Chemical Equations: Titrations

Question Paper

Level	International A Level
Subject	Chemistry
Exam Board	Edexcel
Topic	Chemistry Lab Skills 1
Sub Topic	Chemical Equations: Titrations
Booklet	Question Paper

Time Allowed: **90 minutes**

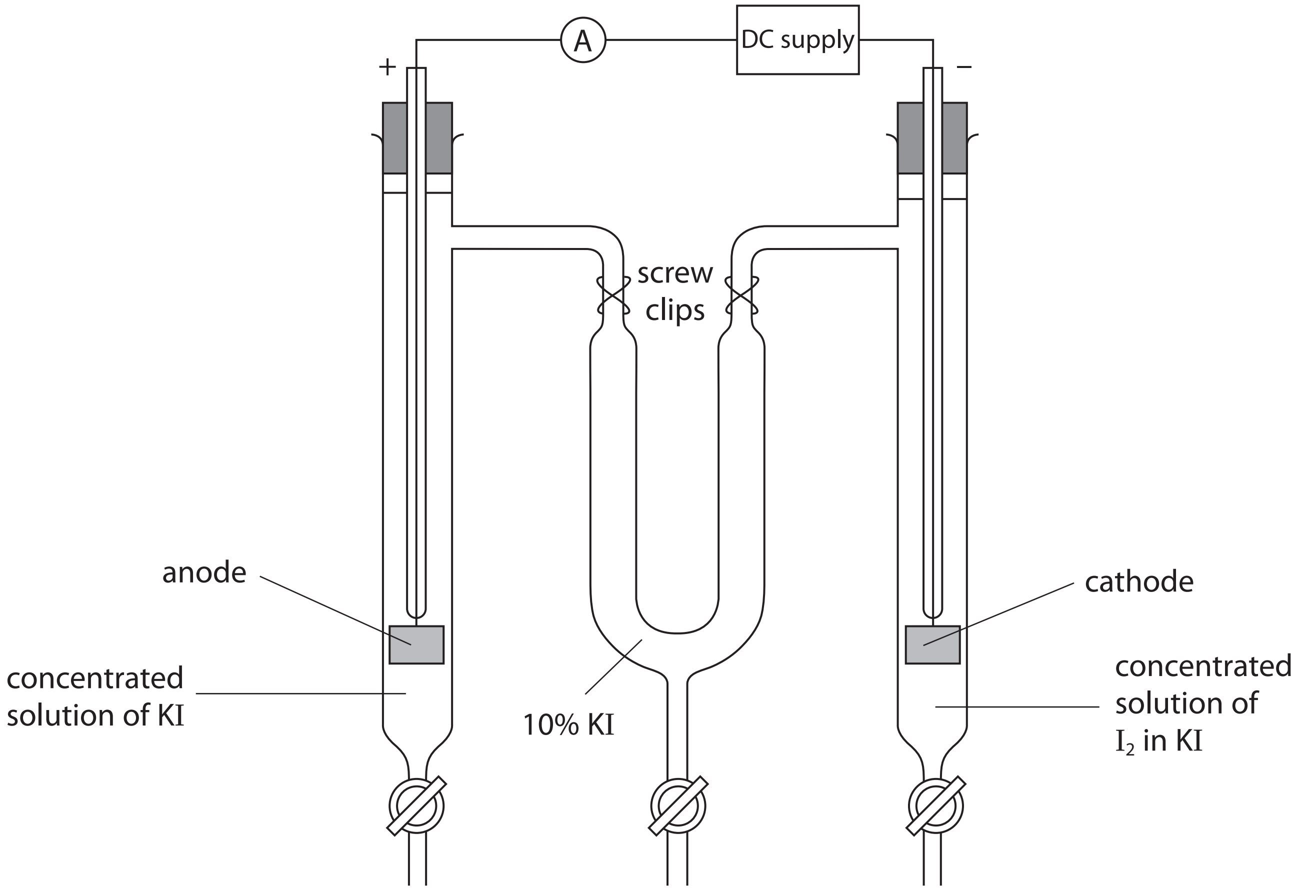
Score: **/76**

Percentage: **/100**

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	'77.5%	70%	62.5%	57.5%	45%	<45%

1 An iodine coulometer can be used to find the equation for the reaction between iodine and sodium thiosulfate.



An iodine coulometer

The DC supply is switched on for 15.0 minutes.

The constant current, measured by the ammeter, is 0.200 A.

The screw clips are closed, the left-hand bung is removed and the contents of the anode (positive electrode) tube are run into a 100 cm^3 volumetric flask. The tube and electrode are rinsed with a little distilled water and the washings added to the volumetric flask. The solution in the volumetric flask is made up to the mark with distilled water and mixed thoroughly.

10.0 cm^3 portions of the contents of the volumetric flask are now titrated with 0.0100 mol dm^{-3} sodium thiosulfate solution.

(a) (i) Name the indicator used for the titration, and give the colour change seen at the end-point.

(2)

Indicator ....

Colour change from .... to ....

(ii) State the appearance of the titration mixture just before the indicator is added.

(1)

....

....

(b) Calculate the number of moles of electrons transferred from the iodide ions to form iodine in the experiment. Use the expression

$$\text{number of moles of electrons} = \frac{\text{current (A)} \times \text{time (s)}}{96\,500}$$

(1)

(c) The total volume of solution in the volumetric flask is 100 cm^3.

10.0 cm^3 portions of the mixture are titrated with 0.0100 mol dm^{-3} sodium thiosulfate solution.

The results are given in the table below.

Titration number	1	2		
Second reading / cm^3	19.45	38.05	19.05	38.25
First reading / cm^3	0.00	19.45	0.00	19.55
Titre / cm^3				

(i) Complete the table.

(1)

(ii) Which result(s) should be discarded? Give a reason for your answer.

(2)

....

....

....

....

(iii) Calculate the mean titre for the remaining values.

(1)

(iv) Calculate the number of moles of thiosulfate ions in this mean titre.

(1)

(v) Calculate the number of moles of thiosulfate ions needed to react with the total amount of iodine in the 100 cm^3 of solution in the flask.

(1)

(d) (i) Complete the ionic half-equations for the oxidation of thiosulfate ions and the oxidation of iodide ions.

(2)

$2S_2O_3^{2-}(aq) \rightarrow S_4O_6^{2-}(aq)$

$2I^-(aq) \rightarrow I_2(aq)$

(ii) In part (b), you calculated the number of moles of electrons lost when the iodide ions are oxidised to form the amount of iodine in the flask.

In part (c)(v), you calculated the number of moles of thiosulfate ions required to reduce this iodine back to iodide ions.

Show that the results calculated from the two experiments are consistent with your ionic half-equations.

(1)

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(e) (i) The uncertainty in each burette reading is ±0.05 cm^3 and the uncertainty in the volume reading for the pipette is ±0.04 cm^3. Calculate the percentage uncertainties for the first burette titre and for the pipette volume of 10.0 cm^3.

(2)

Burette uncertainty = ... %

Pipette uncertainty = ... %

(ii) Explain whether these uncertainties are significant in this experiment.

(1)

....

....

(Total for Question 1 = 16 marks)

2 Washing soda is hydrated sodium carbonate, $Na_2CO_3.xH_2O$, where the number of moles of water of crystallization, x, can vary.

A sample of washing soda is analysed. Two methods are used to determine the value of x in the sample.

Method 1: Heating

2.50 g of the washing soda is placed in a crucible. The crucible is gently heated for three minutes and then heated strongly for five minutes. The mass of the solid after heating is 1.06 g.

$$Na_2CO_3.xH_2O(s) \rightarrow Na_2CO_3(s) + xH_2O(g)$$ **Equation 1**

(a) Suggest why the crucible is heated gently for the first three minutes.

(1)

....

....

(b) What additional step after heating strongly for five minutes is needed to make sure that all of the water of crystallization has been removed?

(1)

....

....

(c) What is the correct chemical term for sodium carbonate without water of crystallization?

(1)

....

(d) (i) Calculate the number of moles of sodium carbonate that remain after heating the sample, assuming that all of the water of crystallization has been removed.

(2)

(ii) Calculate the number of moles of water lost from the sample of washing soda on heating.

(1)

(iii) Hence deduce the value of x in the sample of washing soda, $Na_2CO_3.xH_2O$, obtained using Method 1.

(1)

x = ...

Method 2: Titration

Sodium carbonate reacts with hydrochloric acid as follows:

$$Na_2CO_3 + 2HCl \rightarrow 2NaCl + CO_2 + H_2O \qquad \textbf{Equation 2}$$

A 2.50 g sample of the washing soda is placed in a beaker and dissolved in deionized water. This solution is poured into a 250 cm^3 volumetric flask, made up to the mark and mixed thoroughly.

A pipette is then used to transfer 25.00 cm^3 of the washing soda solution to each of three conical flasks. A burette is filled with hydrochloric acid, of concentration 0.100 mol dm^{-3}, and titrations are carried out. The results are shown in the table.

Titration numbers	1	2	3
Burette reading (final) / cm^3	17.00	33.55	16.45
Burette reading (initial) / cm^3	0.00	17.00	0.00
Titre / cm^3	17.00	16.55	16.45

(e) What should be done to make sure that all of the washing soda is transferred to the volumetric flask?

(1)

....

....

(f) Explain why only titrations 2 and 3 are used to calculate the mean titre.

(1)

....

....

(g) (i) Calculate the mean titre, and then calculate the number of moles of hydrochloric acid in the mean titre.

(1)

(ii) Using your answer to part (g)(i) and **Equation 2**, calculate the number of moles of sodium carbonate present in 25 cm^3 of the washing soda solution.

(1)

(iii) Hence calculate the total number of moles of sodium carbonate present in 250 cm^3 of the washing soda solution.

(1)

(iv) Calculate the molar mass of the hydrated washing soda, $Na_2CO_3.xH_2O$. Hence deduce the value of x in the sample of washing soda from the data in Method 2.

(2)

x = ...

(h) A student carrying out Method 2 overshot the end-point of each titration.

Explain how this would affect the calculated value of x.

(2)

....

....

....

....

....

(Total for Question 2 = 16 marks)

3 A titration was carried out to find the relative molecular mass of a solid acid.
The formula of the acid can be written H_2A.

(a) 1.05 g of the acid was dissolved in water and the solution made up to 250 cm^3.

Name the piece of apparatus used for making a solution with volume exactly 250 cm^3.

(1)

....

(b) 25.0 cm^3 of the acid solution was pipetted into a conical flask and titrated with 0.100 mol dm^{-3} sodium hydroxide solution. This titration was repeated three times.

The equation for the reaction is shown below.

$$H_2A(aq) + 2NaOH(aq) \rightarrow Na_2A(aq) + 2H_2O(l)$$

(i) The indicator used in the titration was phenolphthalein. What colour change took place at the end point of the titration?

H_2A and its ions are colourless.

(2)

From .... to ....

(ii) The following results were recorded.

Titration number	1	2	3	4
Burette reading (final) /cm^3	23.60	46.90	24.35	47.65
Burette reading (initial) /cm^3	0.00	23.60	1.00	24.40
Volume of NaOH used /cm^3	23.60	23.30	23.35	23.25

Titration number 1 was a rangefinder, or rough titration.
Describe how you would use the rough titration value when carrying out the accurate titrations.

(1)

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....

(iii) The uncertainty in each burette reading was ± 0.05 cm^3.

Calculate the percentage uncertainty in titration number 2.

(1)

(iv) Calculate the mean titre for titration numbers 2, 3 and 4.

(1)

Mean titre = ... cm^3

(v) Calculate the number of moles of sodium hydroxide in the mean titre and hence calculate the number of moles of H_2A in the 25.0 cm^3 pipette samples.

(2)

(vi) Calculate the relative molecular mass of H_2A. You **must** show your working.

(2)

(c) The acid, H_2A, can be prepared by the oxidation of ethane-1,2-diol, $HOCH_2CH_2OH$.

(i) State the reagents and conditions needed for this oxidation reaction.

(2)

Reagents .... and ....

Conditions ....

(ii) What colour change would occur when the oxidation took place?

(1)

From .... to ....

(iii) Use the formula of ethane-1,2-diol to deduce the **displayed** formula of H_2A.

(1)

(Total for Question 3 = 14 marks)

4 (a) The concentrations of acids and alkalis can be found by titration using a suitable indicator.

Give the colours which are seen if the indicator phenolphthalein is used.

(2)

Colour in acid ....

Colour in alkali ....

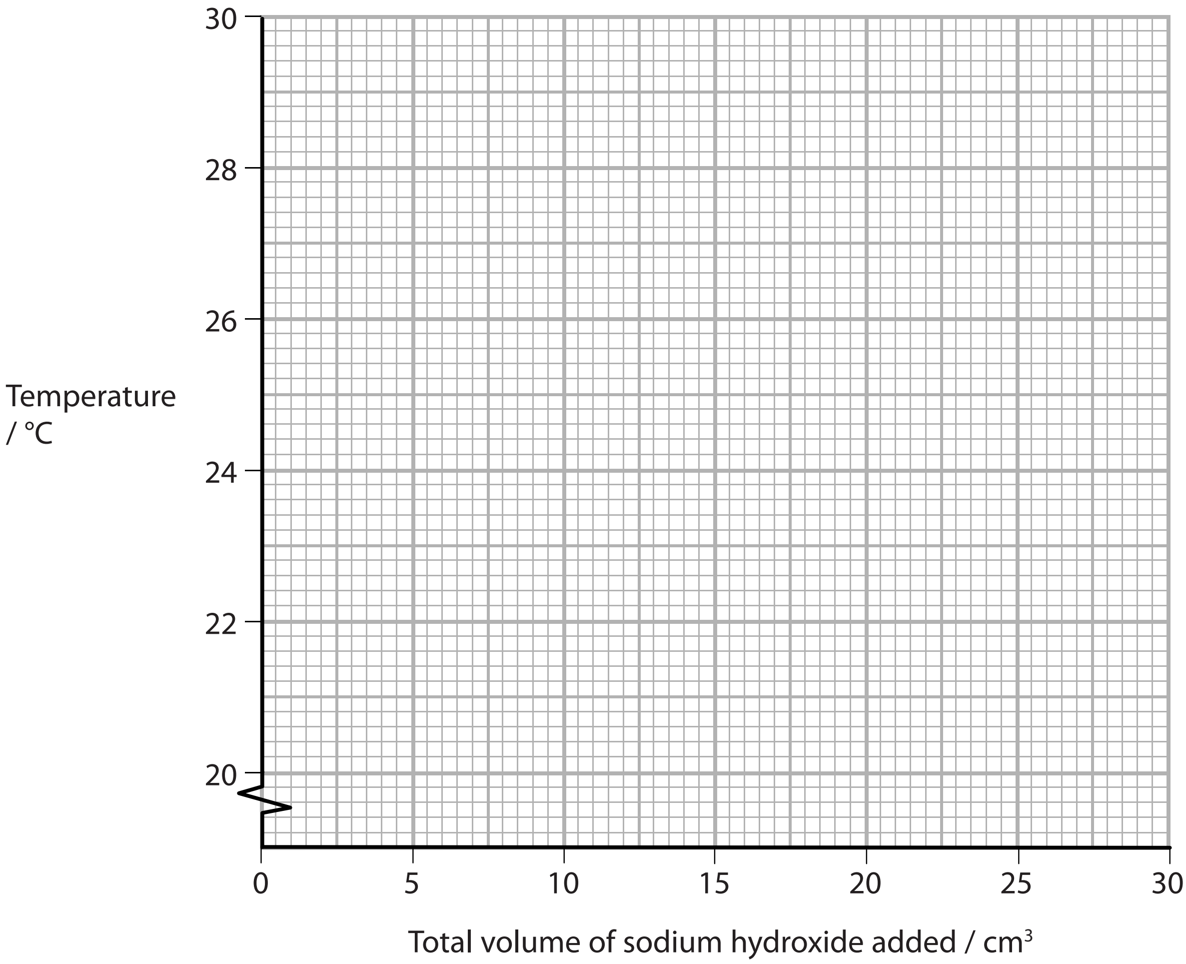
(b) Another type of titration is a **thermometric** titration.

In a thermometric titration, 20.0 cm^3 of 1.50 mol dm^{-3} hydrochloric acid was placed in a well-insulated cup, and its temperature was measured. Portions of sodium hydroxide solution were added from a burette. The mixture was stirred continuously and the temperature measured after each addition.

Total volume of sodium hydroxide added /cm^3	0.00	5.00	10.00	15.00	20.00	25.00	30.00
Temperature / °C	20.4	22.8	25.5	28.0	27.2	24.1	20.8

On the axes opposite, plot a graph of temperature against the total volume of sodium hydroxide added. Draw two straight lines on your graph and extrapolate the lines until they intersect. Hence find the maximum temperature of the reaction mixture and the total volume of sodium hydroxide which just neutralized the hydrochloric acid.

(4)



Maximum temperature ....

Total volume of sodium hydroxide that just neutralized the hydrochloric acid.

....

(c) In an experiment using a **different** sample of sodium hydroxide solution, 20.0 cm^3 of 1.50 mol dm^{-3} hydrochloric acid was neutralized by 15.50 cm^3 of sodium hydroxide solution. The starting temperature was 20.4°C and the temperature at neutralization was 30.6°C.

(i) Calculate the energy, in joules, transferred when the acid is just neutralized.

$$\underset{(J)}{\text{Energy transferred}} = \underset{(g)}{\text{total mass of solution}} \times \underset{(J\ g^{-1}\ {}^\circ C^{-1})}{4.18} \times \underset{({}^\circ C)}{\text{temperature rise}}$$

Assume that the density of the solution is 1 g cm^{-3}.

(1)

(ii) The number of moles of hydrochloric acid used was 3.00×10^{-2}.

Calculate the enthalpy change of the reaction, in kJ mol^{-1}, for the neutralization of one mole of hydrochloric acid.
Give your answer to **three** significant figures and include a sign.

(2)

ΔH = ... kJ mol^{-1}

(iii) Why is it important that the temperature readings are taken as quickly as possible?

(1)

....

....

(iv) Thermometric titrations can also be carried out using an electronic probe connected to a computer, instead of a thermometer.

The sodium hydroxide is run into the acid from the burette at a steady rate. The acid is in an insulated beaker with a magnetic stirrer. The computer then produces a plot of the results.

Explain why this modified method can give improved results, other than because of any increase in accuracy of the temperature readings by the electronic probe.

(2)

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(d) (i) Calculate the concentration, in mol dm^{-3}, of the sodium hydroxide used when 20.0 cm^3 of 1.50 mol dm^{-3} hydrochloric acid is neutralized by 15.50 cm^3 of sodium hydroxide.

(2)

(ii) Each time a burette is read, the error is ±0.05 cm^3.

Calculate the percentage error in using a burette to measure a volume of 5.00 cm^3 of sodium hydroxide.

(1)

(e) (i) When a titration is carried out using an indicator, the concentrations of acid and alkali are usually between 0.05 and 0.20 mol dm^{-3}.

Explain why more concentrated solutions are used in thermometric titrations.

(1)

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(ii) Sodium hydroxide is described as an irritant at concentrations less than 0.50 mol dm^{-3}.

In what way is more concentrated sodium hydroxide hazardous?

(1)

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(Total for Question 4 = 17 marks)

5 The mass of magnesium hydroxide, $Mg(OH)_2$, in an indigestion tablet was determined as follows:

Step 1 The tablet was crushed and dissolved in exactly 40.00 cm^3 of dilute hydrochloric acid (an excess).

Step 2 The amount of hydrochloric acid remaining was measured by titration with 0.250 mol dm^{-3} sodium hydroxide solution.

22.80 cm^3 of this sodium hydroxide solution was required.

$$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$$

(a) (i) A student suggested using Universal Indicator for the titration. Why would this indicator be unsuitable?

(1)

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....

(ii) Suggest a suitable indicator and give its colours in acidic and alkaline solutions.

(2)

Indicator ....

Colour in acid ....

Colour in alkali ....

(b) (i) Calculate the number of moles of sodium hydroxide used in the titration.

(1)

(ii) Hence state the number of moles of hydrochloric acid that react with the sodium hydroxide in (b)(i).

(1)

(iii) The amount of acid added to the tablet in **Step1** was 2.00×10^{-2} mol. Use this information and your answer to (b)(ii) to calculate the number of moles of hydrochloric acid that reacted with the tablet.

(1)

(iv) The equation for the reaction of the magnesium hydroxide in the tablet with hydrochloric acid is shown below.

$$Mg(OH)_2(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + 2H_2O(l)$$

Calculate the mass of magnesium hydroxide in the tablet. Give your answer to **three** significant figures.

The molar mass of magnesium hydroxide is 58.3 g mol^{-1}.

(2)

(c) The volume of hydrochloric acid added to the tablet was 40.00 cm^3.

(i) Suggest a change in the procedure which would make the result of the experiment **more reliable** for each tablet which is analysed.

(1)

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....

(ii) The hydrochloric acid was measured using a burette. Each time the burette was read, the error was ± 0.05 cm^3. Calculate the total percentage error in measuring 40.00 cm^3 of hydrochloric acid.

(2)

(d) When an indigestion tablet reacts with hydrochloric acid in the stomach, it is important that the reaction is not too exothermic.

The enthalpy change of this reaction can be determined by reacting magnesium hydroxide with an excess of hydrochloric acid in an insulated container and measuring the maximum temperature change.

State **two** ways, other than improvements in insulation or use of more accurate measuring instruments, which would ensure that the measured temperature change was the **maximum** possible for the amounts of reactants used.

(2)

1 ....

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2 ....

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(Total for Question 5 = 13 marks)