Back titration

OCR A H432 · Full A-level

Show your working where needed. Check the worked answers when you finish.

Name _____ Date _____

1. Limestone purity

Only $CaCO_3$ in a 0.500 g sample reacts with 50.0 cm^3 of excess 0.200 mol dm^{-3} HCl. Leftover HCl needs 20.00 cm^3 of 0.100 mol dm^{-3} NaOH. Find the mass percentage of $CaCO_3$ (M_r = 100.09). One mole $CaCO_3$ uses two moles HCl.

2. Magnesium oxide content

Only MgO in a 1.00 g sample reacts with 50.0 cm^3 of excess 1.00 mol dm^{-3} HCl. Make up to 250.0 cm^3. A 25.0 cm^3 portion requires 12.80 cm^3 of 0.100 mol dm^{-3} NaOH. Find the mass percentage of MgO (M_r = 40.31). One mole MgO uses two moles HCl.

3. Calcium carbonate in an antacid

Three antacid tablets (mean mass 1.200 g) contain $CaCO_3$ and inert material. Add 75.0 cm^3 of excess 0.500 mol dm^{-3} HCl and make up to 250.0 cm^3. A 25.0 cm^3 portion needs 10.50 cm^3 of 0.100 mol dm^{-3} NaOH. For each mole of $CaCO_3$, 2 mol HCl react. Find the mean mass of $CaCO_3$ per tablet in mg and its mass percentage (M_r = 100.09).

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4. Identify a Group 2 metal

0.800 g of MCO_3 reacts with 50.0 cm^3 of excess 0.500 mol dm^{-3} HCl. Leftover acid needs 30.05 cm^3 of 0.300 mol dm^{-3} NaOH. One mole MCO_3 uses two moles HCl. Find $M_r(MCO_3)$ and identify M. A_r: Mg 24.31, Ca 40.08, Sr 87.62, Ba 137.33, C 12.01, O 16.00.

5. Concentration of a cleaner

Only Na_2CO_3 reacts in 25.0 cm^3 of cleaner. Add 50.0 cm^3 of excess 0.300 mol dm^{-3} HCl. The rest needs 25.00 cm^3 of 0.400 mol dm^{-3} NaOH. One mole Na_2CO_3 uses two moles HCl. Find the original concentration in mol dm^{-3} and g dm^{-3} (M_r = 105.99).

6. An oxide and excess sulfuric acid

Only ZnO in an 0.800 g sample reacts with 60.0 cm^3 of 0.200 mol dm^{-3} H_2SO_4. The rest uses 32.0 cm^3 of 0.250 mol dm^{-3} NaOH. H_2SO_4 reacts 1:1 with ZnO and 1:2 with NaOH. Find the mass percentage of ZnO (M_r = 81.38).

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7. Purity from a redox titration

0.800 g of impure Na_2SO_3 reacts with 50.0 cm^3 of excess 0.100 mol dm^{-3} I_2. Leftover I_2 takes 10.00 cm^3 of 0.100 mol dm^{-3} thiosulfate. Na_2SO_3 reacts 1:1 with I_2, which reacts 1:2 with thiosulfate. Find the mass percentage of Na_2SO_3 (M_r = 126.04).

8. Hydrogen peroxide by redox titration

25.0 cm^3 H_2O_2 reacts with 25.0 cm^3 of excess acidified 0.0400 mol dm^{-3} MnO_4^-. The rest needs 20.00 cm^3 of 0.100 mol dm^{-3} Fe^{2+}. MnO_4^- reacts 2:5 with H_2O_2 and 1:5 with Fe^{2+}. Find the H_2O_2 concentration in mol dm^{-3} and g dm^{-3} (M_r = 34.0).

9. Extra challenge · Recover a mass percentage from two reactions

Dissolve 2.50 g drink powder to make 100.0 cm^3. Add 25.0 cm^3 of excess 0.0500 mol dm^{-3} I_2 to a 20.0 cm^3 portion. Vitamin C reacts with I_2 in a 1:1 ratio. Leftover I_2 needs 14.40 cm^3 of 0.1000 mol dm^{-3} thiosulfate.

$I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$. Calculate the mass percentage of vitamin C (M_r = 176.12). How would oxidation by air before the iodine addition affect the result?

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Worked answers

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1. Limestone purity

The flask initially contains 0.0500 × 0.200 = 0.0100 mol HCl. From the titration, 0.02000 × 0.100 = 0.00200 mol remains.

0.0100 − 0.00200 = 0.00800 mol HCl reacted with the sample. This corresponds to 0.00400 mol $CaCO_3$.

Mass of $CaCO_3$ = 0.00400 × 100.09 = 0.40036 g. Percentage by mass = (0.40036 ÷ 0.500) × 100 = 80.1%.

2. Magnesium oxide content

Initially there is 0.0500 mol HCl. One portion contains 0.01280 × 0.100 = 0.001280 mol HCl, so the whole flask contains 0.01280 mol unreacted HCl.

0.0500 − 0.01280 = 0.03720 mol HCl reacted. The 2:1 acid-to-oxide ratio gives 0.01860 mol MgO.

Mass of MgO = 0.01860 × 40.31 = 0.749766 g. The percentage is 75.0% to three significant figures.

3. Calcium carbonate in an antacid

Initial HCl = 0.03750 mol. The portion contains 0.01050 × 0.100 = 0.001050 mol excess HCl. The full flask therefore contains 0.01050 mol excess HCl.

HCl reacting with $CaCO_3$ = 0.03750 − 0.01050 = 0.02700 mol. The carbonate amount is 0.01350 mol, or 1.351215 g in all three tablets.

Mean = (1.351215 ÷ 3) × 1000 = 4.50×10^2 mg to three significant figures. The percentage is (1.351215 ÷ 3.600) × 100 = 37.5%.

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Worked answers

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4. Identify a Group 2 metal

HCl added = 0.02500 mol and HCl left = 0.03005 × 0.300 = 0.009015 mol. The acid that reacted is 0.015985 mol.

The carbonate amount is half of this, 0.0079925 mol. $M_r(MCO_3)$ = 0.800 ÷ 0.0079925 = 100.1…

Subtract 12.01 + 3 × 16.00 to estimate A_r(M) at 40.1. This matches calcium most closely.

5. Concentration of a cleaner

HCl added = 0.0150 mol. Remaining HCl = 0.0100 mol. The Na_2CO_3 used up 0.00500 mol of HCl.

The equation gives 0.00250 mol Na_2CO_3 in 25.0 cm^3. The molar concentration is 0.00250 ÷ 0.0250 = 0.100 mol dm^{-3}.

Mass concentration = 0.100 × 105.99 = 10.6 g dm^{-3}.

6. An oxide and excess sulfuric acid

H_2SO_4 added = 0.0120 mol. NaOH = 0.00800 mol, so excess H_2SO_4 = 0.00400 mol. Acid reacting with ZnO = 0.00800 mol.

The ZnO amount is 0.00800 mol. Mass = 0.00800 × 81.38 = 0.65104 g. The sample is 81.4% ZnO by mass.

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Worked answers

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7. Purity from a redox titration

Initial I_2 = 0.00500 mol. Thiosulfate used = 0.00100 mol. The second equation shows that 0.000500 mol I_2 remained.

The sulfite used 0.00500 − 0.000500 = 0.00450 mol I_2. From the first equation the original sample contained 0.00450 mol Na_2SO_3.

The mass of Na_2SO_3 is 0.00450 × 126.04 = 0.56718 g, giving (0.56718 ÷ 0.800) × 100 = 70.9%.

8. Hydrogen peroxide by redox titration

MnO_4^- added = 0.00100 mol. The titre contains 0.00200 mol Fe^{2+}, equivalent to 0.000400 mol unreacted MnO_4^-.

MnO_4^- reacting with the peroxide = 0.000600 mol. The first equation gives 0.000600 × (5 ÷ 2) = 0.00150 mol H_2O_2 in 25.0 cm^3.

Concentration = 0.00150 ÷ 0.0250 = 0.0600 mol dm^{-3}. Mass concentration = 0.0600 × 34.0 = 2.04 g dm^{-3}.

9. Extra challenge · Recover a mass percentage from two reactions

Iodine added = 0.001250 mol. Thiosulfate = 0.001440 mol, so iodine remaining = 0.000720 mol. Vitamin C in the portion consumes 0.001250 − 0.000720 = 0.000530 mol iodine.

Vitamin C in the 100.0 cm^3 is 5 × 0.000530 = 0.00265 mol, equivalent to 0.4667 g. Percentage by mass = 100 × 0.4667/2.50 = 18.7%.

Oxidation before the iodine addition leaves less vitamin C to react with iodine. More iodine remains, so the calculated amount and percentage of vitamin C are too low.

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