1 **(a)** Solutions of Group 2 hydrogencarbonates, $M(HCO_3)_2$, decompose on heating to give the corresponding metal carbonate, carbon dioxide and water.

(i) Write an equation for the decomposition of strontium hydrogencarbonate, $Sr(HCO_3)_2$.

..... [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 $MgF_2(s)$.

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

ΔH_{sol} of $MgF_2(s)$ = ... 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_{sp} =

units .....
[2]

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

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

K_{sp} = ... [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, CH_3CH_2COOH, is 1.35×10^{-5} mol dm^{-3} at 298 K.

Solution **C** is a solution of CH_3CH_2COOH with a pH of 3.60 at 298 K.

(i) Calculate the concentration of CH_3CH_2COOH in solution **C**.

[CH_3CH_2COOH] = ... mol dm^{-3} [2]

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

[OH^-] = ... mol dm^{-3} [1]

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

concentration = ... mol dm^{-3} [1]

(iv) Table 3.1 shows three possible values of the K_a of dimethylpropanoic acid, $(CH_3)_3CCOOH$.

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} CH_3CH_2COOH and 100 cm^3 of 0.100 mol dm^{-3} NaC*l*.

The pH of solution **D** is measured as small amounts of H_2SO_4(aq) are added to it, and when small amounts of NaOH(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, $Mn(OH)_2$, is only slightly soluble in water.

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

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

$[Mn(OH)_2]$ = ... mol dm^{-3} [1]

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

K_{sp} =

units = ...

[2]

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

K_{sp} = ... [1]

[Total: 15]

1 The concentration of aqueous chloride ions can be found by titration with aqueous silver nitrate, $AgNO_3(aq)$.

$$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$$

The indicator used is aqueous potassium chromate(VI), $K_2CrO_4(aq)$.

As $AgNO_3(aq)$ is added to aqueous chloride ions, a white precipitate of $AgCl(s)$ is formed.

When all the chloride ions have reacted, further addition of $AgNO_3(aq)$ leads to the formation of a red precipitate of silver chromate(VI), $Ag_2CrO_4(s)$. 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, $BaCl_2 \cdot xH_2O(s)$.

(a) The student makes 250.0 cm^3 of 0.0500 mol dm^{-3} $AgNO_3(aq)$ to use for the titration.

(i) Calculate the mass of solid silver nitrate, $AgNO_3(s)$, needed to make 250.0 cm^3 of 0.0500 mol dm^{-3} $AgNO_3(aq)$.

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

mass of $AgNO_3(s)$ = ... g [1]

(ii) Describe how the student should make 250.0 cm^3 of 0.0500 mol dm^{-3} $AgNO_3(aq)$ starting from the mass of $AgNO_3(s)$ 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 $BaCl_2 \cdot xH_2O(s)$ 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, $Na_2SO_4(aq)$, to the flask and swirl the mixture to remove barium ions from the solution.

step 4 Add 2–3 drops of $K_2CrO_4(aq)$ indicator to the flask.

step 5 Titrate the contents of the flask against 0.0500 mol dm^{-3} $AgNO_3(aq)$.

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.

$$2AgNO_3(aq) + BaCl_2(aq) \rightarrow Ba(NO_3)_2(aq) + 2AgCl(s)$$

(i) Calculate the amount, in mol, of $AgNO_3(aq)$ in the mean titre of 20.65 cm^3.

amount of $AgNO_3$ = ... mol [1]

(ii) Calculate the amount, in mol, of $BaCl_2(aq)$ in 250 cm^3 of solution **A**.

amount of $BaCl_2$ = ... mol [1]

(iii) Calculate the value of x in the formula $BaCl_2 \cdot xH_2O$.

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 $BaCl_2 \cdot xH_2O(s)$. 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]