So far, we have

ch 7
- looked at how to determine the composition by mass of a compound from a formula
- converted from MASS to MOLES (related to the number of atoms/molecules)
- converted from MOLES to MASS

Are we missing anything?

- What about SOLUTIONS, where the desired chemical is not PURE, but found DISSOLVED IN WATER?

- How do we deal with finding the moles of a desired chemical when it's in solution?

MOLAR CONCENTRATION

- unit: MOLARITY (M): moles of dissolved substance per LITER of solution

$$M = MOLARITY = \frac{moles\ of\ solute}{L\ solution}$$

$$6.0\ M\ HCl\ solution: \quad \frac{6.0\ mol\ HCl}{L}$$

There are 6.0 moles of hydrochloric acid in each liter of this solution, so
you can write this relationship another way:

$$6.0\ mol\ HCl = 1\ L$$

If you have 0.250 L (250 mL) of 6.0 M HCl, how many moles of HCl do
you have?

$$0.250\ L \times \frac{6.0\ mol\ HCl}{1\ L} = \boxed{1.5\ mol\ HCl}$$

If you need 0.657 moles of hydrochloric acid, how many liters of 0.0555 <u>M</u> HCl do you need to measure out?

0.0555 mol HCl = 1 L

$$0.657 \text{ mol HCl} \times \frac{1 \text{ L}}{0.0555 \text{ mol HCl}} = \boxed{11.8 \text{ L of solution}}$$

11,800 mL ✓

... a bit large for a benchtop experiment!

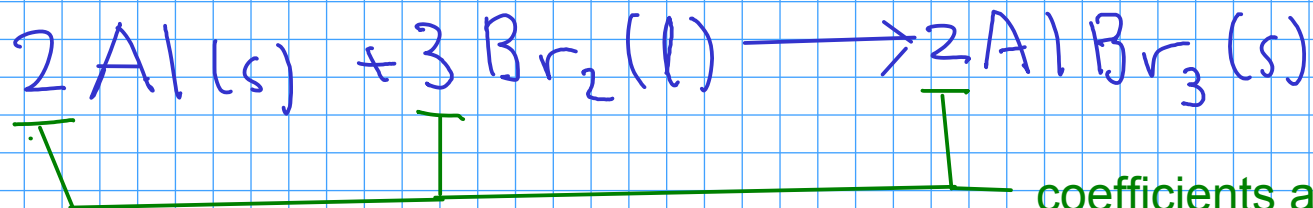What if we used 6.00 M HCl?

6.00 mol HCl = 1 L

$$0.657 \text{ mol HCl} \times \frac{1 \text{ L}}{6.00 \text{ mol HCl}} = \boxed{0.110 \text{ L of solution}}$$

110. mL

... a more reasonable volume for a benchtop experiment!

- 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

$$2 \text{ Al (s)} + 3 \text{ Br}_2 \text{ (l)} \longrightarrow 2 \text{ AlBr}_3 \text{ (s)}$$

coefficients are in terms of atoms and molecules!

$$2 \text{ atoms Al} = 3 \text{ molecules Br}_2 = 2 \text{ formula units AlBr}_3$$

$$2 \text{ mol Al} = 3 \text{ mol Br}_2 = 2 \text{ mol AlBr}_3 \quad *$$

- 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

$$2\,Al\,(s) + 3\,Br_2\,(\ell) \longrightarrow 2\,AlBr_3\,(s)$$
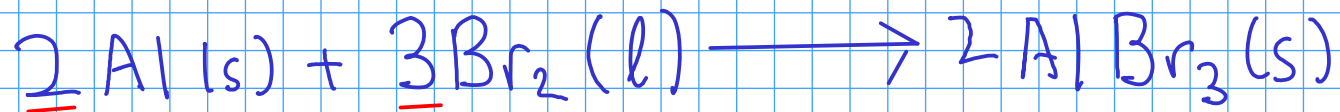
* Given that we have 25.0 g of liquid bromine, how many grams of aluminum would we need to react away all of the bromine? How many grams of aluminum bromide would be produced?

① Convert grams of bromine to moles: Need formula weight Br_2 : $\dfrac{2 \times 79.90}{159.80}$

$$159.80\,g\ Br_2 = 1\,mol\ Br_2$$

$$25.0\,g\ Br_2 \times \frac{1\,mol\ Br_2}{159.80\,g\ Br_2} = 0.15645\,mol\ Br_2$$

② Use the chemical equation to relate moles of bromine to moles of aluminum

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

$$0.15645\,mol\ Br_2 \times \frac{2\,mol\ Al}{3\,mol\ Br_2} = 0.10430\,mol\ Al$$

③ Convert moles aluminum to mass: Need formula weight Al : 26.98

$$26.98\,g\ Al = 1\,mol\ Al$$

$$0.10430\,mol\ Al \times \frac{26.98\,g\ Al}{1\,mol\ Al} = \boxed{2.81\,g\ Al}$$

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

$$25.0 \text{ g } Br_2 \times \frac{1 \text{ mol } Br_2}{159.80 \text{ g } Br_2} \times \frac{2 \text{ mol } Al}{3 \text{ mol } Br_2} \times \frac{26.98 \text{ g } Al}{1 \text{ mol } Al} = \boxed{2.81 \text{ g } Al}$$

①   ②   ③

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

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?

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

$$AlBr_3: \quad Al = 1 \times 26.98$$
$$Br = 3 \times 79.90$$
$$\underline{} = 266.68$$

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

$$2 HCl\ (aq) + Na_2CO_3\ (s) \longrightarrow H_2O\ (l) + CO_2\ (g) + 2NaCl\ (aq)$$
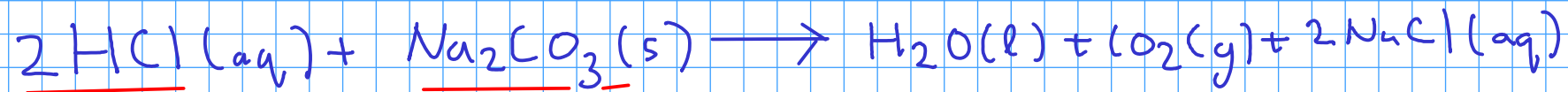
- Convert mass of sodium carbonate to moles using formula weight
- Convert moles of sodium carbonate to moles hydrochloric acid using chemical equation
- Convert moles of hydrochloric acid to volume using concentration (M = moles/L)

- Convert mass of sodium carbonate to moles using formula weight

Na_2CO_3:

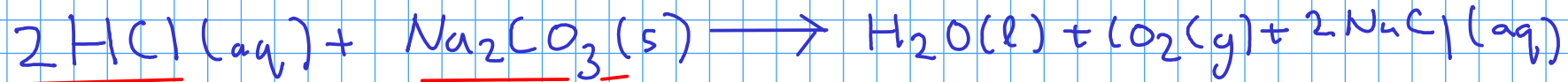$$\begin{array}{l} Na : 2 \times 22.99 \\ C : 1 \times 12.01 \\ O : 3 \times 16.00 \\ \hline 105.99 \end{array}$$

$\Big\}$ $105.99\ g\ Na_2CO_3 = 1\ mol\ Na_2CO_3$

$$25.0\ g\ Na_2CO_3 \times \frac{1\ mol\ Na_2CO_3}{105.99\ g\ Na_2CO_3} = 0.235871\ mol\ Na_2CO_3$$

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

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

- Convert moles of sodium carbonate to moles hydrochloric acid using chemical equation

$$2 \text{ mol } HCl = 1 \text{ mol } Na_2CO_3$$

$$0.235871 \text{ mol } Na_2CO_3 \times \frac{2 \text{ mol } HCl}{1 \text{ mol } Na_2CO_3} = 0.471743 \text{ mol } HCl$$

- Convert moles of hydrochloric acid to volume using concentration (M = moles/L)

$$6.00 \underline{m} \ HCl : \qquad 6.00 \text{ mol } HCl = 1 L$$

$$0.471743 \text{ mol } HCl \times \frac{1 L}{6.00 \text{ mol } HCl} = 0.0786 L \text{ solution}$$

... convert 0.0786 L to mL since problem specifically asks for mL!

$$mL = 10^{-3} L$$

$$0.0786 L \text{ solution} \times \frac{mL}{10^{-3} L} = \boxed{78.6 \text{ mL solution}}$$

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?

① Convert 2545g Cl_2 to moles; FW = 70.90

② Convert mol Cl_2 to mol Na; equation 2 mol Na = 1 mol Cl_2

③ Convert mol Na to grams; FW = 22.99

$$70.90 \text{ g } Cl_2 = 1 \text{ mol } Cl_2 \mid 2 \text{ mol } Na = 1 \text{ mol } Cl_2 \mid 22.99 \text{ g } Na = 1 \text{ mol } Na$$

$$2545 \text{ g } Cl_2 \times \frac{1 \text{ mol } Cl_2}{70.90 \text{ g } Cl_2} \times \frac{2 \text{ mol } Na}{1 \text{ mol } Cl_2} \times \frac{22.99 \text{ g } Na}{1 \text{ mol } Na} = \boxed{1650. \text{ g } Na}$$

①   ②   ③

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?

① Convert 15.0 mL of 2.00 M H_2SO_4 to moles

② Convert mol H_2SO_4 to mol NaOH

③ Convert mol NaOH to volume

Convert volume to liters, since molarity (M) is based on liters

$$mL = 10^{-3} L$$

$$15.0 \, mL \times \frac{10^{-3} L}{mL} = 0.0150 L$$

This is the initial amount of sulfuric acid in liters.

$$\underset{①}{2.00 \, mol \, H_2SO_4 = 1L} \quad \Big| \quad \underset{②}{1 \, mol \, H_2SO_4 = 2 \, mol \, NaOH} \quad \Big| \quad \underset{③}{0.250 \, mol \, NaOH = 1L}$$

$$0.0150 L \times \underset{①}{\frac{2.00 \, mol \, H_2SO_4}{1L}} \times \underset{②}{\frac{2 \, mol \, NaOH}{1 \, mol \, H_2SO_4}} \times \underset{③}{\frac{1L}{0.250 \, mol \, NaOH}} = 0.240 L \, of \, NaOH \, solution$$

Since problem asks for mL, do a quick conversion of 0.240L to mL

$$mL = 10^{-3} L$$

$$0.240 L \times \frac{mL}{10^{-3} L} = \boxed{240. \, mL \, of \, 0.250 M \, NaOH}$$