

Answers

AS Level practice questions

Quantitative experiments

- 1 a**
- Weigh a clean, dry 100 cm³ beaker.
 - Weigh the same beaker containing the 2.5 g of anhydrous sodium carbonate powder.
 - Add about 30 cm³ distilled water, stirring with a glass rod until all of the solid has dissolved.
 - Using a clean glass filter funnel, pour the contents of the beaker into a clean 250 cm³ volumetric flask.
 - Rinse the glass rod, beaker and filter funnel and add the washings to the volumetric flask.
 - Add distilled water until the meniscus is just entering the neck of the flask.
 - Stopper firmly and invert the flask several times to ensure thorough mixing.
 - With the flask on a horizontal surface, add distilled water until the bottom of the meniscus is on the mark.
 - Stopper firmly and invert the flask several times to thoroughly mix the contents.
- [1 mark for any point [6]]*
- b**
- The concentration of the Na₂CO₃ solution is (2.5/106) mol in 250 cm³ or 0.094 mol dm⁻³. This is only about a tenth of the HCl concentration and so the HCl solution needs to be diluted accurately.
 - Rinse a clean 25 cm³ pipette with distilled water and then with a little 1.0 mol dm⁻³ HCl solution. Then pipette 25 cm³ of the 1.0 mol dm⁻³ HCl solution and put it in a second clean 250 cm³ volumetric flask and make up to the mark with distilled water. Label both flasks clearly.
 - Rinse a burette with distilled water. Then rinse it with a little of the diluted hydrochloric acid solution, allowing the acid to run out through the tap and ensuring the tap works smoothly. Discard the hydrochloric acid solution.
 - Fill the burette with the diluted hydrochloric acid solution, ensuring the space below the tap is filled and there are no air bubbles above or below the tap. Ensure the meniscus is on the scale.
 - Set the burette in a stand so that it is vertical; place a white tile on the base of the stand.
 - Rinse a 100 cm³ conical flask with distilled water – this is the reaction vessel.
 - Rinse a clean 25 cm³ pipette with distilled water and then with a little Na₂CO₃ solution. Pipette 25 cm³ of the solution into the reaction vessel.
 - Add 3 drops of the indicator.
 - Record the initial burette reading. Add acid from the burette while swirling the flask and stop adding as soon as the indicator turns from blue to green or yellow. Record the final burette reading. This is the rough reading.
 - Discard the reaction mixture, wash the flask and pipette another 25 cm³ portion.
 - Take the initial burette reading. Run acid into the flask quickly until near the end point. Then add 1 drop at a time while swirling the flask until the indicator changes colour. Record the final burette reading.
 - Repeat the titration until two titres agree within 0.10 cm³.

[1 mark for two bullet points [6]]

2 a

Titration	rough	1	2	3
Initial burette reading/cm ³	19.50	18.35	18.75	19.20
Final burette reading/cm ³	47.75	47.75	48.10	48.50
Volume KMnO ₄ run in/cm ³	28.25	29.40	29.35	29.30

Note that the reading is taken from the top of the meniscus as KMnO₄ is in the burette. All readings are to 0.05 cm³.

b Discard the rough result. The other three readings are within 0.10 cm^3 so all can be used.

$$(29.40 + 29.35 + 29.30)/3 = 29.35 \text{ cm}^3$$

c i $(0.05/1000) \times 29.35 = 1.468 \times 10^{-3}$

ii From the equation, 1 mol KMnO_4 reacts with $(5/2)$ moles H_2O_2 .

$$1.468 \times 10^{-3} \text{ mol KMnO}_4 \text{ reacts with } 1.468 \times 10^{-3} \times (5/2) \text{ moles H}_2\text{O}_2 \text{ in } 10 \text{ cm}^3 \text{ pipetted} = 3.669 \times 10^{-3}$$

$$[\text{H}_2\text{O}_2] = (3.669 \times 10^{-3}) \times (1000/10) = 0.367 \text{ mol dm}^{-3}$$

d $2\text{H}_2\text{O}_2(\text{aq}) \rightarrow 2\text{H}_2\text{O}(\text{l}) + \text{O}_2(\text{g})$

$$3.669 \times 10^{-3} \text{ moles H}_2\text{O}_2 \text{ produces } \frac{1}{2} \times 3.669 \times 10^{-3} \text{ moles O}_2(\text{g}) = \frac{1}{2} \times 3.669 \times 10^{-3} \times 24 \text{ dm}^3 \text{ O}_2(\text{g}) \\ = 44.0 \text{ cm}^3$$

3

	Rough	1	2	3
Final burette reading/ cm^3	10.95	18.30	25.60	33.00
Initial burette reading/ cm^3	3.50	10.95	18.30	25.60
Volume titre/ cm^3	7.45	7.35	7.30	7.40

a $(7.35 + 7.30 + 7.40)/3 = 7.35 \text{ cm}^3$

b The solution would be more concentrated near the bottom of the flask, so the rough titre would be larger and subsequent titres would become smaller.

c $(0.01/1000) \times 7.35 = 7.35 \times 10^{-5}$

d $5\text{Fe}^{2+}(\text{aq}) + \text{MnO}_4^{-}(\text{aq}) + 8\text{H}^{+}(\text{aq}) \rightarrow \text{Mn}^{2+}(\text{aq}) + 5\text{Fe}^{3+}(\text{aq}) + 4\text{H}_2\text{O}(\text{l})$

e $7.35 \times 10^{-5} \times 5 = 3.68 \times 10^{-3}$

f $3.68 \times 10^{-3} \times 392.0 \text{ g} = 1.44 \text{ g}$

g Mass of the iron(III) ammonium sulfate = $(5.00 - 1.44) \text{ g} = 3.56 \text{ g}$ $(3.56/482.0) = 0.00739$

h Total moles of iron = $0.00739 + 0.00368 = 0.0111$ Mass = $0.0111 \times 55.8 = 0.617$

i $(0.617/5.00) \times 100\% = 12.3\%$

4 a $4\text{MnO}_4^{-} + 5[(\text{COOH})_2 \cdot (\text{HOCCOOK})] \cdot x\text{H}_2\text{O} + 17\text{H}^{+} \rightarrow 20 \text{ CO}_2 + 4\text{Mn}^{2+} + 5\text{K}^{+} + (16 + 5x)\text{H}_2\text{O}(\text{l})$

b The reaction may not go to completion and so the titres will be smaller.

c The potassium salt may decompose and so the titres would be smaller.

d The solution in the flask will be colourless and the end-point is indicated by the first faint pink tinge.

e $(31.50/1000) \times 0.012 = 3.78 \times 10^{-4}$

f $(31.50/1000) \times 0.012 \times 5/4 = 0.000473$

g 0.00473

h $(1.20/0.00473) = 253.7/254$

i $M_r = 218.1 + 18x = 253.7$

$$18x = 35.6$$

$$x = 2$$

5 a $5\text{NO}_2^{-} + 2\text{MnO}_4^{-} + 6\text{H}^{+} \rightarrow 2\text{Mn}^{2+} + 5\text{NO}_3^{-} + 3\text{H}_2\text{O}$

b i No of moles of $\text{NaNO}_2 = (1.05/69) = 0.0152$

$$\text{Concentration} = (0.0152/250) \times 1000 = 0.0609 \text{ mol dm}^{-3}$$

$$\text{Concentration of the diluted solution} = 0.00609 \text{ mol dm}^{-3}$$

- ii No of moles of NaNO_2 in 25 cm^3 of the diluted solution = $(0.00609/1000) \times 25 = 1.52 \times 10^{-4}$
 No of moles KMnO_4 required = $(2/5) \times 1.52 \times 10^{-4} = 6.09 \times 10^{-5}$
 Volume $\text{KMnO}_4 = 6.09 \times 10^{-5}/0.01 = 6.10 \text{ cm}^3$

iii To speed up the reaction.

iv The weak acid HNO_2 would be formed from NO_2^- and H^+ . The acid is volatile and so would be lost from the mixture. The titres would be smaller.

v As soon as the acidified KMnO_4 is added, some of the NaNO_2 will be oxidised but some will form HNO_2 from the H^+ being added. This acid is volatile and will be lost from the solution.

c i $(0.0200/1000) \times 8.00 = 0.0001600$

ii $2\text{MnO}_4^- + 5(\text{COOH})_2 + 6\text{H}^+ \rightarrow 2\text{Mn}^{2+} + 10\text{CO}_2 + 8\text{H}_2\text{O}$

iii $0.00016 \times 5/2 = 0.0004$

iv 20 cm^3 of $0.100 \text{ mol dm}^{-3}$ oxalic acid contain $(0.100/1000) \times 20 \text{ mol} = 0.002 \text{ mol}$
 0.0004 mol are in excess and so $(0.002 - 0.0004) = 0.0016 \text{ mol}$ reacted with the excess KMnO_4 initially added.

v $(0.0016 \times 2/5) = 0.00064$

vi 100 cm^3 of 0.02 mol dm^{-3} KMnO_4 contain $(0.0200/1000) \times 100 = 0.002 \text{ mol}$
 Number of moles of KMnO_4 reacted with 25 cm^3 of NaNO_2 solution = $0.002 - 0.00064 = 0.00136$

vii $0.00136 \times 5/2 = 0.0034$

viii Number of moles = 0.034
 Mass = $0.034 \times 69 = 2.35 \text{ g}$

ix $(2.35/2.85) \times 100 = 82.5\%$

6 a See 1a for a detailed explanation of how to make a volumetric solution.

b The blue colour of $\text{CuSO}_4(\text{aq})$ fades and a white precipitate of CuI forms with a brown solution of $\text{I}_2(\text{aq})$.

- c
- See 1b for how to set up the burette, use the pipette and obtain accurate titration results.
 - The burette is rinsed with a little sodium thiosulfate which is discarded and then filled with sodium thiosulfate solution ensuring the part below the tap is filled, there are no air bubbles and the meniscus is on the scale.
 - The iodine solution is already in the conical flask after the reaction of 25 cm^3 CuSO_4 with excess $\text{KI}(\text{aq})$.
 - The initial burette reading is taken and recorded from the bottom of the meniscus.
 - Sodium thiosulfate is run in while swirling the conical flask until the solution has become pale straw coloured.
 - 1 cm^3 of fresh starch solution is added and the titration continued slowly until the addition of 1 drop of solution changes the colour from intense blue-black to colourless (there will still be a white precipitate).
 - Read and record the final burette reading.
 - Carry out a rough and as many accurate titrations as are needed to get at least two titres within 0.1 cm^3 .

d i

	1	2	3	4
Initial burette reading/ cm^3	0.50	1.20	3.45	24.00
Final burette reading/ cm^3	23.25	21.60	23.95	44.50
Volume run in/ cm^3	22.75	20.40	20.50	20.50

[1 mark for all correct headings; 1 mark for all correct units;
 1 mark for correct arithmetic; 1 mark for all numbers to two decimal places [4]]

ii $(20.50 + 20.50)/2 = 20.50 \text{ cm}^3$

iii 20.50 cm^3 of $0.051 \text{ mol dm}^{-3} \text{ Na}_2\text{S}_2\text{O}_3$ contains $(0.051/1000) \times 20.50 \text{ mol} = 1.046 \times 10^{-3} \text{ mol}$

... which reacts with $\frac{1}{2} \times 1.046 \times 10^{-3} \text{ mol I}_2$ (from the second equation)

... which is formed from $1.046 \times 10^{-3} \text{ mol CuSO}_4$ (from the first equation) in 25 cm^3 pipetted.

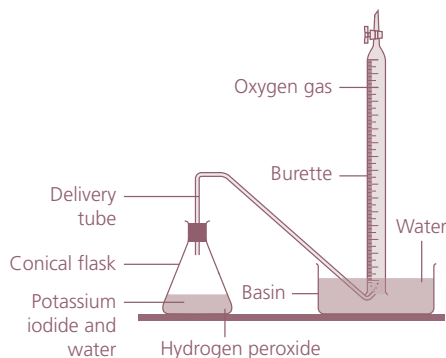
$$[\text{CuSO}_4] = 1.046 \times 10^{-3} \times (1000/25) \text{ mol dm}^{-3} = 0.0418 \text{ mol dm}^{-3}$$

iv The no of moles of CuSO_4 = no of moles $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ in 250 cm^3 solution = 0.01046

$$M_r [\text{CuSO}_4 \cdot 5\text{H}_2\text{O}] = 249.6 \text{ and mass of } \text{CuSO}_4 \cdot 5\text{H}_2\text{O} \text{ in } 3.15 \text{ g crystals} = 0.01046 \times 249.6 = 2.611 \text{ g}$$

v $(2.611/3.15) \times 100\% = 82.9\%$

7 a

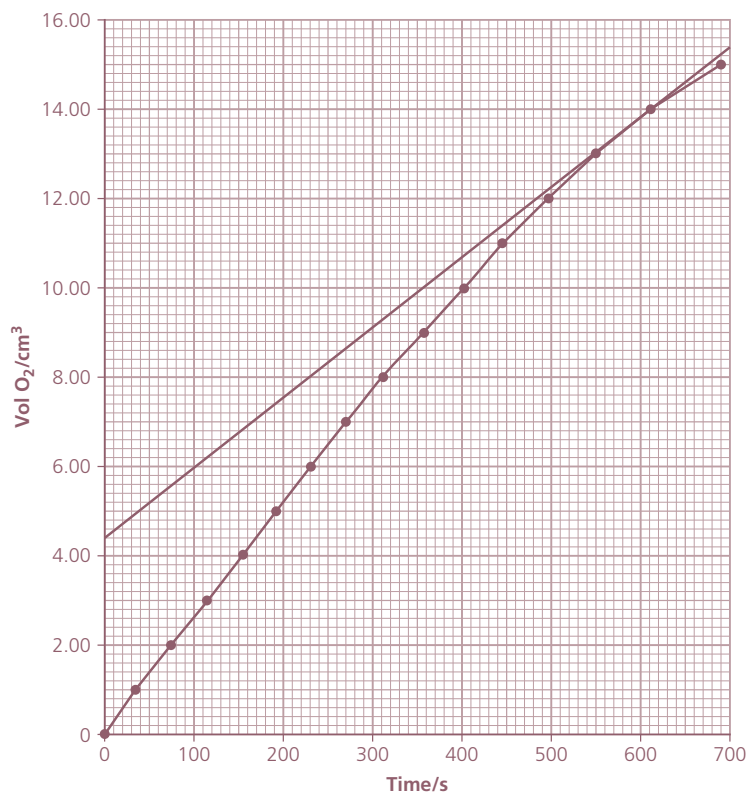


[1 mark for collection over water; 1 mark for sealed apparatus;
1 mark for labelled reagents; 1 mark for two other correct labels [4]]

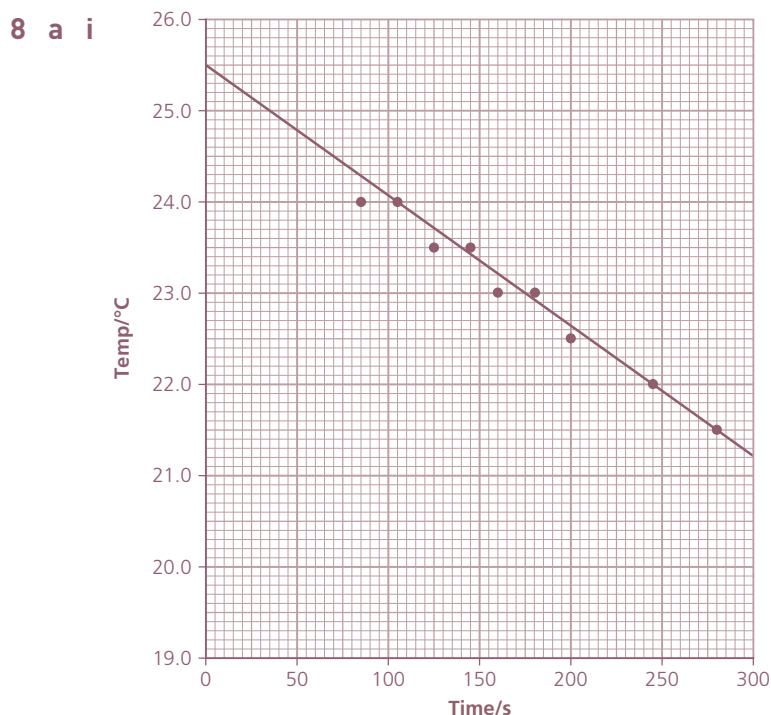
b

Burette reading/ cm^3	48.70	47.70	46.70	45.70	44.70	43.70	42.70	41.70	40.70	39.70	38.70	37.70	36.70	35.70	34.70	33.70
Time/s	0	35	75	115	155	193	231	270	310	358	403	445	498	550	612	690
Volume oxygen/ cm^3	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00

c i



- ii 7.75 cm^3
- iii $7.75/300 = 0.0258 \text{ cm}^3 \text{ s}^{-1}$
- iv $(13.85 - 4.55)/600 = 0.016 \text{ cm}^3 \text{ s}^{-1}$
- v As the concentration of the reagents decreases, so the rate of reaction decreases.
- d The original experiment was carried out at 20°C . At the higher temperature, the rate will increase and so the graph will be above the original graph.
- e When the reaction is complete, add acidified silver nitrate to form silver iodide precipitate. Filter, wash and dry the precipitate. Weigh it and work out the no of moles to show there is the same amount of KI at the beginning and end of the experiment.
- Carry out the same reaction but using an extra 10.0 cm^3 of deionised water in place of the KI(aq) and measure the oxygen volume produced with time.



- ii 25.5°C
- iii $25.5 - 19.0 = 6.5^\circ\text{C}$
- iv $q = mc\Delta T$
 $q = 100 \times 4.18 \times 6.5 = 2717 \text{ J}$
 no of moles $\text{NaOH} = (50/1000) = 0.050$; the reaction is exothermic
 $\Delta H = (-2717/0.05) = -54.3 \text{ kJ mol}^{-1}$
- b Ethanoic acid is a weak acid and some energy has to be used for ionisation.
- c Use a lagged polystyrene cup and lid to minimise any energy loss to the surroundings.
- 9 a i 1.50 g
- ii loss in mass = 0.38 g
 no of moles $\text{CO}_2(\text{g}) = 0.38/(12 + 16 + 16) = 8.64 \times 10^{-3}$
- iii 8.64×10^{-3}
- iv mass of $\text{ZnCO}_3 = 8.64 \times 10^{-3} \times 125.4 = 1.08 \text{ g}$
 $\% \text{ by mass} = (1.08/1.50) \times 100 = 72.2\%$

b		1	2	3	4
	Initial burette reading/cm ³	1.30	2.40	3.55	2.75
	Final burette reading/cm ³	32.25	32.50	33.70	32.95
	Volume NaOH(aq) run in/cm ³	30.95	30.10	30.15	30.20

c i Yellow to blue – the indicator is yellow in the excess HCl(aq) and changes to blue when 1 drop of NaOH turns the solution alkaline.

ii $(30.10 + 30.15 + 30.20)/3 = 30.15 \text{ cm}^3$

iii 30.15 cm^3 of NaOH contains $(0.10/1000) \times 30.15 = 3.015 \times 10^{-3}$ moles

iv no of moles of HCl added to $\text{ZnCO}_3 = (0.5/1000) \times 100 = 0.05 \text{ mol}$

no of moles HCl remaining in 250 cm^3 solution $= 10 \times 3.015 \times 10^{-3} = 3.015 \times 10^{-2}$

no of moles HCl used up by $\text{ZnCO}_3 = 0.05 - 0.03015 = 0.0199$

v no of moles $\text{ZnCO}_3 = \frac{1}{2} \times 0.0199 = 9.93 \times 10^{-3}$

mass of $\text{ZnCO}_3 = 9.93 \times 10^{-3} \times 125.4 = 1.24 \text{ g}$

vi $(1.24/1.50) \times 100\% = 83.0\%$

d i Method 1: The ZnCO_3 may not have completely decomposed. Heat to constant mass.

Method 2: Titration is more accurate but there are several transfers of solid and solution, each one contributing to some small experimental uncertainty. Accurate procedures should be followed for measuring the mass of solid and the volume of acid added.

OR Some of the contaminant may have reacted with the acid.

ii The titration method

10 There are three main sources of systematic error:

- The temperature changing; even a small increase in temperature can increase the rate of a chemical reaction by a large amount. Carrying out the experiment in a constant temperature enclosure, or even a water bath, would minimise this error. [One mark for each of these points.]
- Timing when all four reagents are added together to start the reaction; starting the stopwatch at an appropriate time is a challenge. Timing when the iodine–complex colour is seen and stopping the stopwatch depends on the reaction time of the person holding the stopwatch. [Both of these points are needed for a mark.]
- Having all solutions measured and ready to add with one person adding them while another starts the stopwatch can minimise the timing error at the start. For reproducibility, the same person should always time the onset of the colour to minimise the error at the end of the experiment. [Both of these points are needed for a mark.]

11 Using the given data if you have not been able to carry out the practical work:

a mass of **FA 1** $= (11.78 - 10.01) = 1.77 \text{ g}$

mass of CO_2 given off $= 165.53 + 1.77 - 166.37 = 0.93 \text{ g}$

b i no of moles $= \text{mass}/M_r = 0.93/44$

$= 0.0211 \text{ mol}$

ii $\text{XCO}_3(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow \text{XCl}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$

iii 0.0211

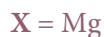
iv $1.77 \text{ g} = 0.0211 \text{ mol}$

$1.00 \text{ mol} = 1.77/0.0211 \text{ g} = 83.9 \text{ g}$

C = 12; O = 16

$83.9 - 12 - (3 \times 16) = 23.9$

$$A_r \text{ of X} = 23.9$$



- c i** If some solution is lost through acid spray, the final mass of the beaker + contents will be less. It will seem as though a greater mass of CO_2 has been given off. The no of moles of CO_2 and XCO_3 will be greater for the same mass of XCO_3 . And so M_r and A_r values will be lower.
- ii** This will give only a small difference in A_r from the actual value and so the A_r will still be close to the actual value.
- iii** Weigh the beaker with a watch glass as a lid and replace the lid immediately on adding the carbonate.

12 a Using the given data if you have not been able to carry out the practical work, the rough titre is 36.70 cm^3

Final burette reading/ cm^3	39.15	38.50	37.85	41.10
Initial burette reading/ cm^3	2.45	1.75	1.30	4.55
Titre/ cm^3	36.70	36.75	36.55	36.55

- b** $(36.55 + 36.55)/2$
 $= 36.55 \text{ cm}^3$
- c i** $(0.04/1000) \times 25$
 $= 1.00 \times 10^{-3} \text{ mol}$
- ii** 36.55 cm^3 contains $1.00 \times 10^{-3} \text{ mol}$
 $250 \text{ cm}^3 \text{ HCl}$ contains $(1.00 \times 10^{-3}/36.55) \times 250 \text{ mol}$
 $= 6.84 \times 10^{-3} \text{ mol}$
- iii** No of moles reacted $= 2 \times 0.0211$
 $= 0.0422 \text{ mol}$
- iv** Total no of moles of $\text{HCl} = 6.84 \times 10^{-3} + 0.0422 = 0.0490$ and this was in 25 cm^3 solution
 Concentration of **FA 2** $= (0.0490/25) \times 1000 = 1.96 \text{ mol dm}^{-3}$
- d i** The volume of **FA 2** was measured using a measuring cylinder which has the greatest percentage error. This could have been reduced by using a 25 cm^3 pipette.
- ii** A greater mass of XCO_3 would use up a greater amount of HCl and so there would be less HCl in the solution. The titre value would be smaller.

Observational experiments

- 13 a** – The blue solution turns paler/colourless.
 – A pale blue precipitate insoluble in excess sodium hydroxide is formed.
- b** – The blue solution turns paler.
 – A pale blue precipitate is formed
 – ... which dissolves in excess to form a dark blue solution.
- c** – The white crystals disappear.
 – Effervescence
- d** – The colourless solution produces a cream [mixture of yellow and white] precipitate.
 – The white part of the precipitate dissolves in concentrated aqueous ammonia to leave a yellow precipitate in a colourless solution.
- e** – The black powder produces bubbles but remains as a black powder in the colourless solution.

- f** – A red-brown precipitate is formed [which masks the pale blue precipitate which also forms].
 – On adding excess ammonia, a red-brown precipitate remains in a dark blue solution.
- g** – The deep purple colour of KMnO_4 disappears.
- h** – A silver mirror is formed.
- i** – A red precipitate forms.
- j** – Yellow crystals are formed.

14 a

Test	Observation
NaOH(aq)	green precipitate, insoluble in excess
$\text{BaCl}_2\text{(aq)}$	white precipitate, insoluble in excess
Acidified KMnO_4	purple colour fades leaving a yellow or orange solution

b

Test	Observation
NaOH(aq)	very pale blue precipitate (white and pale blue) which darkens a little on adding excess (as the white precipitate dissolves but the pale blue remains)
$\text{NH}_3\text{(aq)}$	very pale blue precipitate and on adding excess a dark blue solution with a white precipitate is formed

[For the first row: 1 mark for pale blue precipitate; 1 mark for precipitate darkens or that it partially dissolves. For the second row: 1 mark for pale blue precipitate; 1 mark for dark blue solution; 1 mark for white precipitate]

15 a

Test	Observation
Heating powder	gas produced which gives a white precipitate with lime water
Adding NaOH(aq) to a solution	white precipitate, insoluble in excess
Warming the alkaline solution	fumes are produced which turn moist red litmus paper blue

- b** – Mg^{2+} because there is a white precipitate with NaOH(aq) which is insoluble in excess. NH_4^+ as on warming the alkaline solution ammonia is produced
- c** – A white precipitate with lime water indicates CO_2 produced on addition of the acid, so the anion must be CO_3^{2-} .
- d** – In pure water, the solid would partially dissolve. $(\text{NH}_4)_2\text{CO}_3$ is soluble but MgCO_3 is insoluble.
 – In $\text{H}_2\text{SO}_4\text{(aq)}$, there would be effervescence as the carbonates produce $\text{CO}_2\text{(g)}$. The solid would completely dissolve as both $(\text{NH}_4)_2\text{SO}_4$ and MgSO_4 are soluble.

16 a Oxidation or redox

- b** – Green precipitates with NaOH(aq) are produced by Fe^{2+} and Cr^{3+} salts.
 – NaOH(aq) producing a green precipitate turning brown by air oxidation suggests Fe^{2+} being oxidised to Fe^{3+} .
 – Excess NaOH(aq) producing a green solution suggests $\text{Cr}^{3+}\text{(aq)}$.
 – $\text{NH}_3\text{(aq)}$ produces a green precipitate from both Fe^{2+} and Cr^{3+} salts.
 – Neither Fe^{2+} nor Cr^{3+} forms a complex with excess $\text{NH}_3\text{(aq)}$ and so the green precipitates remain. The Fe(OH)_2 precipitate formed oxidises in air to Fe(OH)_3 .
 – KMnO_4 will oxidise Fe^{2+} to Fe^{3+} and is reduced to Mn^{2+} and so the deep purple colour disappears.
- c** Air oxidation of Fe^{2+} to Fe^{3+}
- d** Add a few drops of $\text{BaCl}_2\text{(aq)}$ acidified with HCl(aq) to solution Y and a white precipitate will be seen.
- e** $\text{MnO}_4^-\text{(aq)} + 5\text{Fe}^{2+}\text{(aq)} + 8\text{H}^+\text{(aq)} \rightarrow \text{Mn}^{2+}\text{(aq)} + 5\text{Fe}^{3+}\text{(aq)} + 4\text{H}_2\text{O(l)}$

17 a i At any point where there is effervescence. Use a delivery tube and bubble the gas produced through lime water. (If CO_2 is present there will be a white precipitate.)

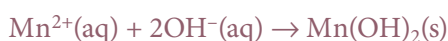
ii The gas is neutral or acidic.

iii The gas cannot be NH_3 as this gas turns moist litmus blue. Cl_2 bleaches litmus. CO_2 does not allow burning. H_2 would extinguish the lighted splint with a pop.

Oxygen would allow more vigorous burning, so it is probably oxygen (in every case).

b i Reducing reagent (as potassium permanganate is an oxidising agent)

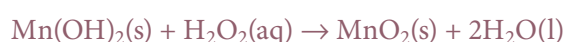
ii Manganese(II) hydroxide



iii It has been reduced (but not to Mn^{2+}), so suggest the black precipitate is MnO_2 .

iv It has been oxidised from Mn^{2+} to MnO_2 .

v In test 2, the black solid, MnO_2 , remains at the bottom but a gas, oxygen, is released. Y is $\text{H}_2\text{O}_2(\text{aq})$.



18 a i

Test	Observations
To a 1 cm depth of FA 5 in a test-tube add a small spatula measure of sodium carbonate.	Effervescence
To a 1 cm depth of FA 5 in a test-tube add two drops of acidified potassium manganate(VII). Leave to stand in the water bath.	Purple colour fades
To a 1 cm depth of FA 5 in a test-tube add a few drops of aqueous silver nitrate.	No effect
To a 1 cm depth of aqueous silver nitrate in a test-tube add a few drops of aqueous sodium hydroxide and then add aqueous ammonia slowly until the grey precipitate that forms just dissolves. This is Tollens' reagent.	No effect
To this solution add a 1 cm depth of FA 5 and leave to stand in the water bath.	
Care: rinse the tube as soon as you have completed this test.	

ii Carboxylic acid and primary or secondary alcohol or ketone

Test	Observations
Place a spatula measure of FA 7 in a boiling tube. Add dilute hydrochloric acid until no further reaction occurs, then	Effervescence Testing the gas by bubbling into lime water produces a white precipitate
transfer a 1 cm depth of the solution into a test tube. To this add aqueous sodium hydroxide.	Pale blue precipitate insoluble in excess

Test	Observations
To a 1 cm depth of FA 8 in a boiling tube add a 1 cm depth of aqueous sodium hydroxide, then	White precipitate
warm gently.	Precipitate remains
To a 1 cm depth of FA 8 in a boiling tube add a piece of aluminium foil and a 1 cm depth of aqueous sodium hydroxide. Warm gently.	Bubbles Gas tested with moist red litmus turns it blue

iii Cu^{2+}

Zinc or magnesium

Add excess $\text{NaOH}(\text{aq})$ and see if the precipitate dissolves. If Zn^{2+} is the ion, the precipitate dissolves but if Mg^{2+} is the ion, the precipitate remains.

iv CO_3^{2-}

Nitrate or nitrite

19 a Corrosive

Toxic

Environmental hazard

Inflammable

b A carboxylic acid

B secondary alcohol

A Effervescence with sodium carbonate indicates a carboxylic acid producing $\text{CO}_2(\text{g})$. The other two tests are negative.

B Both aldehydes and secondary alcohols are oxidised by acidified potassium dichromate. Neither of these will react with sodium carbonate. Aldehydes do not react with alkaline iodine but a methyl secondary alcohol can.

c Cl**d** Esterification

A Level practice questions

1 a Acidified/ H^+ and $\text{Na}_2\text{Cr}_2\text{O}_7$ or KMnO_4 **b** Use a heating mantle/electronic heater as reactant and product are flammable.**c** Diagram for reflux apparatus:

- vertically mounted condenser, open at the top
- water in at the bottom and out at the top of the condenser, and the condenser open to the atmosphere
- round-bottomed or pear-shaped flask containing reaction mixture and labels to condenser and reaction mixture
- indication of where the apparatus is heated (arrow or picture of heating mantle)

d Place the reaction vessel onto a mass balance and zero the balance.

Then pour in 10.0 g of butan-2-ol using a teat/dropping pipette

e RFM of butan-2-ol = 74, RFM of butanone = 72

Expected mass of butanone = $10.0 \times (72/74) = 9.73 \text{ g}$

f Distillation – collect the fraction that distils at the boiling temperature of butanone**g i** $(3.19/\text{answer to e}) \times 100$

= 32.8% if 9.73 used as the theoretical 100% yield

ii Any from:

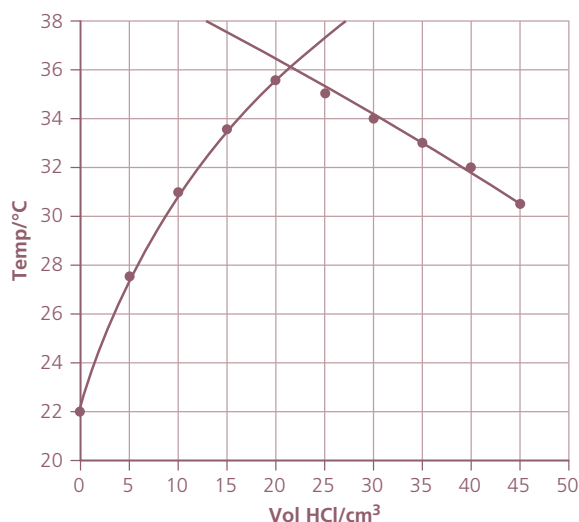
- Reaction is incomplete
- Reaction reaches a position of equilibrium
- Side reactions may have occurred

h Reaction with 2,4-DNP or Brady's reagent to give an orange precipitate confirms the presence of the carbonyl group (so ketone or aldehyde).

No reaction with Fehling's or Tollens' so no aldehyde present



b and c



d 21.5 cm^3

e moles of HCl reacted = $(21.5/1000) \times 2.50 = 0.0538$ moles

moles of KOH = moles of HCl = 0.0538 moles

concentration of KOH = $0.0538/(20/1000) = 2.69 \text{ mol dm}^{-3}$

f Use a thermometer with greater precision, insulation around the beaker, more points around the peak

g The alkali contaminant would have neutralised some of the acid in the burette. This means the acid used in the experiment would have been less than 2.50 mol dm^{-3} , so the calculated value for the concentration of KOH would have been lower.

3 a Repeated heating and weighing until the measured mass no longer changes. This is done to ensure the reaction is complete/all the waters of crystallisation have been driven off.

- b**
- Weigh and record the mass of a crucible.
 - Add the sample of magnesium sulfate to the crucible.
 - Weigh and record the mass of the sample and crucible.
 - Place the crucible on a pipe-clay triangle above a Bunsen burner.
 - Heat gently, then more strongly for approximately 5 minutes.
 - Allow to cool, then reweigh the mass of the residue and crucible.
 - Repeat the last two instructions until the masses do not change on heating.

*[1 mark for description of weighing initial mass; 1 mark for apparatus description;
1 mark for heating and reweighing; 1 mark for repeats to a constant mass]*

c Handling the hot crucible is a risk, mitigated by allowing it to cool before moving.

Reactant spitting when hot is a risk, mitigated by heating slowly then strongly or using a lid.

d i mass of $\text{MgSO}_4 \cdot x\text{H}_2\text{O} = 53.23 - 48.22 = 5.01 \text{ g}$

mass of residue = $50.71 - 48.22 = 2.49 \text{ g}$

mass of water removed = $5.01 - 2.49 = 2.52 \text{ g}$

(Three masses correctly calculated)

RFM of $\text{MgSO}_4 = 120.4 \text{ g mol}^{-1}$, RFM of water = 18 g mol^{-1}

moles of MgSO_4 in residue = $2.49/120.4 = 0.0207$ moles

moles of H_2O removed = $2.52/18 = 0.140$ moles

(both mole calculations)

value of $x = 0.140/0.0207 = 6.76 = 7$ (to nearest integer)

- ii The solid MgSO_4 may have started to decompose. This would mean less mass of residue/ MgSO_4 or more mass of water removed, so the value of x would then be higher.

4 a Cyclohexane is a flammable hydrocarbon; keep away from naked flames.

b Phenolphthalein, as it is a strong base and weak acid.

$$c \quad K_{\text{part}} = \frac{[\text{C}_4\text{H}_9\text{COOH}]_{\text{organic}}}{[\text{C}_4\text{H}_9\text{COOH}]_{\text{aqueous}}}$$

d i $(20/1000) \times 0.0100 = 2.00 \times 10^{-4}$ moles

ii $(7.80/1000) \times 0.0100 = 7.80 \times 10^{-5}$ moles

iii $2.00 \times 10^{-4} - 7.80 \times 10^{-5} = 1.22 \times 10^{-4}$ moles

iv The volumes cancel as they are both the same.

v $K_{\text{part}} = \text{moles in organic layer} / \text{moles in aqueous layer}$
 $= 1.22 \times 10^{-4} / 7.80 \times 10^{-5} = 1.56$

e The volume of aqueous layer used in the titration will be lower, so the no of moles in the aqueous layer determined will be lower. This means the no of moles in the organic layer will be higher, so the value of K_{part} will be higher.

5 a $\text{Cr}_2\text{O}_7^{2-} + 14\text{H}^+ + 6\text{e}^- \rightarrow 2\text{Cr}^{3+} + 7\text{H}_2\text{O}$

The $\text{Cr}_2\text{O}_7^{2-}$ is gaining electrons and so is being reduced. OR Cr is changing its oxidation state from +6 to +3 and so is being reduced

b $\text{C}_5\text{H}_{11}\text{OH} \rightarrow \text{C}_4\text{H}_9\text{CHO} + 2\text{H}^+ + 2\text{e}^-$

	From	To
Colour	orange	green
Species responsible for colour	$\text{Cr}_2\text{O}_7^{2-}$	Cr^{3+}

d i Pentanal has the lowest as it cannot form hydrogen bonds. Pentanoic acid has the highest as it forms more hydrogen bonds/has stronger dispersion forces than pentan-1-ol.

ii Distillation

- Liebig condenser drawn at an angle with correct water in and out
- Round-bottomed or pear-shaped flask with reaction mixture and heat
- T-piece with thermometer in correct position, sealed
- Collection apparatus and delivery tube

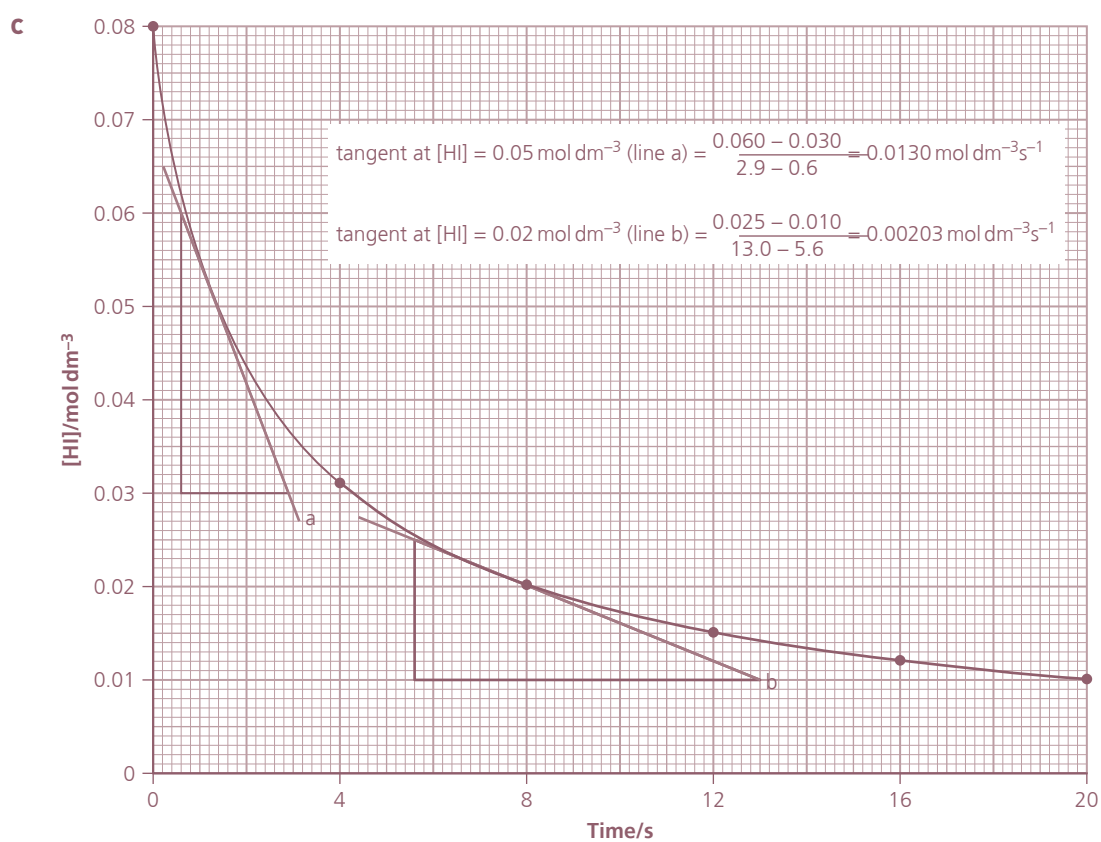
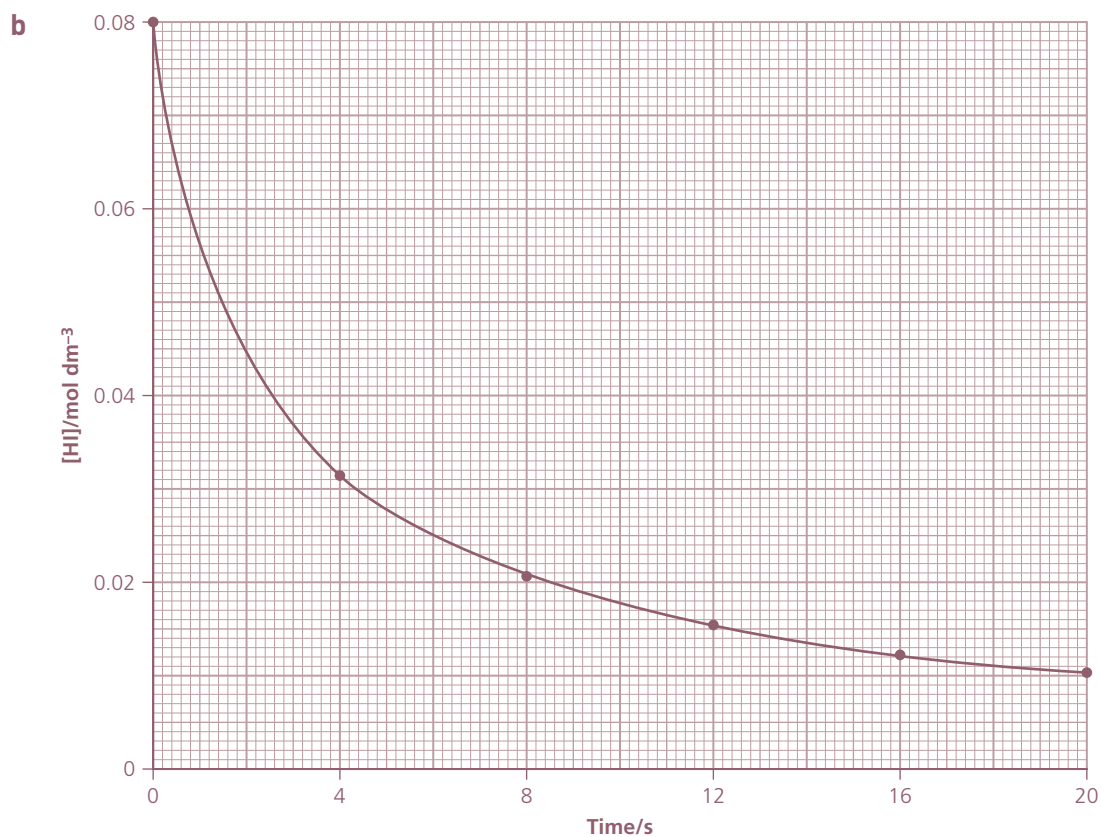
iii Sulfuric acid – shake with a soluble carbonate in a separating funnel (and remove the aqueous layer); dry the product with an anhydrous salt, e.g. CaCl_2 .

e Fehling's solution gives a brick-red precipitate OR Tollens' reagent gives silver mirror test

f ^1H spectra: 3 peaks; one doublet with an area of 6; one septet/heptet/multiplet with an area of 1; one singlet

^{13}C spectra: 3 peaks

6 a I_2 is coloured, so colorimetry could be used to follow the change in colour caused by $[I_2]$.



d Values of 0.0130 and 0.00203 give a ratio of gradients of 6.40.

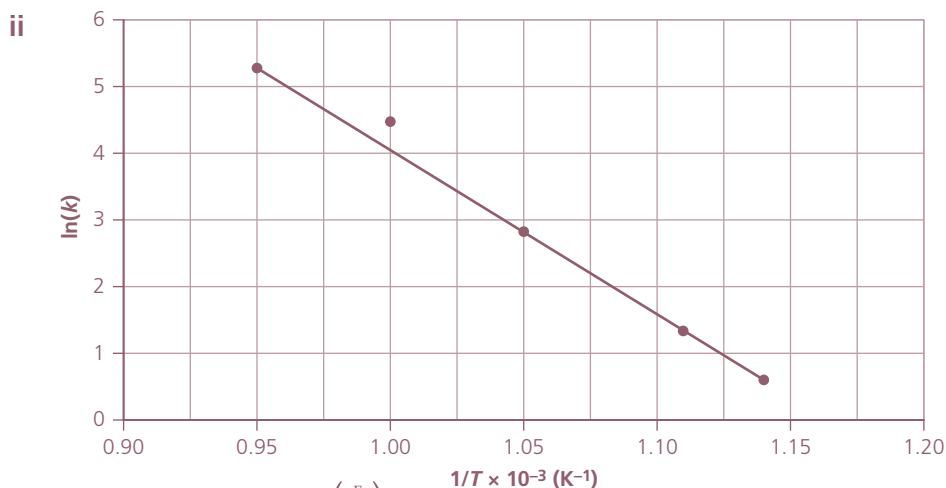
The ratio of concentrations is 2.5

$$(2.5)^n = 6.4$$

$n = 2$ (approximately), so it is second order

e rate = $k[\text{HI}]^2$, units for k are $\text{mol}^{-1} \text{dm}^3 \text{s}^{-1}$

f i	Temperature, T (K)	k (units left blank)	$1/T$ (K^{-1})	$\ln(k)$
	875	1.76	1.14×10^{-3}	0.565
	900	3.87	1.11×10^{-3}	1.35
	950	16.5	1.05×10^{-3}	2.80
	1000	87.3	1.00×10^{-3}	4.47
	1050	198	0.95×10^{-3}	5.29



use of Arrhenius: $k = Ae^{\left(\frac{E_A}{RT}\right)}$

rearranged to give $\ln(k) = -\frac{E_A}{R} \cdot \frac{1}{T} + \ln(A)$

gradient is approximately $-24\,800 \text{ K}^{-1}$ ($= -E_A/R$)

g So $E_A = -(-24\,800 \times 8.31) = +206\,088 \text{ J mol}^{-1} \approx +206 \text{ kJ mol}^{-1}$

7 a i $2\text{Mg}(\text{NO}_3)_2 \rightarrow 2\text{MgO} + 4\text{NO}_2 + \text{O}_2$

ii 1 mol of $\text{Mg}(\text{NO}_3)_2$ produces 1 mol of MgO

$M_r(\text{MgO}) = 24.3 + 16.0 = 40.3 \text{ g mol}^{-1}$, so 1 mol has a mass of **40.3 g**

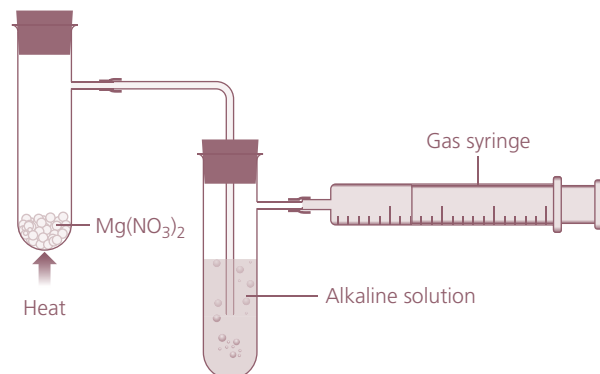
1 mol of $\text{Mg}(\text{NO}_3)_2$ produces 2 mols of NO_2 and 0.5 mol of O_2

1 mol of any gas under room conditions has a volume of 24.0 dm^3 , so

volume of $\text{NO}_2 = 2 \times 24.0 = \mathbf{48 \text{ dm}^3}$

volume of $\text{O}_2 = 0.5 \times 24.0 = \mathbf{12 \text{ dm}^3}$

b i Diagram such as:



- A directly heated vessel containing the $\text{Mg}(\text{NO}_3)_2$ with tube at exit
- The gas stream led into a liquid that will absorb the NO_2 labelled 'alkali' or 'alkaline solution'
- Collects gas in a gas syringe (or over water) connected properly
- All parts of the apparatus connected correctly and in the right order

- ii State correct volume for gas collector, for example a 100 cm^3 gas syringe, and calculate the correct mass of $\text{Mg}(\text{NO}_3)_2$ to fill 50–90% of the gas collector.

e.g. for a 100 cm^3 collection vessel, 90 cm^3 could be collected.

$$90\text{ cm}^3 / 24\,000\text{ cm}^3\text{ mol}^{-1} = 0.00375\text{ mol of gas}$$

Oxygen is produced in a 2:1 ratio from the solid, so $0.00375 \times 2 = 0.0075\text{ mol of Mg}(\text{NO}_3)_2$ needed

$$\text{Mass of Mg}(\text{NO}_3)_2 \text{ needed is } 0.0075 \times 148.3 = 1.11\text{ g}$$

- c Mass of $\text{Mg}(\text{NO}_3)_2$ at start and mass of MgO at end, OR mass of tube with solid at start and end.

Mass of container (with alkali) at start and end

Volume of oxygen collected

- d i Heat to constant mass or heat to constant volume

ii Allow the apparatus to cool to room temperature

- e Use the experimental results to calculate the moles of $\text{Mg}(\text{NO}_3)_2$ AND the moles of one of the three products. Then compare with the molar ratio in the equation given in 7a.

- f Ensure the apparatus is airtight/no leakage before heating begins OR any other sensible suggestion relating to exposure to NO_2 or use of apparatus.

- 8 a i $\text{HCOO}^- \rightarrow \text{CO}_2 + \text{H}^+ + 2\text{e}^-$



- ii M_r of $\text{Mg}(\text{HCOO})_2$ is 114.3 g mol^{-1}

$$150\text{ g of Mg}(\text{HCOO})_2 \text{ is } 150/114.3 = 1.312\text{ mol}$$

$$\text{so } [\text{Mg}(\text{HCOO})_2] = 1.312\text{ mol dm}^{-3}$$

$$[\text{HCOO}^-] \text{ is } 2 \times [\text{Mg}(\text{HCOO})_2] = 2.624\text{ mol dm}^{-3}$$

- iii Use volumetric apparatus (pipette or burette) to measure 5.0 cm^3 of the $\text{Mg}(\text{HCOO})_2$. Add to a 250 cm^3 volumetric flask AND make up to the mark (with water).

- iv H^+ /acid is required for the reaction with the manganate(VII). So long as the acid is in excess, its volume does not matter.

- v A **pale** pink colour (*not just pink*) or first permanent pink **tinge**

- vi mols of MnO_4^- in titre = $0.0200 \times (25.50/1000) = 0.00051\text{ mols}$

$$\text{no of moles of HCOO}^- = 0.00051 \times 2.5 = 0.001275\text{ mols}$$

$$[\text{HCOO}^-] = 0.001275/(25.0/1000) = 0.051\text{ mol dm}^{-3}$$

- vii The original solution underwent a 50-fold dilution, so

$$\text{original } [\text{HCOO}^-] = 50 \times 0.051 = 2.55\text{ mol dm}^{-3}$$

$$\text{original } [\text{Mg}(\text{HCOO})_2] = 2.55/2 = 1.275\text{ mol dm}^{-3} \text{ (or } 1.28\text{ mol dm}^{-3})$$

- b Independent variable: temperature

Dependent variable: $[\text{Mg}(\text{HCOO})_2]$

- c** ΔH is positive (endothermic) (in the forward direction).

An increase in temperature moves the position of equilibrium towards the products.

- d** The barium ions would form a precipitate with the acid as BaSO_4 is insoluble.

- 9 a** A 25–250 cm^3 volumetric flask

If volumetric flask is 250 cm^3 :

mols of propanone = $1 \times (250/1000) = 0.250$ mols

mass of propanone = $0.250 \times 58.0 = 14.5$ g

- b i** Either A or C must be added last.

ii A and C are the reactants, so one of them must be added last to start the reaction.

- c i** A 10 cm^3 pipette

ii NaHCO_3 will effervesce (bubble). When the effervescence stops, all the acid has been removed.
 NaOH will react with the I_2 and/or the CH_3COCH_3 .

- d i** mols of $\text{I}_2 = (10/100) \times 0.2 \times (50/1000) = 1.00 \times 10^{-3}$ mol

mols of $\text{S}_2\text{O}_3^{2-} = 2 \times 1.00 \times 10^{-3} = 2.00 \times 10^{-3}$ mol

Volume of $0.100 \text{ mol dm}^{-3} \text{ S}_2\text{O}_3^{2-} = 2.00 \times 10^{-3} / (0.1/1000) = 20.0 \text{ cm}^3$

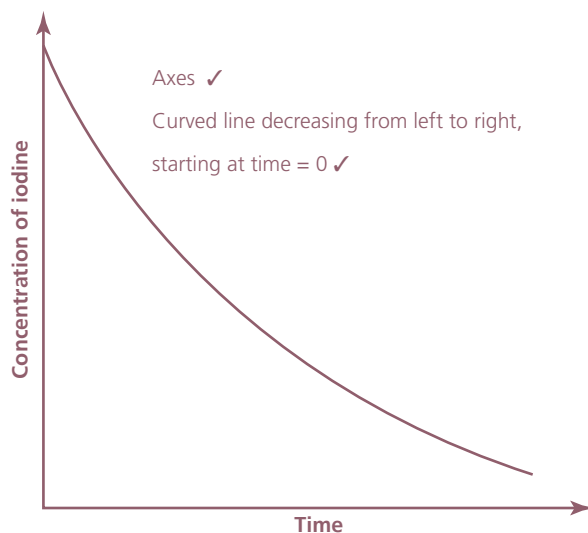
ii Starch: blue–black to colourless

- e** Time in seconds or (s)

Volume of $\text{S}_2\text{O}_3^{2-}$ (cm^3)

- f** Temperature

- g i**



ii Idea of curve showing a constant half-life or calculating tangents (rates) at various concentrations and finding that the rate/concentration graph is linear and goes through zero.

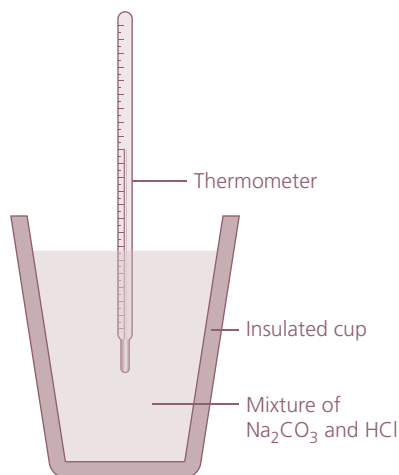
- h** The student is incorrect as half-life will still be constant OR temperature has no effect on the order of reaction.

- 10 a** The Bunsen burner is applying heat OR the reaction is taking place in a solvent/water OR you cannot tell when the reaction is complete.

- b i** The reactants were mixed together at 4 minutes.

The temperature of the mixture/ HCl was measured every minute.

ii Diagram of an insulated container and labelled thermometer in the liquid:



c 5.3°C

d $q = mc\Delta T = 50 \times 4.18 \times 5.3 = 1107.7\text{ J}$

mols of $\text{Na}_2\text{CO}_3 = 3.18/106.0 = 0.0300\text{ mol}$

$\Delta H_1 = 1107.7/0.0300 = 36\,923\text{ J mol}^{-1} = 36.9\text{ kJ mol}^{-1}$

e i To allow the temperature of the HCl to reach room temperature.

ii The reaction was not complete.

f Weighing by mass difference ensures that the mass of all the solid transferred is measured.

g i % error is (error in measurement/measurement) $\times 100\%$, so

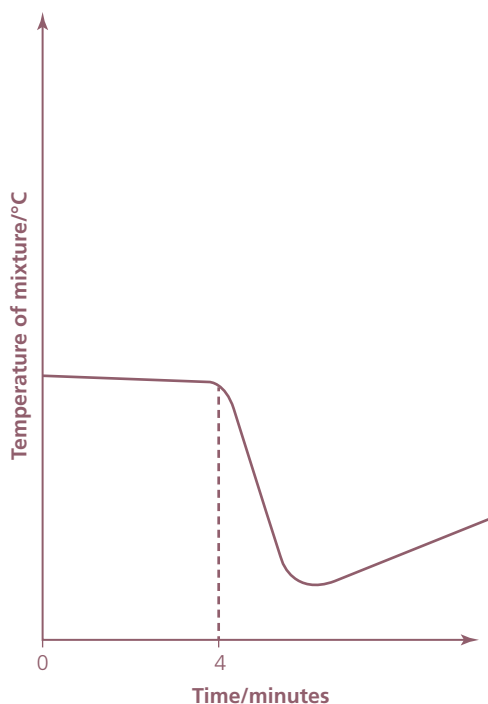
% error = $(0.5/50) \times 100\% = 1\%$

ii The HCl is in excess.

iii They could either decrease the volume of HCl used or increase the mass of Na_2CO_3 used.

h Horizontal line up to 4 minutes, then another line below it

The second line shows an increase in temperature (and doesn't reach the temperature of the first line).



i Use of 2×24.2

$$2 \times 24.2 - (-36.9) = (+)85.3 \text{ kJ mol}^{-1}$$

11 a $\text{Ag}^+(\text{aq}) + \text{Cl}^-(\text{aq}) \rightarrow \text{AgCl}(\text{s})$

b i Buchner funnel with filter paper ✓

Sealed to the top of the vacuum flask with a cork ✓

ii Increased rate of filtration/faster filtration

c i Warm/heat to a constant mass

ii

mass of crucible + dry silver chloride/g	24.898
mass of empty crucible/g	19.162
mass of dry silver chloride/g	5.736

$$(5.736/143.4 = 0.0400)$$

0.040

iii Number of moles of $\text{MCl}_2 = 0.0400/2 = 0.0200$

$$\text{Molar mass of } \text{MCl}_2 = 3.172/0.0200 = 158.6$$

$$A_r \text{ of M} = 158.6 - 71.0 = 87.6, \text{ so M} = \text{Sr}$$

158.6

Sr

iv It would increase because tap water contains chloride ions.