Quantity Relationships in Chemical Reactions

\[2\text{AgNO}_3 + \text{Na}_2\text{CO}_3 \rightarrow \text{Ag}_2\text{CO}_3 + 2\text{NaNO}_3\]

what is the ratio of the reactivity

- 2 molecules AgNO\(_3\) → 2 moles NaNO\(_3\)
- 1 molecule AgNO\(_3\) → 1 mole Na\(_2\)CO\(_3\)

ex: How many moles of Na\(_2\)CO\(_3\) are needed to react with 22 moles of AgNO\(_3\)?

Given: 22 moles AgNO\(_3\) wanted: moles of NaCO\(_3\)

\[
\begin{array}{c|c|c}
22 \text{ moles AgNO}_3 & 1 \text{ mole Na}_2\text{CO}_3 & = 11 \text{ mole Na}_2\text{CO}_3 \\
2 \text{ mole Ag NO}_3 & & \\
\end{array}
\]

ex: How many grams of NaNO\(_3\) is produced from 4.00 moles Na\(_2\)CO\(_3\)?

Given: 4 moles Na\(_2\)CO\(_3\) wanted: grams NaNO\(_3\) m.m.: 85.0g NaNO\(_3\)

\[
\begin{array}{c|c|c|c}
4.00 \text{ moles Na}_2\text{CO}_3 & 2 \text{ mole NaNO}_3 & 85.0 \text{ g NaNO}_3 & = 680 \text{ g NaNO}_3 \\
1 \text{ mole Na}_2\text{CO}_3 & & 1 \text{ mole NaNO}_3 & \\
\end{array}
\]

H.2 Mass Calculations

Three steps to convert: How to solve a Stoichiometry problem

1. mass A → moles A
2. moles A → moles B (balanced formula)
3. moles B → mass B
mass of given (A) $\rightarrow$ moles of given (A) $\rightarrow$ moles of wanted (B) $\rightarrow$ mass of wanted (B)

\[
x \text{ mol G} \quad x \text{ mol W} \quad x \text{ g W}
\]

\[
g \text{ G} \quad \text{mol G} \quad \text{mol W}
\]

(step 1) \hspace{1cm} (step 2) \hspace{1cm} (step 3)

EX: How many g of Fe$_2$O$_3$ is produced by reacting 3.5g of Fe?

\[
4 \text{Fe}(s) + 3 \text{O}_2(g) \rightarrow 2 \text{Fe}_2\text{O}_3(s)
\]

\[
\begin{array}{ccc}
3.5 \text{ g Fe} & 1 \text{ mole Fe} & 2 \text{ mole Fe}_2\text{O}_3 \\
55.9 \text{ g} & 4 \text{ mole Fe} & 159.7 \text{ g} \\
\text{(step 1)} & \text{(step 2)} & \text{(step 3)}
\end{array}
\]

EX: How many grams of H$_2$O were consumed if 33.6g of H$_3$BO$_3$ were produced,

\[
\text{BF}_3 + 3\text{H}_2\text{O} \rightarrow 3\text{HF} + \text{H}_3\text{BO}_3
\]

\[
\begin{array}{ccc}
33.6\text{g H}_3\text{BO}_3 & 1 \text{ mole H}_3\text{BO}_3 & 3 \text{ moles H}_2\text{O} \\
61.8\text{g} & 1 \text{ mole H}_3\text{BO}_3 & 18.0\text{g} \\
\text{(step 1)} & \text{(step 2)} & \text{(step 3)}
\end{array}
\]

H.5 Percent Yield

- Theoretical yield: the amount of product formed from the complete conversion; 100% Rxn, no loss
- Actual yield: a measured quantity, determined by experience or experiment; what you measure in lab
- Percent yield: \( \%\text{yield} = \frac{\text{actual/ theoretical}}{} \times 100 \)

EX: AlCl$_3$ + 3NaOH $\rightarrow$ Al(OH)$_3$ + 3NaCl

Have 13.4g of AlCl$_3$ and excess NaOH, calculate theoretical yield of NaCl
$$13.4 \text{ g AlCl}_3 \quad 1 \text{ mole AlCl}_3 \quad 3 \text{ moles NaCl} \quad 58.4 \text{ g} = 17.6 \text{ g}$$

recovered 16.2g of NaCl; calculate % yield

actual $\rightarrow$ 16.2g x 100 = 92%

theo. $\rightarrow$ 17.6g

Percent yield 84.2% = 84.2g (actual)/100g (theoretical)

EX: 212g of theoretical yield, how many grams of product

$$\frac{212 \text{ g theo}}{84.2 \text{ g actual}} = 178 \text{ g actual}$$

100g theoretical

EX: Want 157g of In$_2$O$_3$, how manyg of O$_2$ should be used if the yield is 83.4%

$$4\text{In}(s) + 3\text{O}_2(G) \rightarrow 2\text{In}_2\text{O}_3(s)$$

$$\begin{array}{cccc}
157 \text{ g actual} & 100 \text{ g theoretical} & 1 \text{ moles In}_2\text{O}_3 & 3 \text{ mole O}_2 \\
83.4 \text{ g actual} & 277.6 \text{ g In}_2\text{O}_3 & 2 \text{ mole In}_2\text{O}_3 & 1 \text{ mole O}_2 \\
& & & 32.0 \text{ g} = 32.6 \text{ g}
\end{array}$$

**H.6 Limiting Reactions**

Reactant that is completely used up

EX: If you have 30.3g of Zn and 64.0g of HCl, which one is the limiting reagent

$$\text{Zn} + 2\text{HCl} \rightarrow \text{H}_2 + \text{ZnCl}_2$$

1) pick one product (add the molar mass)

$$\begin{array}{cccc}
30.3 \text{ g Zn} & 1 \text{ mole Zn} & 1 \text{ mole H}_2 & 2.00 \text{ g} = 0.927 \text{ g H for Zn} \\
65.4 \text{ g Zn} & 1 \text{ mole Zn} & 1 \text{ mole H}_2 \\
& & & 1.76 \text{ g H}_2
\end{array}$$

$$\begin{array}{cccc}
64.0 \text{ g HCl} & 1 \text{ mole HCl} & 1 \text{ mole H}_2 & 2.00 \text{ g}
\end{array}$$
36.5g \hspace{0.5cm} 1 \text{ mole HCl} \hspace{0.5cm} 1 \text{ mole H}_2

Zn is the limiting reagent \ldots 0.927g \text{ H}_2 \text{ of Zn} < 1.76g \text{ H}_2 \text{ of HCl}

How much HCl remains \ldots \text{ pick limiting reagent: Zn 30.3g}

\[
\begin{array}{ccc}
30.3g \text{ Zn} & 1 \text{ mole Zn} & 2 \text{ moles HCl} \\
65.4g & 1 \text{ mole Zn} & 1 \text{ mole HCl}
\end{array}
\]

\[
\frac{30.3g \text{ Zn}}{30.3g} \times \frac{1 \text{ mole Zn}}{1 \text{ mole Zn}} \times \frac{2 \text{ moles HCl}}{1 \text{ mole HCl}} = 33.8g \text{ HCl}
\]

this shows how much was consumed of HCl; go back to original number of HCl, 64.0-33.8=30.2g

EX: sodium hydroxide + iron(III) sulfate forms sodium sulfate plus Iron(III) hydroxide

\[
\text{NaOH} + \text{FeSO}_4 \rightarrow \text{Na}_2\text{SO}_4 + \text{Fe(OH)}_3
\]

Have 7.01g of sodium hydroxide and 8.03g of Iron(III) sulfate, calculate limiting reagent and calculate how much sodium sulfate is produced

\[
6\text{NaOH} + \text{Fe}_2(\text{SO}_4)_3 \rightarrow 3\text{Na}_2\text{SO}_4 + 2\text{Fe(OH)}_3
\]

\[
\begin{array}{ccc}
7.01g \text{ NaOH} & 1 \text{ moles NaOH} & 3 \text{ mole Na}_2\text{SO}_4 \\
40.0g \text{ NaOH} & 6 \text{ moles NaOH} & 1 \text{ mole Na}_2\text{SO}_4
\end{array}
\]

\[
\frac{7.01g \text{ NaOH}}{40.0g} \times \frac{1 \text{ moles NaOH}}{6 \text{ moles NaOH}} \times \frac{3 \text{ mole Na}_2\text{SO}_4}{1 \text{ mole Na}_2\text{SO}_4} = 12.5g
\]

\[
\begin{array}{ccc}
8.03g \text{ Fe}_2(\text{SO}_4)_3 & 1 \text{ moles Fe}_2(\text{SO}_4)_3 & 3 \text{ mole Na}_2\text{SO}_4 \\
400.0g \text{ NaOH} & 1 \text{ moles Fe}_2(\text{SO}_4)_3 & 1 \text{ mole Na}_2\text{SO}_4
\end{array}
\]

\[
\frac{8.03g \text{ Fe}_2(\text{SO}_4)_3}{400.0g} \times \frac{1 \text{ moles Fe}_2(\text{SO}_4)_3}{1 \text{ mole Fe}_2(\text{SO}_4)_3} \times \frac{3 \text{ mole Na}_2\text{SO}_4}{1 \text{ mole Na}_2\text{SO}_4} = 8.56g
\]

Produce 8.56g Iron(III) sulfate is limiting reagent.

H.9 Energy

Units of heat: nearly all chemical changes involve an energy transformation, usually in the form of heat

Calorie: amount of energy required to raise the temperature of 1 gram of water 1°C: 1ml

\[
\text{H}_2\text{O} \rightarrow 1°C
\]
S.I. = 1 calorie = 4.185J  4.185J/cal  Joule is defined in terms of three base units as 1kg x m$^2$/sec$^2$

$\Delta H =$ transfer of heat
exothermic = $-\Delta H$ (amount of heat energy given off)
endothermic = $+\Delta H$ (amount of heat energy absorbed)

end of Exam 2 material