ACID-BASE TITRATION

1.

FA 1 is sulfuric acid, H_2SO_4, of approximate concentration 0.7 mol dm^{-3}.
FA 2 is 0.150 mol dm^{-3} sodium hydroxide.
You are also provided with phenolphthalein (indicator).

You will determine the exact concentration of **FA 1** by titration.

$$H_2SO_4(aq) + 2NaOH(aq) \longrightarrow Na_2SO_4(aq) + 2H_2O(l)$$

(a) Method

Dilution

- Pipette 25.0 cm^3 of **FA 1** into the 250 cm^3 graduated (volumetric) flask labelled **FA 3**.
- Make the solution up to the mark using distilled water.
- Shake the flask to mix the solution of **FA 3**.

Titration

- Rinse out the pipette with distilled water and then with **FA 3**.
- Pipette 25.0 cm^3 of **FA 3** into a conical flask.
- Add 5 drops of phenolphthalein indicator to the flask. The indicator should remain colourless.
- Fill the burette with **FA 2**.
- Titrate **FA 3** with **FA 2**, until a permanent pale pink colour is obtained.

You should perform a **rough titration**.
In the space below record your burette readings for this rough titration.

The rough titre is .... cm^3.

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Record in a suitable form below all of your burette readings and the volume of **FA 2** added in each accurate titration.
- Make sure that your recorded results show the precision of your practical work.

[7]

(b) From your accurate titration results, obtain a suitable value to be used in your calculations.
Show clearly how you have obtained this value.

25.0 cm^3 of **FA 3** required .... cm^3 of **FA 2**. [1]

(c) Calculations

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

(i) Calculate how many moles of NaOH were present in the volume of **FA 2** calculated in **(b)**.

.... mol of NaOH

(ii) Calculate how many moles of H_2SO_4 were present in 25.0 cm^3 of **FA 3**.

$$H_2SO_4(aq) + 2NaOH(aq) \longrightarrow Na_2SO_4(aq) + 2H_2O(l)$$

.... mol of H_2SO_4

(iii) Calculate how many moles of H_2SO_4 were present in 25.0 cm^3 of the undiluted solution **FA 1**.

.... mol of H_2SO_4

(iv) Calculate the concentration, in mol dm^{-3}, of H_2SO_4 in **FA 1**.

The concentration of H_2SO_4 in **FA 1** was .... mol dm^{-3}. [4]

[Total: 12]

P3,MJ' 11

2.

FA 1 contains the monoprotic (monobasic) acid RCO_2H. You are to determine the relative molecular mass, M_r, of the acid and deduce its molecular formula.

You are provided with the following.

FA 1, the aqueous acid, containing 38.68 g dm^{-3} RCO_2H
FA 2, aqueous sodium hydroxide containing 3.40 g dm^{-3} NaOH
Phenolphthalein indicator.

(a) Dilution of FA 1

By using a burette measure between 38.00 cm^3 and 39.00 cm^3 of **FA 1** into the 250 cm^3 graduated (volumetric) flask labelled **FA 3**.
Record your burette readings and the volume of **FA 1** added to the flask in the space below.

Make up the contents of the flask to the 250 cm^3 mark with distilled water. Place the stopper in the flask and mix the contents thoroughly by slowly inverting the flask a number of times.

Titration

Fill a second burette with **FA 3**, the diluted solution containing RCO_2H.

Pipette 25.0 cm^3 of **FA 2** into the conical flask and add 2–3 drops of phenolphthalein indicator.

Titrate the sodium hydroxide in the flask with **FA 3** until the solution just turns colourless.

Perform a rough (trial) titration and sufficient further titrations to obtain accurate results.

Record your titration results in the space below. Make certain that your recorded results show the precision of your working.

[6]

(b) From your titration results obtain a volume of **FA 3** to be used in your calculations.
Show clearly how you obtained this volume.

[1]

Calculations

Show your working and appropriate significant figures in all of your calculations.

(c) Calculate how many moles of NaOH have been pipetted into the conical flask.
[A_r: H, 1.0; O, 16.0; Na, 23.0]

.... mol of NaOH were pipetted into the conical flask.

Use your titre volume in **(b)** and the answer above to calculate how many moles of RCO_2H are contained in 250 cm^3 of the diluted acid **FA 3**.

250 cm^3 of **FA 3** contains .... mol of RCO_2H.

Use this answer to calculate the concentration, in mol dm^{-3}, of the undiluted acid in **FA 1**.

The concentration of RCO_2H in **FA 1** is .... mol dm^{-3}.

Use this answer to calculate, correct to **3 significant figures**, the relative molecular mass, M_r, of RCO_2H.

The relative molecular mass, M_r, of RCO_2H is ....

Use this answer to deduce the formula of the acid RCO_2H.

The formula of RCO_2H is ....

[5]

[Total: 12]

P3, ON' 08

WATER OF CRYSTALIZATION

1.

FA 1 is a hydrated metal sulphate, $XSO_4.7H_2O$.

You are required to determine the mass of water of crystallisation (the $7H_2O$ in the formula above) in a weighed sample of **FA 1** and to calculate the relative atomic mass, A_r, of the element **X**.

(a) Accurately weigh the hard glass test-tube provided. Record the mass in Table 1.1 below.

Add to the test-tube between 2.00 g and 2.50 g of **FA 1** and accurately weigh the test-tube and contents. Record this mass in Table 1.1 below.

Table 1.1 Mass of **FA 1**

Mass of test-tube + **FA 1**	/ g	
Mass of empty test-tube	/ g	
Mass of **FA 1**	/ g	

(b) Heat the test-tube, gently at first then strongly, to drive off the water of crystallisation. The crystals will 'crackle' at first as water is lost and 'steam' (condensed water vapour) will be seen coming out of the mouth of the tube.

If the crystals are overheated the sulphate can decompose and give off sulphur trioxide which will be seen as white fumes. If you see white fumes, do not confuse this with steam, stop heating.

Place the test-tube on a heat proof mat and leave to cool. Do **not** move about the laboratory with a hot test-tube.

(You are advised to continue with the second question while the tube cools.)

When cool, reweigh the test-tube and its contents. Record the mass in Table 1.2 below.

Table 1.2 Mass of **FA 1** after heating

Mass of test-tube + **FA 1** after heating	/ g	
Mass of empty test-tube (from Table 1.1)	/ g	
Mass of **FA 1** after heating	/ g	

(c) By repeating the heating, cooling and reweighing, show clearly by your results in Table 1.2 that all the water of crystallisation has been driven from the crystals, **FA 1**.

[4]

(d) Calculate

(i) the mass of anhydrous XSO_4 present in the crystals.

(ii) the mass of water driven from the crystals of **FA 1**.

[1]

(e) Calculate how many moles of water are present in the sample of **FA 1** used.
[A_r; H, 1.0; O, 16.0.]

[1]

(f) Use your answer to **(e)** and the formula $XSO_4.7H_2O$ to calculate how many moles of XSO_4 are present in the sample of **FA 1** used.

[1]

(g) Use your answers to **(d)** and **(f)** to calculate the relative molecular mass, M_r, of XSO_4.

[1]

(h) Calculate the relative atomic mass, A_r, of the element **X**.
[A_r; O, 16.0; S, 32.0.]

[1]

[Total : 15]

P3, ON'02

2.

'Washing soda' is made from crystals of sodium carbonate, which contain 62.94% water and 37.06% sodium carbonate.

When stored, these crystals lose some of the water in the crystals to the atmosphere.

You are to determine in two separate experiments the amount of water that has been lost to the atmosphere.

Weigh the empty boiling-tube labelled **X** and record the mass in Table 1.1.

Transfer approximately half of the 'washing soda' crystals, **FA 1**, from boiling-tube **Y** into boiling-tube **X**. Keep the remaining solid for use in Question **2**.

Reweigh the boiling-tube **X** and **FA 1** and record the mass in Table 1.1

Table 1.1

Mass of empty boiling-tube **X**	/ g	
Mass of boiling-tube **X** + **FA 1** before heating	/ g	
Mass of boiling–tube **X** + solid after heating	/ g	
Mass of boiling–tube **X** + solid after re-heating	/ g	
Mass of anhydrous Na_2CO_3 left after heating	/ g	

[6]

Gently heat the crystals in the tube. The solid will dissolve into the water contained in the crystals.
Continue the gentle heating until all the water has evaporated and solid remains in the tube.
Take care to avoid any loss of material during this initial heating.
Warm the upper parts of the boiling-tube to evaporate any water that may have condensed there.
When all the water has evaporated heat the solid strongly to drive off any remaining water.
Allow the boiling-tube to cool, reweigh and record the mass in Table 1.1.
Reheat, cool and reweigh the boiling-tube and its contents. Record the mass in Table 1.1.

(a) How can you be sure that all of the water has been driven off from the crystals?

[1]

(b) Calculate the mass of crystals at the start of the experiment.

[1]

(c) Calculate the mass of water driven from the crystals.

[1]

(d) What is the percentage of water in your sample of **FA 1**?

[1]

[Total : 10]

P3, ON' 03

3.

You are provided with the following reagents.

- **FA 1**, hydrated iron(II) sulfate
- **FA 2**, aqueous iron(II) sulfate
- **FA 3**, aqueous potassium manganate(VII)
- **FA 4**, sulfuric acid

The formula of hydrated iron(II) sulfate is $FeSO_4.\boldsymbol{x}H_2O$ where ***x*** shows the number of molecules of water of crystallisation present.

The value of ***x*** can be found by two different methods.

Method 1 involves heating to drive off water of crystallisation while **Method 2** uses a titration to determine the concentration of Fe^{2+}(aq).

(a) Method 1

- Weigh a crucible and record the mass.
- Add between 1.80 g and 2.00 g of **FA 1** and record the new mass.
- Place the crucible containing **FA 1** on a pipe clay triangle and heat gently for about four minutes with a Bunsen burner.

- Allow the crucible to cool. You should continue with **Method 2** while the crucible is cooling.
- Weigh the crucible and its contents.

Record all masses in the space below.

[3]

(b) Calculate the mass of water lost and the mass of iron(II) sulfate that remained after heating.

mass of water lost = ... g

mass of iron(II) sulfate remaining = ... g

[1]

(c) Use your answer to **(b)** to calculate how many moles of water were lost and the moles of iron(II) sulfate, $FeSO_4$, remaining after heating.
Show all of your working.
[A_r : Fe, 55.8; H, 1.0; O, 16.0; S, 32.1]

The hydrated iron(II) sulfate contained .... mol of water

and .... mol of $FeSO_4$. [2]

(d) Use your answer to **(c)** to determine the value of ***x*** in the formula of hydrated iron(II) sulfate, $FeSO_4.\boldsymbol{x}H_2O$.

x = ... [2]

(e) Method 2

- Fill the burette with **FA 3**, aqueous potassium manganate(VII).
- Pipette $25.0\,cm^3$ of **FA 2** into a conical flask and use a measuring cylinder to add approximately $20\,cm^3$ of **FA 4.**
- Titrate this solution with **FA 3** from the burette until the first permanent pink colour remains in the solution.
- Perform sufficient further titrations to obtain accurate results.
- Record your titration results in the space below. Make certain that your recorded results show the precision of your working.

Summary

$25.0\,cm^3$ of **FA 2** reacted with .... cm^3 of **FA 3**.

Show which results you used to obtain the value of the volume of **FA 3** by placing a tick (✓) under the readings used in your results. [11]

(f) All experimental methods contain errors, some of which are concerned with uncertainty of measurements.

Complete the table below to show the uncertainties in measuring the volume of potassium manganate(VII) used in **Method 2**.

maximum uncertainty in a single reading with a burette	± .... cm^3
volume of potassium manganate(VII), **FA 3**, from the summary in **(e)**	.... cm^3
maximum percentage error in the volume of potassium manganate(VII) used	.... %

[2]

(g) **Method 1** is usually less accurate than **Method 2** for finding the value of ***x*** in the formula of hydrated iron(II) sulfate, $FeSO_4.\boldsymbol{x}H_2O$.

A group of students carried out **Method 1** correctly but calculated a value of 9 for ***x***. The true value for ***x*** is 7.
Suggest an error in the practical procedure of the experiment that could account for this difference.

....

.... [1]

(h) Suggest a modification that could be made to the practical procedure in **Method 1** to reduce this error.
Explain why this modification should give an answer nearer to 7.

modification ....

....

explanation ....

.... [2]

[Total: 24]

P33, ON'09

4.

You are provided with the following reagents.

- **FB 1**, hydrated copper(II) sulfate
- **FB 2**, aqueous copper(II) sulfate
- **FB 3**, aqueous sodium thiosulfate
- **FB 4**, aqueous potassium iodide
- **FB 5**, starch indicator solution

The formula of hydrated copper(II) sulfate is $CuSO_4.\boldsymbol{x}H_2O$ where ***x*** shows the number of molecules of water of crystallisation present.
The value of ***x*** can be found by two different methods.
Method 1 involves heating to drive off water of crystallisation while **Method 2** uses a titration to determine the concentration of Cu^{2+}(aq).

(a) Method 1

- Weigh a crucible and record the mass.
- Add between 2.50 g and 2.70 g of **FB 1** and record the new mass.
- Place the crucible containing **FB 1** on a pipe clay triangle and heat gently for about four minutes with a Bunsen burner.
- Allow the crucible to cool. You should continue with **Method 2** while the crucible is cooling.
- Weigh the crucible and its contents.

Record all masses in the space below.

[3]

(b) Calculate the mass of water lost and the mass of copper(II) sulfate that remained after heating.

mass of water lost = ... g

mass of copper(II) sulfate remaining = ... g
[1]

(c) Use your answer to **(b)** to calculate how many moles of water were lost and the moles of copper(II) sulfate, $CuSO_4$, remaining after heating.
Show all of your working.
[A_r : Cu, 63.5; H, 1.0; O, 16.0; S, 32.1]

The hydrated copper(II) sulfate contained .... mol of water

and .... mol of $CuSO_4$. [2]

(d) Use your answer to **(c)** to determine the value of ***x*** in the formula of hydrated copper(II) sulfate, $CuSO_4.\boldsymbol{x}H_2O$.

x = ... [2]

(e) **Method 2**

- Fill the burette with **FB 3**, aqueous sodium thiosulfate.
- Pipette 25.0 cm^3 of **FB 2** into a conical flask and use a measuring cylinder to add 10 cm^3 of **FB 4.**
- Titrate this solution with **FB 3** from the burette until the mixture becomes yellow-brown. Do **not** add too much **FB 3** at this stage.
- An off-white precipitate is also present in the flask and this will mask the colour of the solution.
- Add approximately 1 cm^3 of **FB 5**. The solution will become blue-black as a starch iodine complex is formed.
- Continue the titration until the blue-black colour of the complex just disappears leaving the off-white precipitate.
- Perform sufficient further titrations to obtain accurate results.

- Record your titration results in the space below. Make certain that your recorded results show the precision of your working.

Summary

25.0 cm^3 of **FB 2** reacted with .... cm^3 of **FB 3**.

Show which results you used to obtain the value of the volume of **FB 3** by placing a tick (✓) under the readings used in your results. [11]

(g) **Method 1** is usually less accurate than **Method 2** for finding the value of ***x*** in the formula of hydrated copper(II) sulfate, $CuSO_4.\boldsymbol{x}H_2O$.

A group of students carried out **Method 1** correctly but calculated a value of 4 for ***x***. The true value for ***x*** is 5.

Suggest an error in the practical procedure of the experiment that could account for this difference.

....

.... [1]

(h) Suggest a modification that could be made to the practical procedure in **Method 1** to reduce this error.

Explain why this modification should give an answer nearer to 5.

modification ....

....

explanation ....

.... [2]

[Total: 24]

P34,ON'09