

- $2\text{CaCO}_3(\text{s}) + 2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{CaSO}_4(\text{s}) + 2\text{CO}_2(\text{g})$   
 No. of moles of  $\text{SO}_2 = 256 \times 10^6 / 64 = 4 \times 10^6$  mols  
 From the equation, 1 mol of  $\text{SO}_2$  requires 1 mol of  $\text{CaCO}_3$   
 Hence,  $4 \times 10^6$  mols of  $\text{SO}_2$  requires  $4 \times 10^6$  mols of  $\text{CaCO}_3$   
 Mass of  $\text{CaCO}_3 = 4 \times 10^6$  mols  $\times 100 = 400 \times 10^6$  g = 400 tonnes. (3 s.f.)
- $\text{N}_x\text{O}_y \rightarrow \text{NO} + \text{O}_2$   
 Vol ratio: 100 : 100 : 50  
 Mole ratio: 2 : 2 : 1  
 Hence, equation becomes  $2\text{N}_x\text{O}_y \rightarrow 2\text{NO} + \text{O}_2$   
 Comparing the number of atoms of O and N on both sides,  
 $X = 1$  and  $y = 2$   
 The molecular formula of this gaseous oxide of nitrogen is  $\text{NO}_2$   
 To check, rewrite the equation:  $2\text{NO}_2 \rightarrow 2\text{NO} + \text{O}_2$  which is balanced.
- No. of moles of  $\text{NaOH} = 10/1000 \times 5.00 = 0.0500$  mol  
 Let the volume of water added be  $V \text{ cm}^3$   
 New volume is  $(V+10) \text{ cm}^3$ .  
 Concentration in  $\text{mol/dm}^3 = \text{no. of mole} / \text{volume in dm}^3$   
 $0.5 \text{ mol/dm}^3 = \frac{0.05}{\frac{V+10}{1000}}$   
 $V = 90.0 \text{ cm}^3$  (3 s.f.)
- (a) No. of moles of gas =  $12/24 = 0.500$  mol.  
 (b) From equation, 5 mols of gases requires 2 mols of metal nitrate  
 Hence, 0.500 mol of gases requires  $0.5/5 \times 2 = 0.200$  mol metal nitrate. (3 s.f.)  
 (c) 0.200 mol of metal nitrate = 37.8g  
 1 mol of metal nitrate =  $37.8/0.200 = 189$ g  
 Formula mass of the metal nitrate = 189g (3 s.f.)  
 (d) Let the mass of X be  $m$  g.  
 $m + 2 \times (14 + 16 \times 3) = 189$   
 $m = 65$       The atomic mass of metal X = 65
- (a)  $\text{K}_2\text{CO}_3 + 2\text{HCl} \rightarrow 2\text{KCl} + \text{H}_2\text{O} + \text{CO}_2$   
 (b) No. of moles of  $\text{HCl} = 34.2/1000 \times 2.00 = 0.0684$   
 From equation, 2 mols of acid reacts with 1 mol of  $\text{K}_2\text{CO}_3$   
 Hence, 0.0684 mol of acid reacts  $0.0684/2 = 0.0342$  mol of  $\text{K}_2\text{CO}_3$   
 Mass of carbonate reacted =  $0.0342 \times (39 \times 2 + 12 + 16 \times 3) = 4.7196 = 4.72$ g  
 % purity =  $4.7196/5 \times 100 = 94.392 = 94.4$ g (3 s.g.)
- Mass of S =  $0.032 \times 100 = 3.20$ g (3 s.f.)  
 No. of moles of S =  $3.2/32 = 0.100$  mol.  
 No. of moles of  $\text{FeS}$  formed = 0.100 mol.  
 Hence the mass of  $\text{FeS} = 0.100 \times (56 + 32) = 8.80$ g (3 s.f.)
- (a) No. of moles of acid =  $10/1000 \times 2.0 = 0.0200$  mol (3 s.f.)  
 (b) From the equation, 1 mol of acid produces 1 mol of  $\text{ZnSO}_4$   
 Hence, 0.0200 mol of acid produces 0.0200 mol of  $\text{ZnSO}_4$   
 Mass of zinc sulfate =  $0.0200 \times (65 + 32 + 16 \times 4) = 3.22$ g
- In reacting gases, mol ratio = vol ratio  
 $100 \text{ cm}^3$  of ethane requires  $300 \text{ cm}^3$  of oxygen.  
 Since oxygen makes up 20% of air, the vol of air needed =  $300 \times 5 = 1.5 \text{ dm}^3$

9.

	C	S
	15.8%	84.2%
Mass in 100g of compound	15.8g	84.2g
No. of mol	$\frac{15.8}{12} = 1.3167$	$\frac{84.2}{32} = 2.63125$
Mole ratio	$\frac{1.3167}{1.3167} = 1$	$\frac{2.63125}{1.3167} = 1.998 \approx 2$

Hence, empirical formula = CS<sub>2</sub>

Empirical mass x n = molecular mass

$$(12 + 32 \times 2) \times n = 76$$

$$n = 1$$

Molecular formula = CS<sub>2</sub>

10. (a) No. of moles of HCl =  $20/1000 \times 0.1 = 0.00200$  mol (3 s.f.)  
 (b) From equation, 2 mols HCl reacts with 1 mol Zn,  
 Hence, 0.002 mol HCl reacts with 0.001 mol Zn  
 Mass of Zn =  $0.001 \times 65 = 0.0650$ g (3 s.f.)  
 (c) From equation, 2 mols HCl produces with 1 mol H<sub>2</sub>,  
 Hence, 0.002 mol HCl produces with 0.00100 mol H<sub>2</sub> (3 s.f.)  
 (d) Vol. of hydrogen =  $0.001 \times 24000 = 24.0$  cm<sup>3</sup> (3 s.f.)
11. (a) No. of mol of Pb =  $62.1/207 = 0.3$  mol.  
 3 mols of Pb needed 1 mol of Pb<sub>3</sub>O<sub>4</sub>  
 Hence, 0.3 mols of Pb needed 0.1 mol of Pb<sub>3</sub>O<sub>4</sub>  
 Mass of 0.1 mol of Pb<sub>3</sub>O<sub>4</sub> =  $0.1 \times (207 \times 3 + 16 \times 4) = 68.5$ g  
 (b) 3 mols of Pb needed 4 mol of CO  
 Hence, 0.3 mols of Pb needed 0.4 mol of CO  
 Mass of 0.1 mol of CO =  $0.4 \times 24$  dm<sup>3</sup> = 9.60 dm<sup>3</sup> (3 s.f.)
12. (a) No. of moles of acid =  $196/98 = 2.00$  mol  
 (b) 72dm<sup>3</sup> of hydrogen =  $72/24 = 3.00$  mol  
 (c) 2H<sub>n</sub>X → 3H<sub>2</sub>  
 By comparing both sides, 2n = 6, so n = 3  
 So there are 3 hydrogen atoms per molecular of acid.
13. (a)  $3.65/0.2 = 18.25 = 18.3$ g/dm<sup>3</sup> (3 s.f.)  
 (b)  $18.25 / 36.5 = 0.500$  mol/dm<sup>3</sup>

14.

	N	O
	30.43%	69.57%
Mass in 100g of compound	30.43g	69.57g
No. of mol	$\frac{30.43}{14} = 2.17357$	$\frac{69.57}{16} = 4.348125$
Mole ratio	$\frac{2.17357}{2.17357} = 1$	$\frac{4.348125}{2.17357} = 2$

Hence, empirical formula = NO<sub>2</sub>

Empirical mass x n = molecular mass

$$(14 + 16 \times 2) \times n = 92$$

$$n = 2$$

Molecular formula = N<sub>2</sub>O<sub>4</sub>

15. Mr of  $\text{Mg}(\text{NO}_3)_2 = 24 + 2 \times (14 + 16 \times 3) = 148$   
 Mr of  $\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O} = 148 + 6 \times (2 + 16) = 256$   
 percentage by mass of the anhydrous salt =  $148/256 \times 100\% = 57.8125 = 57.8\%$  (3 s.f.)
16.  $2\text{HCl}(\text{aq}) + \text{Zn}(\text{s}) \rightarrow \text{ZnCl}_2(\text{aq}) + \text{H}_2(\text{g})$   
 No. of mole of acid =  $0.5 \times 0.25 = 0.125$  mol  
 0.125 mol HCl reacts with  $0.125/2 = 0.0625$  mol of Zn  
 Hence, maximum mass of zinc dissolved =  $0.0625 \times 65 = 4.0625 = 4.06\text{g}$
17. (a) No. of moles of  $\text{Na}_2\text{S}$  used =  $1.56/(23 \times 2 + 32) = 0.0200$  mol  
 No. of moles of  $\text{H}_2\text{S}$  evolved =  $480/24000 = 0.0200$  mol  
 (b)  $\text{Na}_2\text{S} + 2\text{HCl} \rightarrow 2\text{NaCl} + \text{H}_2\text{S}$
18. (a)  $\text{PbCO}_3 + 2\text{HNO}_3 \rightarrow \text{Pb}(\text{NO}_3)_2 + \text{H}_2\text{O} + \text{CO}_2$   
 (b) bright yellow (colour of  $\text{PbI}_2$ )  
 (c)  $\text{Pb}^{2+}(\text{aq}) + 2\text{I}^{-}(\text{aq}) \rightarrow \text{PbI}_2(\text{s})$   
 (d) Mr of  $\text{PbI}_2 = 207 + 2 \times 127 = 461$   
 (e) 461g of  $\text{PbI}_2$  contains 207g of Pb  
 1.48g of  $\text{PbI}_2$  contains  $1.48/461 \times 207\text{g} = 0.664555\text{g} = 0.665\text{g}$  of Pb (3 s.f.)  
 (f) % of lead in the ore =  $0.665/6.61 \times 100 = 10.0537 = 10.1\%$
19. (a)  $2\text{NH}_3 + 3\text{CuO} \rightarrow 3\text{Cu} + \text{N}_2 + 3\text{H}_2\text{O}$   
 (b) No. of moles of ammonia gas =  $6/24 = 0.250$  mol  
 (c) 2 mols of  $\text{NH}_3$  produces 3 moles of Cu  
 0.25 mol of  $\text{NH}_3$  produced  $0.25/2 \times 3 = 0.375$  mol of Cu  
 Mass of Cu =  $0.375 \times 64 = 24.0\text{g}$
20. (a) Mr of  $\text{HNO}_3 = 63$   
 Concentration of acid =  $6.9\text{g}/\text{dm}^3 \div 63 = 0.1095238 = 0.110$  mol/ $\text{dm}^3$  (3 s.f.)  
 (b)  $\frac{M_a V_a}{M_b V_b} = \frac{n_a}{n_b}$   
 $\frac{0.1095238 \times 50}{M_b \times 40} = \frac{1}{1}$   
 $M_b = 0.1369 = 0.137$  mol/ $\text{dm}^3$  (3 s.f.)  
 (c) Since  $\frac{\text{concentration in g}/\text{dm}^3}{\text{relative molecular mass}} = \text{concentration in mol}/\text{dm}^3$ ,  
 $\frac{7.67 \text{ g}/\text{dm}^3}{\text{relative molecular mass}} = 0.1369 \text{ mol}/\text{dm}^3$   
 Relative molecular mass = 56.0  
 (d) Let relative atomic mass of X be  $m_x$ .  
 $m_x + 16 + 1 = 56$   
 $m_x = 39$  X is potassium (since it is in Group I and has mass of 39)
21.  $\text{C}_2\text{H}_4 + \text{H}_2\text{O} \rightarrow \text{C}_2\text{H}_5\text{OH}$   
 280g of  $\text{C}_2\text{H}_4 = 280/28 = 10$  mol  
 From the equation, 1 mol of  $\text{C}_2\text{H}_4$  produces 1 mol of  $\text{C}_2\text{H}_5\text{OH}$   
 Hence, 10 mol of  $\text{C}_2\text{H}_4$  produces 10 mol of  $\text{C}_2\text{H}_5\text{OH}$   
 Mass of ethanol produced =  $10 \times (2 \times 12 + 5 + 16 + 1) = 460\text{g}$

22. (a)  $\text{C}_2\text{H}_5\text{OH}_{(l)} + 3\text{O}_{2(g)} \rightarrow 2\text{CO}_{2(g)} + 3\text{H}_2\text{O}_{(g)}$   
 (b)  $138\text{g ethanol} = 138/46 = 3 \text{ mols}$   
 From equation, 1 mol of ethanol produces 3 mols of water.  
 Hence, 3 mols of ethanol will produce 9 mols of water.  
 Mass of water produced =  $9 \times 18 = 162\text{g}$   
 (c)  $69\text{g ethanol} = 69/46 = 1.5 \text{ mols}$   
 From equation, 1 mol of ethanol requires 3 mols of oxygen gas.  
 Hence, 1.5 mols of ethanol will require 4.5 mols of oxygen.  
 Volume of oxygen needed =  $4.5 \times 24 = 108 \text{ g}$ .
23. (a)  $\text{CuSO}_4 + 2\text{NaOH} \rightarrow \text{Cu}(\text{OH})_2 + \text{Na}_2\text{SO}_4$   
 From the equation, 1 mol of  $\text{Cu}(\text{OH})_2$  needed 2 mols of NaOH  
 (b)  $3.2\text{g of copper (II) sulfate} = 3.2/160 = 0.02 \text{ mol}$   
 0.02 mol of  $\text{CuSO}_4$  will produce 0.02 mol of  $\text{Cu}(\text{OH})_2$   
 Mass of  $\text{Cu}(\text{OH})_2$  produced =  $0.02 \times (64+16 \times 2+1 \times 2) = 1.96\text{g}$
24.  $\text{Na}_2\text{CO}_3 + 2\text{HCl} \rightarrow 2\text{NaCl} + \text{H}_2\text{O} + \text{CO}_2$   
 $200 \text{ cm}^3 \text{ of CO}_2 = 200/24000 = 8.33 \times 10^{-3} \text{ mol}$   
 From equation, 1 mol of  $\text{CO}_2$  needs 1 mol of  $\text{Na}_2\text{CO}_3$   
 $8.33 \times 10^{-3} \text{ mol of CO}_2$  needs  $8.33 \times 10^{-3} \text{ mol of Na}_2\text{CO}_3$   
 Mass of  $\text{Na}_2\text{CO}_3$  needed =  $8.33 \times 10^{-3} \times (23 \times 2 + 12 + 16 \times 3) = 0.883333 = 0.883\text{g}$  (3 s.f.)
25.  $\text{Pb}(\text{NO}_3)_{2(aq)} + 2\text{HCl}_{(aq)} \rightarrow \text{PbCl}_{2(s)} + 2\text{HNO}_{3(aq)}$   
 No. of mol of  $\text{Pb}(\text{NO}_3)_2 = 6.62 / (207 + 14 \times 2 + 16 \times 6) = 0.02$   
 From equation, 1 mol of  $\text{Pb}(\text{NO}_3)_2$  produces 1 mol  $\text{PbCl}_2$   
 Hence, 0.02 mol of  $\text{Pb}(\text{NO}_3)_2$  produces 0.02 mol  $\text{PbCl}_2$   
 Mass of  $\text{PbCl}_2$  produced =  $0.02 \times (207 + 35.5 \times 2) = 5.56\text{g}$   
 $\% \text{ yield} = \frac{5.00}{5.56} \times 100\% = 89.928 = 89.9\%$  (3 s.f.)
26. (a)  $0.05 \text{ dm}^3 \times 0.2 \text{ mol/dm}^3 = 0.01 \text{ mol}$   
 Mass of  $\text{Na}_2\text{CO}_3 = 0.01 \times (23 \times 2 + 12 + 16 \times 3) = 1.06\text{g}$   
 (b)  $2.50 \text{ dm}^3 \times 0.200 \text{ mol/dm}^3 = 0.500 \text{ mol}$   
 Mass of  $\text{NaHCO}_3 = 0.5 \times (23 + 1 + 12 + 16 \times 3) = 42.0\text{g}$
27. No. of moles of  $\text{Ca}(\text{OH})_2 = 17.7/1000 \text{ dm}^3 \times 0.0300 \text{ mol/dm}^3 = 5.841 \times 10^{-4} \text{ mol}$   
 1 mol of  $\text{Ca}(\text{OH})_2$  contains 1 mol  $\text{Ca}^{2+}$  ions and 2 mols  $\text{OH}^-$  ions.  
 (a) No. of moles of  $\text{Ca}^{2+}$  ions =  $5.84 \times 10^{-4} \text{ mol}$   
 (b) No. of moles of  $\text{OH}^-$  ions =  $2 \times 5.841 \times 10^{-4} \text{ mol} = 1.1682 \times 10^{-3} = 1.17 \times 10^{-3} \text{ mol}$
28.  $\text{H}_3\text{AsO}_4 + 3\text{NaOH} \rightarrow \text{Na}_3\text{AsO}_4 + 3\text{H}_2\text{O}$   
 $\frac{M_a V_a}{M_b V_b} = \frac{n_a}{n_b}$   
 $\frac{M_a \times 25.0}{0.100 \times 35.7} = \frac{1}{3}$   
 $M_a = 0.0476 \text{ mol/dm}^3$  (3 s.f.)
29.  $\text{H}_2\text{SO}_4 + 2\text{OH}^- \rightarrow \text{SO}_4^{2-} + 2\text{H}_2\text{O}$   
 $\frac{M_a V_a}{M_b V_b} = \frac{n_a}{n_b}$   
 $\frac{0.114 \times 21.9}{M_b \times 25.0} = \frac{1}{2}$   
 $M_a = 0.199728 = 0.200 \text{ mol/dm}^3$  (3 s.f.)  
 Since the original solution has been diluted 10 times, the concentration of the original solution would be  $20.0 \text{ mol/dm}^3$



$$\frac{M_a V_a}{M_b V_b} = \frac{n_a}{n_b}$$

$$\frac{M_a \times 10.0}{0.194 \times 21.6} = 1$$

$$M_a = 0.41904 = 0.419 \text{ mol/dm}^3 \text{ (3 s.f.)}$$

$$\begin{aligned} \text{Concentration of original concentrated solution} &= 250/10 \times 0.41904 \\ &= 10.476 = 10.5 \text{ mol/dm}^3 \end{aligned}$$



$$\text{No. of moles of NaCl} = 0.25 \times V = 0.25V \text{ mol}$$

$$\text{No. of moles of NaOH} = 0.25 \times V = 0.25V \text{ mol}$$

$$\text{Total volume of the mixture} = V + V = 2V \text{ dm}^3$$

(a) Concentration of sodium ions =  $\frac{0.25V + 0.25V}{2V} = 0.25 \text{ mol/dm}^3$

(b) Concentration of chloride ions =  $\frac{0.25V}{2V} = 0.125 \text{ mol/dm}^3$

(c) Concentration of hydroxide ions =  $\frac{0.25V}{2V} = 0.125 \text{ mol/dm}^3$



Hence, 1 mole of X reacts with 1 mole of sodium hydroxide

*{Before you can use formula to find concentration of acid, you need to convert concentration of sodium hydroxide to mol/dm<sup>3</sup>.}*

$$\text{Concentration of NaOH} = 8/40 = 0.200 \text{ mol/dm}^3$$

$$\frac{M_a V_a}{M_b V_b} = \frac{n_a}{n_b}$$

$$\frac{M_a \times 25.0}{0.2 \times 30.0} = 1$$

$$\frac{M_a \times 25.0}{0.2 \times 30.0} = 1$$

$$M_a = 0.240 \text{ mol/dm}^3 \text{ (3 s.f.)}$$

$$\text{Concentration of X in mol/dm}^3 = 0.240 \text{ mol/dm}^3$$

(b)  $\text{mol/dm}^3 \times M_r = \text{g/dm}^3$

$$0.240 \times M_r = 14.40$$

$$M_r = 60$$

Relative molecular mass of X = 60



(i) Concentration of NaCl =  $0.15 \times 58.5 = 8.775 \text{ g/dm}^3 = 8.78 \text{ g/dm}^3$  (3 s.f.)

(ii) No. of grams of NaCl in 20cm<sup>3</sup> =  $8.775 \text{ g/dm}^3 \times 20/1000 \text{ dm}^3 = 0.1755 \text{ g}$   
= 0.176g (3 s.f.)

(b) (i) Concentration of NaOH in g/dm<sup>3</sup> =  $0.16 \text{ g} \div 50/1000 \text{ dm}^3 = 3.20 \text{ g/dm}^3$

(ii)  $M_r$  of NaOH = 23 + 16 + 1 = 40

$$\text{Concentration of NaOH in mol/dm}^3 = 3.20/40 = 0.0800 \text{ mol/dm}^3$$



$$\text{No. of mole of Pb}(\text{NO}_3)_2 = 1.0 \times 1.0 = 1.00 \text{ mol}$$

$$\text{No. of mole of NaCl} = 50/1000 \times 0.15 = 0.0075 \text{ mol}$$

NaCl is the limiting reactant, hence, 0.0075 mol of NaCl will produce 0.0075/2 = 0.00375 mol of PbCl<sub>2</sub>.

$$\text{The amount of PbCl}_2 \text{ produced} = 0.00375 \times (207 + 35.5 \times 2) = 1.0425 = 1.04 \text{ g (3 s.f.)}$$



$$\text{No. of mole of HCl} = 100/1000 \times 3 = 0.300 \text{ mol}$$

$$\text{No of mole of MgO needed} = 0.300/2 = 0.150 \text{ mol}$$

$$\text{Mass of MgO needed} = 0.150 \times (24 + 16) = 6.00 \text{ g}$$

Since each tablet contains 3g of MgO, the person needs to take 2 tablets.



(a) Concentration of sulfuric acid in  $\text{mol/dm}^3 = 9.8/98 = 0.100 \text{ mol/dm}^3$

$$\frac{M_a V_a}{M_b V_b} = \frac{n_a}{n_b}$$

$$\frac{0.1 \times 25.0}{M_b \times 20.0} = \frac{1}{2}$$

$$\frac{0.1 \times 25.0}{M_b \times 20.0} = \frac{1}{2}$$

$$M_b = 0.250 \text{ mol/dm}^3 \text{ (3 s.f.)}$$

Concentration of **Y** in  $\text{mol/dm}^3 = 0.250 \text{ mol/dm}^3$

(b)  $\text{mol/dm}^3 \times M_r = \text{g/dm}^3$

$$0.250 \times M_r = 14$$

$$M_r = 56$$

Relative molecular mass of **Y** = 56

(c) Relative atomic mass of M =  $56 - 16 - 1 = 39$  {no unit}