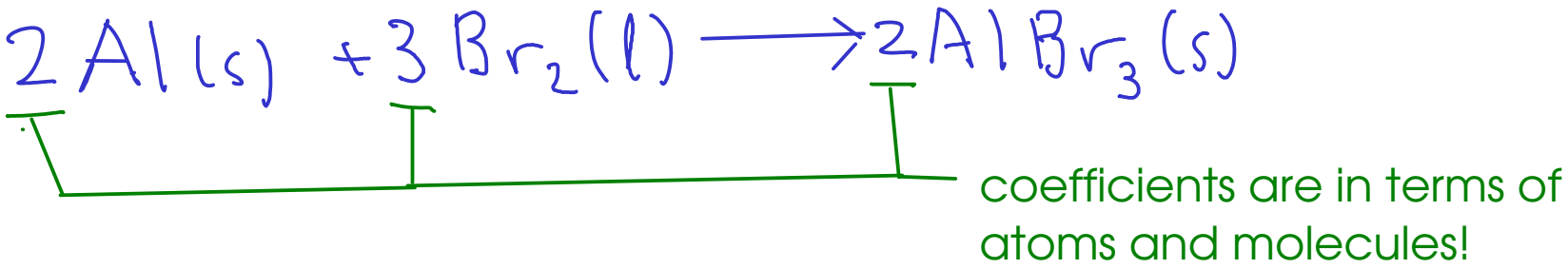
CHEMICAL CALCULATIONS CONTINUED: REACTIONS

- Chemical reactions proceed on an ATOMIC basis, NOT a mass basis!

- To calculate with chemical reactions (i.e. use chemical equations), we need everything in terms of ATOMS ... which means MOLES of atoms



2 atoms Al = 3 molecules Br_2 = 2 formula units $AlBr_3$

2 mol Al = 3 mol Br_2 = 2 mol $AlBr_3$ *

- To do chemical calculations, we need to:

① - Relate the amount of substance we know (mass or volume) to a number of moles

② - Relate the moles of one substance to the moles of another using the equation

③ - Convert the moles of the new substance to mass or volume as desired

$$2\,Al(s) + 3\,Br_2(\ell) \longrightarrow 2\,AlBr_3(s)$$

* Given that we have 25.0 g of liquid bromine, how many grams of aluminum would we need to react away all of the bromine? How many grams of aluminum bromide would be produced?

① Convert the 25.0 g of bromine to moles. Use formula weight. $Br_2: 2 \times 79.90 = 159.8$

$159.8\ g\ Br_2 = mol\ Br_2$

$$25.0\ g\ Br_2 \times \frac{mol\ Br_2}{159.8\ g\ Br_2} = 0.1564456\ mol\ Br_2$$

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② Convert the moles bromine to moles aluminum. Use chemical equation.

$2\ mol\ Al = 3\ mol\ Br_2$

$$0.1564456\ mol\ Br_2 \times \frac{2\ mol\ Al}{3\ mol\ Br_2} = 0.104297038\ mol\ Al$$

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③ Convert the moles aluminum to mass. Use formula weight. $Al: 26.98$

$26.98\ g\ Al = mol\ Al$

$$0.104297038\ mol\ Al \times \frac{26.98\ g\ Al}{mol\ Al} = \boxed{2.81\ g\ Al}$$

You can combine all three steps on one line if you like!

$$25.0\text{ g } Br_2 \times \frac{\text{mol } Br_2}{159.8\text{ g } Br_2} \times \frac{2\text{ mol Al}}{3\text{ mol } Br_2} \times \frac{26.98\text{ g Al}}{1\text{ mol Al}} = \boxed{2.81\text{ g Al}}$$

① ② ③

$$\begin{array}{r} 25.0\text{ g } Br_2 \\ +\ 2.81\text{ g Al} \\ \hline 27.8\text{ g } AlBr_3 \end{array}$$

Conservation of mass!

But ...
...what would you have done to calculate the mass of aluminum bromide IF you had NOT been asked to calculate the mass of aluminum FIRST?

Calculating the mass of aluminum bromide directly:

$$25.0\text{ g } Br_2 \times \frac{1\text{ mol } Br_2}{159.8\text{ g } Br_2} \times \frac{2\text{ mol } AlBr_3}{3\text{ mol } Br_2} \times \frac{266.68\text{ g } AlBr_3}{1\text{ mol } AlBr_3} = 27.8\text{ g } AlBr_3$$

$AlBr_3$: Al : 1×26.98

Br : 3×79.90

266.68

Example:

How many milliliters of 6.00M hydrochloric acid is needed to completely react with 25.0 g of sodium carbonate?

$$2HCl(aq) + Na_2CO_3(s) \longrightarrow H_2O(l) + CO_2(g) + 2NaCl(aq)$$

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1 - Convert 25.0 g of sodium carbonate to moles using formula weight.
2 - Convert moles sodium carbonate to moles hydrochloric acid using chemical equation
3 - Convert moles hydrochloric acid to volume using molar concentration (6.00 moles / L)

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① Na_2CO_3 : Na : 2×22.99
C : 1×12.01
O : 3×16.00

$105.99\ g\ Na_2CO_3 = mol\ Na_2CO_3$

$$25.0\ g\ Na_2CO_3 \times \frac{mol\ Na_2CO_3}{105.99\ g\ Na_2CO_3} = 0.2358713086\ mol\ Na_2CO_3$$

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② $2\ mol\ HCl = mol\ Na_2CO_3$

$$0.2358713086\ mol\ Na_2CO_3 \times \frac{2\ mol\ HCl}{mol\ Na_2CO_3} = 0.4717426172\ mol\ HCl$$

Example:

How many milliliters of 6.00M hydrochloric acid is needed to completely react with 25.0 g of sodium carbonate?

$$2HCl(aq) + Na_2CO_3(s) \longrightarrow H_2O(l) + CO_2(g) + 2NaCl(aq)$$

1 - Convert 25.0 g of sodium carbonate to moles using formula weight.
2 - Convert moles sodium carbonate to moles hydrochloric acid using chemical equation
3 - Convert moles hydrochloric acid to volume using molar concentration (6.00 moles / L)

(3) $6.00\ mol\ HCl = L \qquad mL = 10^{-3} L$

$$0.471742617\ mol\ HCl \times \frac{L}{6.00\ mol\ HCl} \times \frac{mL}{10^{-3} L} = \boxed{78.6\ mL\ solution\ (6.00\ M\ HCl)}$$

If you like, you can solve the whole problem on one line:

$105.99\ g\ Na_2CO_3 = mol\ Na_2CO_3 \qquad 2\ mol\ HCl = mol\ Na_2CO_3$

$6.00\ mol\ HCl = L \qquad mL = 10^{-3} L$

] Conversion factors

$$25.0\ g\ Na_2CO_3 \times \underbrace{\frac{mol\ Na_2CO_3}{105.99\ g\ Na_2CO_3}}_{(1)} \times \underbrace{\frac{2\ mol\ HCl}{mol\ Na_2CO_3}}_{(2)} \times \underbrace{\frac{L}{6.00\ mol\ HCl} \times \frac{mL}{10^{-3} L}}_{(3)} = \boxed{78.6\ mL}$$

EXAMPLE PROBLEM:

$$2\,Na(s) + Cl_2(g) \rightarrow 2\,NaCl(s)$$

How many grams of sodium metal is required to completely react with 2545 grams of chlorine gas?

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1 - Convert 2545 grams of chlorine gas to moles (use formula weight)
2 - Convert moles of chlorine gas to moles of sodium metal (use chemical equation)
3 - Convert moles of sodium metal to grams (use formula weight)

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① Cl_2: 2×35.45 : $70.90\ g\ Cl_2 = mol\ Cl_2$

② $2\ mol\ Na = mol\ Cl_2$

③ $22.99\ g\ Na = mol\ Na$

$$2545\ g\ Cl_2 \times \frac{mol\ Cl_2}{70.90\ g\ Cl_2} \times \frac{2\ mol\ Na}{mol\ Cl_2} \times \frac{22.99\ g\ Na}{mol\ Na} = \boxed{1650.\ g\ Na}$$

① ② ③

$(1.650 \times 10^3\ g\ Na)$

EXAMPLE PROBLEM:

$$H_2SO_4(aq) + 2\,NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

How many mL of 0.250 M sodium hydroxide is required to completely react with 15.0 mL of 2.00 M sulfuric acid?

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1 - Convert 15.0 mL of sulfuric acid solution to moles (use concentration - 2.00 M)
2 - Convert moles sulfuric acid to moles sodium hydroxide (use chemical equation)
3 - Convert moles sodium hydroxide to volume (use concentration - 0.250 M)

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① $1\ mL = 10^{-3}\ L$ $\quad 2.00\ mol\ H_2SO_4 = 1\ L$ | ② $1\ mol\ H_2SO_4 = 2\ mol\ NaOH$

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③ $0.250\ mol\ NaOH = 1\ L$ $\quad 1\ mL = 10^{-3}\ L$

$$15.0\ mL \times \frac{10^{-3}\ L}{mL} \times \frac{2.00\ mol\ H_2SO_4}{L} \times \frac{2\ mol\ NaOH}{mol\ H_2SO_4} \times \frac{L}{0.250\ mol\ NaOH} \times \frac{mL}{10^{-3}\ L} =$$

① ② ③

$$= \boxed{240.\ mL\ of\ 0.250\ M\ NaOH}$$

Shortcut to this problem ... use millimoles instead of moles!

$$15.0\ \cancel{mL} \times \frac{2.00\ \cancel{mol}\ H_2SO_4}{\cancel{L}} \times \frac{2\ \cancel{mol}\ NaOH}{\cancel{mol}\ H_2SO_4} \times \frac{L}{0.250\ \cancel{mol}\ NaOH} = 240.\ mL$$