WORKSHEET 1

TITRATION NO. 1

FA 1 is a solution containing 5.00 g dm^{-3} of hydrated ethanedioic acid, $H_2C_2O_4.\mathbf{x}H_2O$.
FA 2 is a solution containing 2.37 g dm^{-3} of potassium manganate(VII), $KMnO_4$.
You are also provided with 1.00 mol dm^{-3} sulphuric acid, H_2SO_4.

In the presence of acid, potassium manganate(VII) oxidises ethanedioic acid;

$$2MnO_4^-(aq) + 5H_2C_2O_4(aq) + 6H^+(aq) \rightarrow 2Mn^{2+}(aq) + 10CO_2(g) + 8H_2O(l)$$

You are to determine the value of **x** in $H_2C_2O_4.\mathbf{x}H_2O$.

(a) Fill the burette with **FA 2**.

Pipette 25.0 cm^3 of **FA 1** into a conical flask. Use the measuring cylinder provided to add to the flask 25 cm^3 of 1.00 mol dm^{-3} sulphuric acid and 40 cm^3 of distilled water.

Heat the solution in the flask until the temperature is just over 65 °C. The exact temperature is not important.

Be careful when handling hot solutions.

Remove the thermometer and carefully place the hot flask under the burette. If the neck of the flask is too hot to hold safely, use a folded paper towel to hold the flask. Run in about 1 cm^3 of **FA 2**. Swirl the flask until the colour of the manganate(VII) ions has disappeared then continue the titration as normal until a permanent pale pink colour is obtained. This is the end point. Record the burette readings in Table 1.1.

If a brown colour appears during the titration, reheat the flask to 65 °C. The brown colour should disappear and the titration can then be completed.

If the brown colour does **not** disappear on reheating, discard the solution and restart the titration.

Repeat the titration as many times as you think necessary to obtain accurate results.

Make certain that the recorded results show the precision of your practical work.

Table 1.1 Titration of FA 1 with FA 2

final burette reading / cm^3	25.40	35.50	38.50	
initial burette reading / cm^3	0.00	10.30	13.40	
volume of **FA 2** used / cm^3	25.40	25.20	25.10	
		✓	✓	

Summary

$$\frac{25.20 + 25.10}{2}$$

25.0 cm^3 of **FA 1** reacted with ...25.15...... cm^3 of **FA 2**.

Show which results you used to obtain this volume of **FA 2** by placing a tick (✓) under the readings in Table 1.1.

[7]

For Examiner's Use

You are advised to show full working in all parts of the calculations.

(b) Calculate how many moles of potassium manganate(VII), $KMnO_4$, were run from the burette during the titration.
[A_r: K, 39.1; Mn, 54.9; O, 16.0.]

$n = \frac{m}{M_r} = \frac{2.37}{158} = 0.0150\ mol\,dm^{-3}$

$n = cV = 0.0150 \times \frac{25.10}{1000}$

$3.77 \times 10^{-4}\ mol$

[2]

(c) Calculate how many moles of ethanedioic acid, $H_2C_2O_4$, reacted with the potassium manganate(VII) run from the burette.

$KMnO_4 : H_2C_2O_4$
$2 : 5$
$3.77 \times 10^{-4} : x$

$9.41 \times 10^{-4}\ mol$

[1]

(d) Calculate the mass of $H_2C_2O_4$ in each dm^3 of **FA 1**.
[A_r: H, 1.0; C, 12.0; O, 16.0.]

$c = \frac{n}{V} = \frac{9.41 \times 10^{-4}}{25.0/1000}$

$= 0.0377\ mol\,dm^{-3}$

$mol \cdot dm^{-3} = \frac{g \cdot dm^{-3}}{M_r}$

$0.0377 = \frac{g \cdot dm^{-3}}{90}$

$3.39\ g\,dm^{-3}$

[3]

(e) Calculate the mass of water in the 5.00 g of $H_2C_2O_4.\mathbf{x}H_2O$.

$5.00 - 3.39 = 1.61\ g$

[1]

(f) Calculate the value of **x**, in $H_2C_2O_4.\mathbf{x}H_2O$.

$H_2C_2O_4 = \frac{3.39}{90} = 0.0377$

$H_2O = \frac{1.61}{18} = 0.0894$

$H_2C_2O_4 \quad H_2O$
$0.0377 — 0.0894$
$1 — x$

$2.37 \approx 2$

[1]

[Total: 15]

TITRATION NO. 2

In this experiment you will determine the concentration of a solution of sulfuric acid by titration.

FA 1 is sulfuric acid, H_2SO_4.
FA 2 is aqueous sodium hydroxide, containing 4.20 g NaOH dissolved in 1.00 dm^3 of water.
methyl orange indicator

(a) Method

Dilution of FA 1

- Use a measuring cylinder to measure **10.0 cm^3** of **FA 1** into the 250 cm^3 volumetric flask.
- Make the solution up to the mark using distilled water.
- Shake the flask thoroughly.
- This diluted solution of sulfuric acid is **FA 3**. Label the flask **FA 3**.

Titration

- Fill the burette with **FA 2**.
- Pipette **25.0 cm^3** of **FA 3** into a conical flask.
- Add a few drops of methyl orange indicator.
- Perform a rough titration and record your burette readings in the space below. The end point is reached when the solution turns a permanent pale yellow colour.

Final burette reading / cm^3	25.60
Initial burette reading / cm^3	0.00
Volume of FA2 used / cm^3	25.60

The rough titre is 25.60 cm^3.

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

Final burette reading / cm^3	39.30	33.70	40.50	
Initial burette reading / cm^3	14.00	8.50	15.20	
Volume of FA2 used / cm^3	25.30	25.20	25.30	
	✓		✓	

I	
II	
III	
IV	
V	
VI	
VII	

[7]

(b) From your accurate titration results, obtain a suitable value for the volume of **FA 2** to be used in your calculations.
Show clearly how you obtained this value.

$\frac{25.30 + 25.30}{2}$

25.0 cm³ of **FA 3** required ......25.30...... cm³ 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 the number of moles of sodium hydroxide present in the volume of **FA 2** calculated in **(b)**.
Mr of NaOH is 40.

$n = \frac{m}{M_r}$

$= \frac{4.20}{40} = 0.105 \text{ mol dm}^{-3}$

$n = cV$

$= 0.105 \times \frac{25.30}{1000}$

moles of NaOH = ...2.66×10^{-3}...... mol

(ii) Complete the equation for the reaction of sulfuric acid with sodium hydroxide. State symbols are required.

......H_2SO_4...... + ...$2NaOH$...... → ...... $Na_2SO_4(aq)$ + ...$2H_2O$......

(iii) Use your answers to **(i)** and **(ii)** to calculate the number of moles of sulfuric acid used in each titration.

NaOH : H_2SO_4

2 : 1

2.66×10^{-3} : x

moles of H_2SO_4 = ...1.33×10^{-3}...... mol

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

$c = \frac{n}{V} = \frac{1.33 \times 10^{-3}}{25.0/1000}$

concentration of H_2SO_4 in **FA 3** = ...0.0532...... mol dm^{-3}

(v) Calculate the concentration, in mol dm^{-3}, of sulfuric acid in **FA 1**.

FA1 FA3

$C_1V_1 = C_2V_2$

$C_1 \times \frac{10.0}{1000} = 0.0532 \times \frac{250}{1000}$

concentration of H_2SO_4 in **FA 1** = ...1.33...... mol dm^{-3}

[5]

[Total: 13]

TITRATION NO. 3

1 In this experiment you will determine the relative atomic mass, A_r, of magnesium by a titration method.

FB 1 is 2.00 mol dm^{-3} hydrochloric acid, HC*l*.
FB 3 is 0.120 mol dm^{-3} sodium hydroxide, NaOH.
magnesium ribbon
bromophenol blue indicator

(a) Method

Reaction of magnesium with FB 1

- Pipette 25.0 cm^3 of **FB 1** into the 250 cm^3 beaker.
- Weigh the strip of magnesium ribbon and record its mass.

mass of magnesium = 0.20 g

- Coil the strip of magnesium ribbon loosely and then add it to the **FB 1** in the beaker.
- Stir the mixture occasionally and wait until the reaction has finished.

Dilution of the excess acid

- Transfer all the solution from the beaker into the volumetric flask.
- Make the solution up to the mark using distilled water.
- Shake the flask to mix the solution before using it for your titrations.
- Label this solution of hydrochloric acid **FB 2**.

Titration

- Fill the burette with **FB 2**.
- Rinse the pipette out thoroughly. Then pipette 25.0 cm^3 of **FB 3** into a conical flask.
- Add several drops of bromophenol blue indicator.
- Perform a rough titration, by running the solution from the burette into the conical flask until the mixture just becomes yellow.
- Record your burette readings in the space below.

Final burette reading / cm^3	25.60
Initial burette reading / cm^3	0.00
Volume of FB2 used / cm^3	25.60

The rough titre is 25.60 cm^3.

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

	1	2	3	4
Final burette reading / cm^3	25.30	35.20	42.00	
Initial burette reading / cm^3	0.00	10.20	16.80	
Volume of FB2 used / cm^3	25.30	25.20	25.20	
		✓	✓	

I	
II	
III	
IV	
V	
VI	
VII	

[7]

(b) From your accurate titration results, obtain a suitable value for the volume of **FB 2** to be used in your calculations.
Show clearly how you have obtained this value.

$$\frac{25.20 + 25.20}{2}$$

25.0 cm^3 of **FB 3** required ..25.20...... cm^3 of **FB 2**. [1]

(c) Calculations

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

(i) Calculate the number of moles of sodium hydroxide present in 25.0 cm^3 of solution **FB 3**.

$n = CV$
$= 0.120 \times \frac{25.0}{1000}$

moles of NaOH = 3.00×10^{-3} mol

(ii) Give the equation for the reaction of hydrochloric acid, HC*l*, with sodium hydroxide, NaOH. State symbols are **not** required.

$HCl + NaOH \longrightarrow NaCl + H_2O$

Deduce the number of moles of hydrochloric acid in the volume of **FB 2** you calculated in **(b)**.

mole ratio NaOH : HCl
1 : 1
3.00×10^{-3} : x

moles of HC*l* = 3.00×10^{-3} mol

(iii) Calculate the number of moles of hydrochloric acid in 250 cm^3 of **FB 2**.

25.20 cm^3 —— 3.00×10^{-3}
250 cm^3 —×— x

moles of HC*l* in 250 cm^3 of **FB 2** = 0.0298 mol

(iv) Calculate the number of moles of hydrochloric acid in 25.0 cm^3 of **FB 1**.

$n = CV$
$= 2.00 \times \frac{25.0}{1000}$

moles of HC*l* in 25.0 cm^3 of **FB 1** = 0.0500 mol

(v) In **(a)**, you reacted 25.0 cm^3 of **FB 1** with your weighed piece of magnesium. After the reaction, the unreacted hydrochloric acid was used to prepare 250 cm^3 of **FB 2**.

Use your answers to **(iii)** and **(iv)** to calculate the number of moles of hydrochloric acid that reacted with the magnesium ribbon.

0.0500 − 0.0298

moles of HC*l* reacting with Mg = 0.0202 mol

(vi) Complete the equation below, for the reaction of magnesium with hydrochloric acid. State symbols **are** required.

$Mg_{(s)}$ + 2 $HCl_{(aq)}$ → $MgCl_{2\,(aq)}$ + $H_{2\,(g)}$

Use your answer to **(v)** to calculate the number of moles of magnesium used.

mole ratio Mg : HCl
1 : 2
x : 0.0202

moles of Mg = 0.0101 mol

(vii) Use your answer to **(vi)** to calculate the relative atomic mass, A_r, of magnesium.

$n = \frac{m}{A_r}$

$0.0101 = \frac{0.20}{A_r}$

A_r of Mg = 19.80

[6]

(d) **(i)** State **one** observation that proves that the hydrochloric acid in **FB 1** was in excess for the reaction with the magnesium ribbon.

Magnesium ribbon was dissolved.

(ii) A student carried out exactly the same experiment but used 1.00 g of magnesium ribbon. State and explain why the student's experiment could not be used to determine the value for the A_r of magnesium.
Include a calculation in your answer.

$n = \frac{m}{A_r} = \frac{1}{24.3} = 0.0412$ mol of Mg, so atleast 0.082 moles of HCl required.

So HCl would become limiting and Mg would be in excess

[3]

[Total: 17]

QUALITATIVE ANALYSIS NO. 1

Qualitative Analysis

At each stage of any test you are to record details of the following.

- colour changes seen
- the formation of any precipitate
- the solubility of such precipitates in an excess of the reagent added

Where gases are released they should be identified by a test, **described in the appropriate place in your observations**.

You should indicate clearly at what stage in a test a change occurs.
Marks are **not** given for chemical equations.
No additional tests for ions present should be attempted.

If any solution is warmed, a boiling tube MUST be used.

Rinse and reuse test-tubes and boiling tubes where possible.

Where reagents are selected for use in a test, the name or correct formula of the element or compound must be given.

(a) **FB 5** is a solution containing one cation and one anion.
Carry out test-tube tests to find out whether the cation in **FB 5** is magnesium and whether the anion is sulfate.

- State what reagents you used.
- Record the observations you made in a table.
- State your conclusions about which ions are present.

tests	observations	conclusion
a) To 1cm depth of solution, add 1cm depth of aq. NaOH then in excess	white ppt. insoluble in excess	Mg^{2+} present
b) To 1cm depth of solution, add 1cm depth of aq. NH_3 then in excess	white ppt. insoluble in excess	
c) To 1cm depth of solution add 1cm depth of aq. $Ba(NO_3)_2$	no change	SO_4^{2-} absent
add dilute HCl	—	

[4]

(b) **FB 6** is a salt containing one cation and one anion from those listed on Qualitative Analysis Notes.

(i) Place a **few** crystals of **FB 6** in a hard-glass test-tube.
Heat gently at first and then strongly.
Leave the test-tube and its contents to cool.

Record **all** your observations below.

Gentle heating → solid melts on heating

Strong heating → - Solid turns yellow,
- brown gas produced,
- glowing splint relights

Cooling → liquid solidify, and turns pale yellow /white

(ii) Dissolve the remainder of **FB 6** in about 20 cm^3 of distilled water in a boiling tube for use in the following tests.

test	*observations*
To a 1 cm depth of the solution of **FB 6** in a test-tube, add a few drops of aqueous silver nitrate.	no change
To a 1 cm depth of the solution of **FB 6** in a test-tube, add a few drops of dilute sulfuric acid.	no change
To a 1 cm depth of the solution of **FB 6** in a test-tube, add aqueous ammonia.	white ppt soluble in excess

test	*observations*
To a 1 cm depth of the solution of **FB 6** in a boiling tube, add aqueous sodium hydroxide until in excess, then	white ppt soluble in excess
heat the mixture gently and carefully, and test any gas produced, then	No change / damp red litmus paper remains red.
add a small piece of aluminium foil while the mixture is still warm. Test any gas produced.	a colorless gas produced which turned damp red litmus paper blue.

(iii) Deduce the formula of the salt in **FB 6**.

Formula is ....$Zn(NO_3)_2$..............

[10]

[Total: 14]

Qualitative Analysis Notes

1 Reactions of aqueous cations

ion	*reaction with*	
	NaOH(aq)	NH_3(aq)
aluminium, Al^{3+}(aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH_4^+(aq)	no ppt. ammonia produced on heating	–
barium, Ba^{2+}(aq)	faint white ppt. is nearly always observed unless reagents are pure	no ppt.
calcium, Ca^{2+}(aq)	white ppt. with high [Ca^{2+}(aq)]	no ppt.
chromium(III), Cr^{3+}(aq)	grey-green ppt. soluble in excess	grey-green ppt. insoluble in excess
copper(II), Cu^{2+}(aq)	pale blue ppt. insoluble in excess	blue ppt. soluble in excess giving dark blue solution
iron(II), Fe^{2+}(aq)	green ppt. turning brown on contact with air insoluble in excess	green ppt. turning brown on contact with air insoluble in excess
iron(III), Fe^{3+}(aq)	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess
magnesium, Mg^{2+}(aq)	white ppt. insoluble in excess	white ppt. insoluble in excess
manganese(II), Mn^{2+}(aq)	off-white ppt. rapidly turning brown on contact with air insoluble in excess	off-white ppt. rapidly turning brown on contact with air insoluble in excess
zinc, Zn^{2+}(aq)	white ppt. soluble in excess	white ppt. soluble in excess

2 Reactions of anions

ion	*reaction*
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, $Cl^-(aq)$	gives white ppt. with $Ag^+(aq)$ (soluble in $NH_3(aq)$)
bromide, $Br^-(aq)$	gives cream ppt. with $Ag^+(aq)$ (partially soluble in $NH_3(aq)$)
iodide, $I^-(aq)$	gives yellow ppt. with $Ag^+(aq)$ (insoluble in $NH_3(aq)$)
nitrate, $NO_3^-(aq)$	NH_3 liberated on heating with $OH^-(aq)$ and Al foil
nitrite, $NO_2^-(aq)$	NH_3 liberated on heating with $OH^-(aq)$ and Al foil; NO liberated by dilute acids (colourless NO $\rightarrow$ (pale) brown NO_2 in air)
sulfate, $SO_4^{2-}(aq)$	gives white ppt. with $Ba^{2+}(aq)$ (insoluble in excess dilute strong acids)
sulfite, $SO_3^{2-}(aq)$	gives white ppt. with $Ba^{2+}(aq)$ (soluble in excess dilute strong acids)

3 Tests for gases

gas	*test and test result*
ammonia, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater (ppt. dissolves with excess CO_2)
chlorine, Cl_2	bleaches damp litmus paper
hydrogen, H_2	'pops' with a lighted splint
oxygen, O_2	relights a glowing splint

The Periodic Table of Elements

Key

atomic number
atomic symbol
name
relative atomic mass

Group 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
							1 H hydrogen 1.0										2 He helium 4.0
3 Li lithium 6.9	4 Be beryllium 9.0											5 B boron 10.8	6 C carbon 12.0	7 N nitrogen 14.0	8 O oxygen 16.0	9 F fluorine 19.0	10 Ne neon 20.2
11 Na sodium 23.0	12 Mg magnesium 24.3											13 Al aluminium 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 Cl chlorine 35.5	18 Ar argon 39.9
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium –	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3
55 Cs caesium 132.9	56 Ba barium 137.3	57–71 lanthanoids	72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium –	85 At astatine –	86 Rn radon –
87 Fr francium –	88 Ra radium –	89–103 actinoids	104 Rf rutherfordium –	105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –	112 Cn copernicium –		114 Fl flerovium –		116 Lv livermorium –		

lanthanoids	57 La lanthanum 138.9	58 Ce cerium 140.1	59 Pr praseodymium 140.9	60 Nd neodymium 144.4	61 Pm promethium –	62 Sm samarium 150.4	63 Eu europium 152.0	64 Gd gadolinium 157.3	65 Tb terbium 158.9	66 Dy dysprosium 162.5	67 Ho holmium 164.9	68 Er erbium 167.3	69 Tm thulium 168.9	70 Yb ytterbium 173.1	71 Lu lutetium 175.0
actinoids	89 Ac actinium –	90 Th thorium 232.0	91 Pa protactinium 231.0	92 U uranium 238.0	93 Np neptunium –	94 Pu plutonium –	95 Am americium –	96 Cm curium –	97 Bk berkelium –	98 Cf californium –	99 Es einsteinium –	100 Fm fermium –	101 Md mendelevium –	102 No nobelium –	103 Lr lawrencium –