experiment to determine the number of molecules of water of crystallisation, x , in hydrated barium chloride, $\text{BaCl}_2 \cdot x\text{H}_2\text{O}(\text{s})$.

(a) The student makes 250.0 cm^3 of $0.0500 \text{ mol dm}^{-3}$ $\text{AgNO}_3(\text{aq})$ to use for the titration.

- (i) Calculate the mass of solid silver nitrate, $\text{AgNO}_3(\text{s})$, needed to make 250.0 cm^3 of $0.0500 \text{ mol dm}^{-3}$ $\text{AgNO}_3(\text{aq})$.

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

mass of $\text{AgNO}_3(\text{s}) = \dots\dots\dots \text{g}$ [1]

- (ii) Describe how the student should make 250.0 cm^3 of $0.0500 \text{ mol dm}^{-3}$ $\text{AgNO}_3(\text{aq})$ starting from the mass of $\text{AgNO}_3(\text{s})$ calculated in (a)(i) in a 50 cm^3 beaker.

Give the name and size of any key apparatus used.

Write your answer using a series of numbered steps.

.....

.....

.....

.....

.....

.....

.....

..... [3]

(b) The student uses the following method.

- step 1 Dissolve 1.58 g of $\text{BaCl}_2 \cdot x\text{H}_2\text{O}(\text{s})$ to form 250 cm^3 of aqueous solution. Label this solution **A**.
- step 2 Transfer 20.0 cm^3 of solution **A** into a conical flask.
- step 3 Add aqueous sodium sulfate, $\text{Na}_2\text{SO}_4(\text{aq})$, to the flask and swirl the mixture to remove barium ions from the solution.
- step 4 Add 2–3 drops of $\text{K}_2\text{CrO}_4(\text{aq})$ indicator to the flask.
- step 5 Titrate the contents of the flask against $0.0500\text{ mol dm}^{-3}\text{ AgNO}_3(\text{aq})$.
- step 6 Repeat steps 2 to 5 to collect sufficient data for analysis.

(i) Suggest a suitable piece of apparatus for transferring 20.0 cm^3 of solution **A** in step 2.

..... [1]

(ii) Suggest why barium ions are removed in step 3 before performing the titration.

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

(iii) Suggest why chemically resistant gloves should be worn to carry out step 4.

..... [1]

(c) The student's results are shown in Table 1.1.

Table 1.1

	rough titration	titration 1	titration 2	titration 3
burette reading (final)/ cm^3	20.10	40.55	20.75	20.90
burette reading (initial)/ cm^3	0.00	20.25	0.05	0.30
titre/ cm^3	20.10	20.30	20.70	20.60

The student uses the titres from titrations 2 and 3 shown in Table 1.1 to calculate a mean titre value of 20.65 cm^3 .

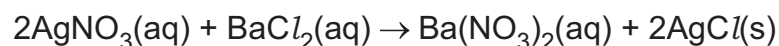
(i) Explain why only these two values are used.

..... [1]

- (ii) Calculate the percentage error in the titre volume for titration 3.
Show your working.

percentage error = [1]

- (d) The equation for the reaction of silver nitrate with barium chloride is shown.



- (i) Calculate the amount, in mol, of $\text{AgNO}_3(\text{aq})$ in the mean titre of 20.65 cm^3 .

amount of AgNO_3 = mol [1]

- (ii) Calculate the amount, in mol, of $\text{BaCl}_2(\text{aq})$ in 250 cm^3 of solution **A**.

amount of BaCl_2 = mol [1]

- (iii) Calculate the value of x in the formula $\text{BaCl}_2 \cdot x\text{H}_2\text{O}$.

x = [2]

- (e) Another student uses a different experimental method to check the value of x obtained by the method described in (b).

Give a **brief** description of another method, not involving titration, that could be used to determine the value of x in the formula $\text{BaCl}_2 \cdot x\text{H}_2\text{O}(\text{s})$. Write your answer using a series of numbered steps.

Your plan should include details of the following:

- the apparatus and method you would use
- the measurements you would make.

You are provided with standard laboratory apparatus.

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... [3]

[Total: 16]