STOICHIOMETRY *Mathematics of the Chemical Equation*

1. $C_3H_8 + 5\,O_2 \rightarrow 3\,CO_2 + 4\,H_2O$

   1 mol x mol

$$x \text{ mol } O_2 = 1\ \cancel{\text{mol } C_3H_8} \times \frac{(5 \text{ mol } O_2)}{(1\ \cancel{\text{mol } C_3H_8})} = 5 \text{ mol } O_2$$

2. $CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O$

   1 mol x mol

$$x \text{ mol } O_2 = 1\ \cancel{\text{mol } CH_4} \times \frac{(2 \text{ mol } O_2)}{(1\ \cancel{\text{mol } CH_4})} = 2 \text{ mol } O_2$$

3. $3\,Na_2S_2O_3 + AgBr \rightarrow NaBr + Na_5[Ag(S_2O_3)_3]$

   x mol 0.1 mol

$$x \text{ mol } Na_2S_2O_3 = 0.1\ \cancel{\text{mol AgBr}} \times \frac{(3 \text{ mol } Na_2S_2O_3)}{(1\ \cancel{\text{mol AgBr}})} = 0.3 \text{ mol } Na_2S_2O_3$$

4. $4\,Al + 3\,O_2 \rightarrow 2\,Al_2O_3$

   100 g x g

$$x \text{ g } Al_2O_3 = 100\ \cancel{\text{g Al}} \times \frac{(1\ \cancel{\text{mol Al}})}{(27\ \cancel{\text{g Al}})} \times \frac{(2\ \cancel{\text{mol } Al_2O_3})}{(4\ \cancel{\text{mol Al}})} \times \frac{(102 \text{ g } Al_2O_3)}{(1\ \cancel{\text{mol } Al_2O_3})} = 189 \text{ g } Al_2O_3$$

5. $\text{CaO} + \text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2$
10 kg   x g

$$x\ \text{g H}_2\text{O} = 10\ \cancel{\text{kg CaO}} \times \frac{(1000\ \cancel{\text{g CaO}})}{(1\ \cancel{\text{kg CaO}})} \times \frac{(1\ \cancel{\text{mol CaO}})}{(56\ \cancel{\text{g CaO}})} \times \frac{(1\ \cancel{\text{mol H}_2\text{O}})}{(1\ \cancel{\text{mol CaO}})} \times \frac{(18\ \text{g H}_2\text{O})}{(1\ \cancel{\text{mol H}_2\text{O}})} = 3214\ \text{g H}_2\text{O}$$

$$x\ \text{g Ca(OH)}_2 = 10{,}000\ \cancel{\text{g CaO}} \times \frac{(1\ \cancel{\text{mol CaO}})}{(56\ \cancel{\text{g CaO}})} \times \frac{(1\ \cancel{\text{mol Ca(OH)}_2})}{(1\ \cancel{\text{mol CaO}})} \times \frac{(74\ \text{g Ca(OH)}_2)}{(1\ \cancel{\text{mol Ca(OH)}_2})} = 13214\ \text{g}$$

6. $2\ \text{C}_{57}\text{H}_{110}\text{O}_6 + 163\ \text{O}_2 \rightarrow 114\ \text{CO}_2 + 110\ \text{H}_2\text{O}$
1 kg "Fat"   x g

$$x\ \text{g H}_2\text{O} = 1\ \cancel{\text{kg "Fat"}} \times \frac{(1000\ \text{g}\ \cancel{\text{"Fat"}})}{(1\ \cancel{\text{kg "Fat"}})} \times \frac{(1\ \cancel{\text{mol "Fat"}})}{(890\ \cancel{\text{g "Fat"}})} \times \frac{(110\ \cancel{\text{mol H}_2\text{O}})}{(2\ \cancel{\text{mol "Fat"}})} \times \frac{(18\ \text{g H}_2\text{O})}{(1\ \cancel{\text{mol H}_2\text{O}})}$$

$$= 1{,}112\ \text{g H}_2\text{O}$$

7. $\text{B}_2\text{H}_6 + 3\ \text{O}_2 \rightarrow \text{B}_2\text{O}_3 + 3\ \text{H}_2\text{O}$
10 kg   x g

$$x\ \text{g O}_2 = 10{,}000\ \cancel{\text{g B}_2\text{H}_6} \times \frac{(1\ \cancel{\text{mol B}_2\text{H}_6})}{(27.6\ \cancel{\text{g B}_2\text{H}_6})} \times \frac{(3\ \cancel{\text{mol O}_2})}{(1\ \cancel{\text{mol B}_2\text{H}_6})} \times \frac{(32\ \text{g O}_2)}{(1\ \cancel{\text{mol O}_2})} = 34{,}783\ \text{g O}_2$$

8. $\text{Br}_2 + 2\ \text{NaI} \rightarrow 2\ \text{NaBr} + \text{I}_2$
0.172 mol   x mol

$$x\ \text{mol NaBr} = 0.172\ \cancel{\text{mol Br}_2} \times \frac{(2\ \text{mol NaBr})}{(1\ \cancel{\text{mol Br}_2})} = 0.344\ \text{mol NaBr}$$

9.

$$\begin{array}{ccccc} 2\ \text{Ca} & + & \text{O}_2 & \rightarrow & 2\ \text{CaO} \\ \text{excess} & & 4.9 \text{ x } 10^5 & & \text{x molecules} \\ & & \text{molecules} & & \end{array}$$

$$\text{x molecules CaO} = 4.9 \text{ x } 10^5\ \cancel{\text{molecules O}_2} \text{ x } \frac{(1\ \cancel{\text{mol O}_2})}{(6.02 \text{ x } 10^{23}\ \cancel{\text{molecules O}_2})} \text{ x } \frac{(2\ \cancel{\text{mol CaO}})}{(1\ \cancel{\text{mol O}_2})} \text{ x } \frac{(6.02 \text{ x } 10^{23} \text{ molecules})}{(1\ \cancel{\text{mol CaO}})}$$

$$= 9.8 \text{ x } 10^5 \text{ molecules CaO}$$

10.

$$\begin{array}{ccccc} 2\ \text{Al} & + & 3\ \text{S} & \rightarrow & \text{Al}_2\text{S}_3 \\ \text{x atoms} & & 1.33 \text{ x } 10^{24} & & \\ & & \text{atoms} & & \end{array}$$

$$\text{x atoms Al} = 1.33 \text{ x } 10^{24}\ \cancel{\text{atoms S}} \text{ x } \frac{(1\ \cancel{\text{mol S}})}{(6.02 \text{ x } 10^{23}\ \cancel{\text{atoms S}})} \text{ x } \frac{(2\ \cancel{\text{mol Al}})}{(3\ \cancel{\text{mol S}})} \text{ x } \frac{(6.02 \text{ x } 10^{23} \text{ atoms Al})}{(1\ \cancel{\text{mol Al}})}$$

$$= 8.9 \text{ x } 10^{23} \text{ atoms Al}$$

11. $CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$

$$\text{x g CH}_4 = 1\ \cancel{\text{g O}_2} \text{ x } \frac{(1\ \cancel{\text{mol O}_2})}{(32\ \cancel{\text{g O}_2})} \text{ x } \frac{(1\ \cancel{\text{mol CH}_4})}{(2\ \cancel{\text{mol O}_2})} \text{ x } \frac{(16 \text{ g CH}_4)}{(1\ \cancel{\text{mol CH}_4})} = 0.25 \text{ g CH}_4$$

12. $C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$

x g 10 g

$$x\text{ g } C_6H_{12}O_6 = 10\ \cancel{\text{g } O_2} \times \frac{(1\ \cancel{\text{mol } O_2})}{(32\ \cancel{\text{g } O_2})} \times \frac{(1\ \cancel{\text{mol } C_6H_{12}O_6})}{(6\ \cancel{\text{mol } O_2})} \times \frac{(180\text{ g } C_6H_{12}O_6)}{(1\ \cancel{\text{mol } C_6H_{12}O_6})} = 9.375\text{ g } C_6H_{12}O_6$$

13. $6\ NH_4ClO_4 + 10\ Al \rightarrow 5\ Al_2O_3 + 3\ N_2 + 6\ HCl + 9\ H_2O$

5×10^6 g x g

$$x\text{ g Al} = 5 \times 10^6\ \cancel{\text{g } NH_4ClO_4} \times \frac{(1\ \cancel{\text{mol } NH_4ClO_4})}{(117.5\ \cancel{\text{g } NH_4ClO_4})} \times \frac{(10\ \cancel{\text{mol Al}})}{(6\ \cancel{\text{mol } NH_4ClO_4})} \times \frac{(27\text{ g Al})}{(1\ \cancel{\text{mol Al}})} = 1{,}914{,}894\text{ g Al}$$

14. silver nitrate + potassium chloride → silver chloride + potassium nitrate

$AgNO_3 + KCl \rightarrow AgCl + KNO_3$

5 g 5 g

/ 170 g/mol / 74.6 g/mol

"Have" 0.0294 mol 0.067 mol

"Need" 0.067 mol 0.0294 mol

Silver Nitrate is LIMITING REACTANT; KCl is in excess.

15. $2\ \text{Ag} + \text{I}_2 \rightarrow 2\ \text{AgI}$

x atoms   531.8 g

2.5×10^{24} atoms   / 74.6 g/mol

x 6.02×10^{23} atoms/mol

[2:1]

$4.19\ \text{mol Ag} \leftarrow 2.09\ \text{mol I}_2$

$$\text{x atoms Ag} = 531.8\ \cancel{\text{g I}_2} \times \frac{(1\ \cancel{\text{mol I}_2})}{(254\ \cancel{\text{g I}_2})} \times \frac{(2\ \cancel{\text{mol Ag}})}{(1\ \cancel{\text{mol I}_2})} \times \frac{(6.02 \times 10^{23}\ \text{atoms Ag})}{(1\ \cancel{\text{mol Ag}})} = 2.5 \times 10^{24}\ \text{atoms Ag}$$

16. $$\%\ \text{Yield} = \frac{\text{Actual Yield}}{\text{Theoretical Yield}} \times 100\ \%$$

$$\%\ \text{Yield} = \frac{480\ \text{tons}}{550\ \text{tons}} \times 100\ \% = 87.3\ \%\ \text{Yield}$$

17. 1 mol N_2 = 22.4 L @ STP

$$\text{x L N}_2 = 16.3\ \cancel{\text{mol N}_2} \times \frac{(22.4\ \text{L N}_2)}{(1\ \cancel{\text{mol N}_2})} = 365\ \text{L N}_2$$

18. 1 mol F_2 = 22.4 L @ STP

1 cc = 1 cm^3 = 1 mL

& 1 dm^3 = 1 L

10 cm = 1 dm

$(10\text{ cm})^3 = (1\text{dm})^3$

1000 cm^3 = 1 dm^3

$$x \text{ mol } F_2 = 0.269\ \cancel{\text{L } F_2} \times \frac{(1 \text{ mol } F_2)}{(22.4\ \cancel{\text{L } F_2})} = 0.012 \text{ mol } F_2$$

19.	N_2	+	2 O_2	→	2 NO_2
	71.11 L		excess		x L

$$x \text{ L } NO_2 = 71.11\ \cancel{\text{L } NO_2} \times \frac{(1\ \cancel{\text{mol } N_2})}{(22.4\ \cancel{\text{L } N_2})} \times \frac{(2\ \cancel{\text{mol } NO_2})}{(1\ \cancel{\text{mol } N_2})} \times \frac{(22.4 \text{ L } NO_2)}{(1\ \cancel{\text{mol } NO_2})} = 142.22 \text{ L } NO_2$$

20.	2 SO_2	+	O_2	→	2 SO_3
	excess		x mol		79.6 mol

$$x \text{ mol } O_2 = 79.6\ \cancel{\text{mol } SO_3} \times \frac{(1 \text{ mol } O_2)}{(2\ \cancel{\text{mol } SO_3})} = 39.8 \text{ mol } O_2$$

21. $2\ H_2$ + O_2 → $2\ H_2O$

50 g 50 g x g

56.25 g

/ 2 g/mol /32 g/mol x 18 g/mol

[1:2]

"Have" 25 mol H_2 1.56 mol O_2 3.125 mol H_2O

"Need" 3.125 mol H_2 12.5 mol O_2

Oxygen is the LIMITING REACTANT; hydrogen is in excess.

$$x\text{ g } H_2O = 50\ \cancel{g\ O_2} \text{ x } \frac{(1\ \cancel{mol\ O_2})}{(32\ \cancel{g\ O_2})} \text{ x } \frac{(2\ \cancel{mol\ H_2O})}{(1\ \cancel{mol\ O_2})} \text{ x } \frac{(18\ g\ H_2O)}{(1\ \cancel{mol\ H_2O})} = 56.25\text{ g } H_2O$$

$2\ H_2$ + O_2 → $2\ H_2O$ + H_2

50 g 50 g 56.25 g + 43.75 g

6.25 g + 43.75 g + 50 g = 56.25 g + 43.75 g

100 g Reactant = 100 g Product

Law of Conservation of Mass is observed!

22.
$$\begin{array}{ccccccc} 2\,C & + & O_2 & \rightarrow & 2\,CO & + & \text{energy} \\ 1\text{ mol} & & & & & & 113\text{ kJ} \\ & & & & & & \\ 100\text{ g} & & & & & & x\text{ Joules} \end{array}$$

Conversion Factor: 1 mol C = 113 kJ

$$x\text{ Joules heat} = 100\,\cancel{\text{g C}} \times \frac{(1\,\cancel{\text{mol C}})}{(12\,\cancel{\text{g C}})} \times \frac{(113\,\cancel{\text{kJ}})}{(1\,\cancel{\text{mol C}})} \times \frac{(1000\text{ J})}{(1\,\cancel{\text{kJ}})} = 942{,}000\text{ Joules}$$

23.
$$\begin{array}{ccccccc} Cu & + & 2\,AgNO_3 & \rightarrow & Cu(NO_3)_2 & + & 2\,Ag \\ 100\text{ g} & & 200\text{ g} & & & & x\text{ atoms} \end{array}$$

7.1 x 10^{23} atoms

/ 63.5 g/mol   / 170 g/mol   x 6.02 x 10^{23} atoms

[2:2]

"Have"   1.57 mol Cu   1.18 mol $AgNO_3$ 1.18 mol Ag

"Need"   0.59 mol Cu   3.14 mol AgNO3

Silver nitrate is LIMITING Reactant; copper is in excess.

$$X\text{ atoms Ag} = 200\,\cancel{\text{g } AgNO_3} \times \frac{(1\,\cancel{\text{mol } AgNO_3})}{(170\,\cancel{\text{g } AgNO_3})} \times \frac{(2\,\cancel{\text{mol Ag}})}{(2\,\cancel{\text{mol } AgNO_3})} \times \frac{(6.02 \times 10^{23}\text{ atoms Ag})}{(1\,\cancel{\text{mol Ag}})}$$

$$= 7.1 \times 10^{23}\text{ atoms Ag}$$

24.	2 ZnS	+	3 O_2	→	2 ZnO	+	2 SO_2
	1.58×10^8 molecules		1000 L				x mol
	/ 6.02×10^{23} molecules/mol		/ 22.4 L/mol				
"Have"	2.49×10^{-16} mol ZnS		44.6 mol O_2				_______________ mol
"Need"					[2:2]		

Zinc sulfide is LIMITING Reactant; oxygen is in excess.

$$X \text{ mol } SO_2 = 1.5 \times 10^8 \cancel{\text{molecules ZnS}} \times \frac{(1\ \cancel{\text{mol ZnS}})}{(6.02 \times 10^{23}\ \cancel{\text{molecules ZnS}})} \times \frac{(2 \text{ mol } SO_2)}{(2\ \cancel{\text{mol ZnS}})}$$

$= 2.5 \times 10^{-16}$ mol SO_2

$\underline{\times\ 0.75}$ (75 % Yield)

1.9×10^{-16} mol SO_2

3a.	6 CO_2	+	6 H_2O	+	energy	→	$C_6H_{12}O_6$	+	6 O_2
			x molecules				1 molecule		

b. 6 molecules H_2O

$$\begin{array}{lccccccccc} \text{c.} & 6\ CO_2 & + & 6\ H_2O & + & \text{energy} & \rightarrow & C_6H_{12}O_6 & + & 6\ O_2 \\ & & & & & & & 2.5\text{ mol} & & x\text{ L} \end{array}$$

$$x\text{ L }O_2 = 2.5\ \cancel{\text{mol }C_6H_{12}O_6} \times \frac{(6\ \cancel{\text{mol }O_2})}{(1\ \cancel{\text{mol }C_6H_{12}O_6})} \times \frac{(22.4\text{ L }O_2)}{(1\ \cancel{\text{mol }O_2})} = 336\text{ L }O_2$$

$$\begin{array}{lccccccccc} \text{d.} & 6\ CO_2 & + & 6\ H_2O & + & \text{energy} & \rightarrow & C_6H_{12}O_6 & + & 6\ O_2 \\ & x\text{ mol} & & & & & & 2.5\text{ mol} & & \end{array}$$

$$x\text{ mol }CO_2 = 2.5\ \cancel{\text{mol }C_6H_{12}O_6} \times \frac{(6\text{ mol }CO_2)}{(1\ \cancel{\text{mol }C_6H_{12}O_6})} = 15\text{ mol }CO_2$$

$$\begin{array}{lccccccccc} \text{e.} & 6\ CO_2 & + & 6\ H_2O & + & \text{energy} & \rightarrow & C_6H_{12}O_6 & + & 6\ O_2 \\ & x\text{ mol} & & & & & & 2.5\text{ mol} & & \end{array}$$

$$x\text{ mol }CO_2 = 2.5\ \cancel{\text{mol }C_6H_{12}O_6} \times \frac{(6.02 \times 10^{23}\ \cancel{\text{molecules }C_6H_{12}O_6})}{(1\ \cancel{\text{mol }C_6H_{12}O_6})} \times \frac{(6\text{ atoms C})}{(1\ \cancel{\text{molecule }C_6H_{12}O_6})}$$

$$= 9.03 \times 10^{24}\text{ atoms C}$$

$$\begin{array}{lccccccccc} \text{f.} & 6\ CO_2 & + & 6\ H_2O & + & \text{energy} & \rightarrow & C_6H_{12}O_6 & + & 6\ O_2 \\ & 9.32\text{ L} & & & & & & & & x\text{ L} \end{array}$$

$$x\text{ L }O_2 = 9.32\ \cancel{\text{L }CO_2} \times \frac{(1\ \cancel{\text{mol }CO_2})}{(22.4\ \cancel{\text{L }CO_2})} \times \frac{(6\ \cancel{\text{mol }O_2})}{(6\ \cancel{\text{mol }CO_2})} \times \frac{(22.4\text{ L }O_2)}{(1\ \cancel{\text{mol }O_2})} = 9.32\text{ L }O_2$$

3. $C_{12}H_{22}O_{11}$ + 12 O_2 → 12 CO_2 + 11 H_2O + energy
816 g x L
(MM = 342 g/mol)

$$x \text{ L } O_2 = 816 \cancel{\text{g } C_{12}H_{22}O_{11}} \times \frac{(1 \cancel{\text{mol } C_{12}H_{22}O_{11}})}{(342 \cancel{\text{g } C_{12}H_{22}O_{11}})} \times \frac{(12 \cancel{\text{mol } O_2})}{(1 \cancel{\text{mol } C_{12}H_{22}O_{11}})} \times \frac{(22.4 \text{ L } O_2)}{(1 \cancel{\text{mol } O_2})} = 641 \text{ L } O_2$$

4. 2 $KClO_3$ → 2 KCl + 3 O_2
x g x g 5 g

K_2CO_3 → K_2O + CO_2
x g 7 g

$$x \text{ g } KClO_3 = 5 \cancel{\text{g } O_2} \times \frac{(1 \cancel{\text{mol } O_2})}{(32 \cancel{\text{g } O_2})} \times \frac{(2 \cancel{\text{mol } KClO_3})}{(3 \cancel{\text{mol } O_2})} \times \frac{(122.6 \text{ g } KClO_3)}{(1 \cancel{\text{mol } KClO_3})} = 12.77 \text{ g } KClO_3$$

$$x \text{ g KCl} = 5 \cancel{\text{g } O_2} \times \frac{(1 \cancel{\text{mol } O_2})}{(32 \cancel{\text{g } O_2})} \times \frac{(2 \cancel{\text{mol KCl}})}{(3 \cancel{\text{mol } O_2})} \times \frac{(74.6 \text{ g KCl})}{(1 \cancel{\text{mol KCl}})} = 7.77 \text{ g KCl "Produced"}$$

$$x \text{ g } K_2CO_3 = 7 \cancel{\text{g } CO_2} \times \frac{(1 \cancel{\text{mol } CO_2})}{(44 \cancel{\text{g } CO_2})} \times \frac{(1 \cancel{\text{mol } K_2CO_3})}{(1 \cancel{\text{mol } CO_2})} \times \frac{(138.2 \text{ g } K_2CO_3)}{(1 \cancel{\text{mol } K_2CO_3})} = 21.99 \text{ g } K_2CO_3$$

Original Mixture: 12.77 g $KClO_3$ + 21.99 g K_2CO_3 + $\underline{\text{x g KCl}}$ = 50 g

x = 15.24 g KCl

12.77 g $KClO_3$ + 21.99 g K_2CO_3 + $\underline{\text{15.24 g KCl}}$ = 50 g