Direct titration calculations

AQA 7404 and 7405 · AS and A level

Show your working. Use the worked answers after you finish.

Name _____ Date _____

1. Use the repeat readings

A trainee records a rough titre of 23.60 cm^3. The subsequent titres are 23.30, 23.35, 23.80 and 23.40 cm^3.

Select the precise repeat results that are within 0.10 cm^3 of one another. Calculate their mean to two decimal places and explain why each other result was left out.

2. Sodium hydroxide solution

$HCl + NaOH \rightarrow NaCl + H_2O$. A 25.00 cm^3 sample of NaOH is neutralised by 22.40 cm^3 of 0.125 mol dm^{-3} HCl. Calculate the NaOH concentration in mol dm^{-3}.

3. Sulfuric acid solution

$H_2SO_4 + 2KOH \rightarrow K_2SO_4 + 2H_2O$. A 20.00 cm^3 portion of H_2SO_4 requires 24.80 cm^3 of 0.150 mol dm^{-3} KOH. Calculate the H_2SO_4 concentration in mol dm^{-3}.

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4. Predict the volume needed

Nitric acid neutralises calcium hydroxide to form calcium nitrate and water. Write the balanced symbol equation.

Calculate the volume in cm^3 of 0.0800 mol dm^{-3} HNO_3 needed to neutralise 25.0 cm^3 of 0.0160 mol dm^{-3} $Ca(OH)_2$.

5. Concentration from a standard solution

A student dissolves 1.325 g of pure Na_2CO_3 and makes the solution up to 250.0 cm^3. A 25.00 cm^3 portion requires 21.60 cm^3 of HCl.

$Na_2CO_3 + 2HCl \rightarrow 2NaCl + CO_2 + H_2O$. $M_r(Na_2CO_3) = 106.0$. Calculate the concentration of HCl.

6. The original acid

A 10.00 cm^3 sample of vinegar is diluted to 100.0 cm^3. A 25.00 cm^3 portion of the diluted vinegar needs 18.60 cm^3 of 0.1000 mol dm^{-3} NaOH.

Ethanoic acid reacts 1:1 with NaOH. Calculate the acid concentration in the original vinegar.

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7. Finding an unknown molar mass

A 0.4200 g sample of a pure diprotic acid is dissolved and made up to 100.0 cm^3. A 25.00 cm^3 portion requires 20.00 cm^3 of 0.1250 mol dm^{-3} NaOH.

$H_2A + 2NaOH \rightarrow Na_2A + 2H_2O$. Calculate the molar mass of H_2A.

8. A missed end point

Standard NaOH in a burette is used to find the concentration of 25.00 cm^3 of HCl. A student adds one drop beyond the end point and uses that titre.

State whether the calculated HCl concentration is too high, too low or unchanged. Explain your answer using the measurements and the amounts of substance.

9. Extra challenge · Investigate an impossible purity

25.00 cm^3 of 0.08000 mol dm^{-3} HCl requires 20.00 cm^3 of NaOH. That NaOH is then used to analyse a 0.690 g impure solid believed to contain a diprotic acid of molar mass 90.0 g mol^{-1} and an inert solid.

The sample is made up to 250.0 cm^3. A 25.00 cm^3 portion requires 16.00 cm^3 of NaOH. Calculate the apparent purity. Explain how leaving distilled water in the NaOH burette before the second titration could contribute to this result.

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Worked answers

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1. Use the repeat readings

Use 23.30, 23.35 and 23.40 cm^3. Their range is 0.10 cm^3. The rough titre was an initial estimate. The 23.80 cm^3 repeat lies outside the stated agreement range.

Mean = (23.30 + 23.35 + 23.40) ÷ 3 = 23.35 cm^3.

2. Sodium hydroxide solution

n(HCl) = 0.125 × 0.02240 = 0.002800 mol. The equation gives 0.002800 mol NaOH in the measured sample.

c(NaOH) = 0.002800 ÷ 0.02500 = 0.112 mol dm^{-3}.

3. Sulfuric acid solution

n(KOH) = 0.150 × 0.02480 = 0.003720 mol. The acid amount is half of this: 0.001860 mol.

c(H_2SO_4) = 0.001860 ÷ 0.02000 = 0.0930 mol dm^{-3}.

4. Predict the volume needed

$2HNO_3 + Ca(OH)_2 \rightarrow Ca(NO_3)_2 + 2H_2O$

n($Ca(OH)_2$) = 0.0160 × 0.0250 = 0.000400 mol. The 2:1 ratio gives 0.000800 mol HNO_3.

V = 0.000800 ÷ 0.0800 = 0.0100 dm^3 = 10.0 cm^3.

5. Concentration from a standard solution

The flask contains 1.325 ÷ 106.0 = 0.01250 mol of Na_2CO_3. The 25.00 cm^3 portion contains 0.001250 mol.

n(HCl) = 2 × 0.001250 = 0.002500 mol. c(HCl) = 0.002500 ÷ 0.02160 = 0.1157 mol dm^{-3}.

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Worked answers

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6. The original acid

n(NaOH) = 0.1000 × 0.01860 = 0.001860 mol. The same amount of acid is in 25.00 cm^3 of diluted vinegar.

c(diluted acid) = 0.001860 ÷ 0.02500 = 0.07440 mol dm^{-3}. The original was 10.00 times as concentrated, so c = 0.7440 mol dm^{-3}.

7. Finding an unknown molar mass

n(NaOH) = 0.1250 × 0.02000 = 0.002500 mol. The portion contains 0.002500 ÷ 2 = 0.001250 mol acid.

Total n(acid) = 4.000 × 0.001250 = 0.005000 mol. Molar mass = 0.4200 ÷ 0.005000 = 84.00 g mol^{-1}.

8. A missed end point

The titre is too large. The NaOH concentration is fixed, so cV gives too many moles of NaOH.

The equation ratio then gives too many moles of HCl. Dividing by the correct fixed acid volume gives an HCl concentration that is too high.

9. Extra challenge · Investigate an impossible purity

The first titre gives c(NaOH) = 0.08000 × 0.02500 ÷ 0.02000 = 0.1000 mol dm^{-3}. The second titre then appears to deliver 0.001600 mol NaOH. The diprotic acid reacts with two OH^- per molecule, so the portion appears to contain 0.0008000 mol acid.

The total appears to be 0.008000 mol and 0.720 g. Apparent purity = 0.720 ÷ 0.690 × 100 = 104%, which is impossible.

Water dilutes the NaOH after standardisation. A greater titre is needed for the same acid amount, so applying the original concentration overestimates the amount of acid.

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