Answers and Worked Solutions

Compare the sequence: amount in moles -> mole ratio -> required quantity.

Set A Solutions

1. Limiting reagent, gas volume and yield

n(Mg) = 0.623/24.31 = 0.02563 mol. n(HCl) = 1.25 x 27.3/1000 = 0.03413 mol. Complete reaction of Mg would need 0.05126 mol HCl, so HCl is limiting. n(H_2) = 0.03413/2 = 0.01706 mol. V = nRT/P = 3.873 x 10^{-4} m^3 = 387 cm^3. Percentage yield = 342/387.3 x 100 = **88.3%**.

2. Acid-base titration

n(HCl) = 0.100 x 23.65/1000 = 2.365 x 10^{-3} mol. The ratio is 1:1, so n(NaOH) is the same. c(NaOH) = 2.365 x 10^{-3}/(25.00/1000) = **0.0946 mol dm^{-3}**.

3. Back titration and percentage by mass

Initial HCl = 0.0500 mol. HCl left in 10.0 cm^3 = 0.001140 mol, so 0.01140 mol remains in 100 cm^3. HCl reacted = 0.03860 mol. n($CaCO_3$) = 0.01930 mol; mass = 1.932 g. Percentage = 1.932/2.016 x 100 = **95.8%**.

4. Water of crystallisation

In 20.0 cm^3, n(NaOH) = 0.001968 mol, so n(oxalic acid) = 0.000984 mol. The full solution contains 0.009840 mol. M(crystals) = 12.402/0.009840 = 126.0 g mol^{-1}. 90.04 + 18.02x = 126.0, so **x = 2**.

5. Atom economy

Total product mass = 2(55.85) + [2(26.98) + 3(16.00)] = 213.66 g. Desired Fe mass = 111.70 g. Atom economy = 111.70/213.66 x 100 = **52.3%**.

Set B Solutions

1. Limiting reagent, gas volume and yield

n(Zn) = 1.31/65.38 = 0.0200 mol. n(HCl) = 0.0360 mol. Zinc would need about 0.0401 mol HCl, so HCl is limiting. $n(H_2)$ = 0.0180 mol. V = 4.460×10^{-4} m^3 = 446 cm^3. Yield = 410/446.0 x 100 = **91.9%**.

2. Acid-base titration

n(NaOH) = 0.150 x 18.40/1000 = 0.002760 mol. $n(H_2SO_4)$ = 0.001380 mol. c = 0.001380/(20.00/1000) = **0.0690 mol dm^{-3}**.

3. Back titration and percentage by mass

Initial HCl = 0.0250 mol. The 25.0 cm^3 portion contains 0.001260 mol excess HCl, so the full solution contains 0.01260 mol. HCl reacted = 0.01240 mol. $n(CaCO_3)$ = 0.006200 mol; mass = 0.6206 g. Percentage = **95.5%**.

4. Water of crystallisation

The aliquot contains 0.002500 mol NaOH, so 0.001250 mol oxalic acid. The full solution contains 0.007500 mol. M = 9.453/0.007500 = 126.0 g mol^{-1}. Therefore **x = 2**.

5. Atom economy

M(CaO) = 56.08 and $M(CaCO_3)$ = 100.09. Atom economy = 56.08/100.09 x 100 = **56.0%**.

Set C Solutions

1. Limiting reagent, gas volume and yield

n(Al) = 0.540/26.98 = 0.0200 mol. n(HCl) = 0.0480 mol. Aluminium would need 0.0600 mol HCl, so HCl is limiting. n(H_2) = 0.0240 mol. V = 5.568 x 10^{-4} m^3 = 557 cm^3. Yield = 525/556.8 x 100 = **94.3%**.

2. Acid-base titration

n(NaOH) = 0.200 x 24.80/1000 = 0.004960 mol. n(H_2SO_4) = 0.002480 mol. c = 0.002480/(25.00/1000) = **0.0992 mol dm^{-3}**.

3. Back titration and percentage by mass

Initial HCl = 0.0320 mol. Excess HCl in the full solution = 0.01420 mol. HCl reacted = 0.01780 mol. n($MgCO_3$) = 0.008900 mol; mass = 0.750 g. Percentage = 0.750/1.20 x 100 = **62.5%**.

4. Water of crystallisation

The aliquot contains 0.002500 mol NaOH and 0.001250 mol oxalic acid. The full solution contains 0.01250 mol. M = 15.755/0.01250 = 126.0 g mol^{-1}, so **x = 2**.

5. Atom economy

Mass of 2 mol $KClO_3$ = 245.10 g. Mass of 3 mol O_2 = 96.00 g. Atom economy = 96.00/245.10 x 100 = **39.2%**.

Set D Solutions

1. Limiting reagent, gas volume and yield

n(Fe) = 1.12/55.85 = 0.02005 mol. n(HCl) = 0.0450 mol. Iron needs 0.0401 mol HCl, so Fe is limiting. n(H_2) = 0.02005 mol. V = 5.067×10^{-4} m^3 = 507 cm^3. Yield = 465/506.7 x 100 = **91.8%**.

2. Acid-base titration

n(Na_2CO_3) = 0.100 x 16.80/1000 = 0.001680 mol. n(HCl) = 0.003360 mol. c(HCl) = 0.003360/(20.00/1000) = **0.168 mol dm^{-3}**.

3. Back titration and percentage by mass

Initial HCl = 0.0300 mol. Excess HCl in the full solution = 0.00800 mol. HCl reacted = 0.02200 mol. n($CaCO_3$) = 0.01100 mol; mass = 1.101 g. Percentage = 1.101/1.50 x 100 = **73.4%**.

4. Water of crystallisation

The aliquot contains 0.002000 mol NaOH and 0.001000 mol oxalic acid. The full solution contains 0.01000 mol. M = 10.802/0.01000 = 108.02 g mol^{-1}. 90.04 + 18.02x = 108.02, so **x = 1**.

5. Atom economy

Reactant mass = 168.02 g. Desired Na_2CO_3 mass = 105.99 g. Atom economy = 105.99/168.02 x 100 = **63.1%**.