SUMMING UP CHEMICAL NOMENCLATURE

- You need to be able to tell, by looking at a name OR a formula, what kind of compound you are working with!

DON'T GET THE NAMING SYSTEMS MIXED UP! EACH KIND OF COMPOUND IS NAMED WITH ITS OWN SYSTEM!

FROM A CHEMICAL NAME

- If the name has a Roman numeral, the name of a metal, or "ammonium", the compound is likely IONIC
- If the name has a Greek prefix AND the prefix is NOT in front of the word "hydrate", the compound is BINARY MOLECULAR
- If the name contains the word "acid":

... and starts with "hydro-", then the compound is a BINARY ACID

... and does not start with "hydro-", the compound is an OXYACID

FROM A CHEMICAL FORMULA

- if the formula contains a metal or the NH_4^+ ion, it is likely IONIC

H_2O H_2O_2

- If the formula starts with H and is not either water or hydrogen peroxide, the compound is likely an ACID. Which kind?

  - BINARY ACIDS contain only two elements

  - OXYACIDS contains oxygen

- If the formula contains only nonmetals (and is not an ammonium compound or an acid), the compound is likely MOLECULAR

Examples:

PCl_3: BINARY MOLECULAR
Name: phosphorus trichloride

NH_4Cl: IONIC (ammonium ion)
Name: ammonium chloride

H_3PO_4: OXYACID (hydrogen, phosphate)
Name: phosphoric acid

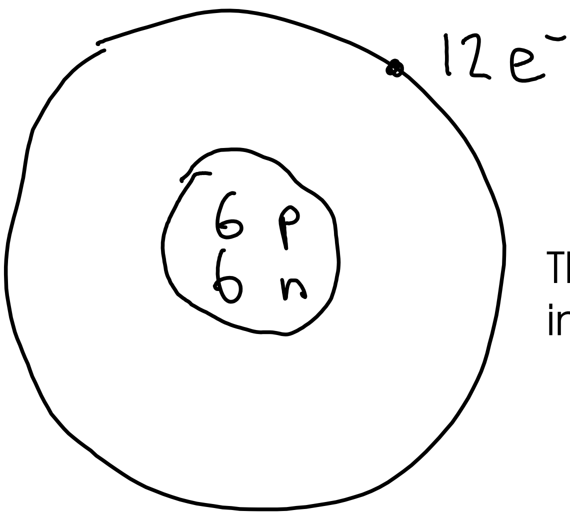
$Fe(OH)_2$: IONIC (starts with a metal)
Name: iron(II) hydroxide

THE MOLE CONCEPT

- A "mole" of atoms is 6.022×10^{23} atoms

Why so big? Because atoms are so small!

- Why - in the metric dominated world of science - do we use such a strange number for quantity of atoms?



carbon-12

The mole is also defined as the number of carbon-12 atoms in exactly 12 g of carbon-12

THE MOLE CONCEPT

- Why define the mole based on an experimentally-measured number?

- The atomic weight of an element (if you put the number in front of the unit GRAMS) is equal to the mass of ONE MOLE of atoms of that element!

Carbon (C): Atomic mass 12.01 ~~amu~~ → 12.01 g

12.01 g → the mass of ONE MOLE of naturally-occurring carbon atoms

Magnesium (Mg): 24.31 g = the mass of ONE MOLE OF MAGNESIUM ATOMS

- So, using the MOLE, we can directly relate a mass and a certain number of atoms!

RELATING MASS AND MOLES

- Use DIMENSIONAL ANALYSIS (a.k.a "drag and drop")

- Need CONVERSION FACTORS - where do they come from?

- We use ATOMIC WEIGHT as a conversion factor.

Mg : 24.31 (Atomic mass) | 24.31 g Mg = mol Mg

"mol" is the abbreviation for "mole"

Example: How many moles of atoms are there in 250. g of magnesium metal?

24.31 g Mg = mol Mg

$$250.\ g\ Mg \times \frac{mol\ Mg}{24.31\ g\ Mg} = \boxed{10.3\ mol\ Mg}$$

Example: You need 1.75 moles of iron. What mass of iron do you need to weigh out on the balance?

Fe: 55.85

55.85 g Fe = mol Fe

$$1.75 \text{ mol Fe} \times \frac{55.85 \text{ g Fe}}{\text{mol Fe}} = \boxed{97.7 \text{ g Fe}}$$

WHAT ABOUT COMPOUNDS? FORMULA WEIGHT

Example: 25.0 g of WATER contain how many MOLES of water molecules?

H_2O: H : 2 x 1.008 = 2.016

O : 1 x 16.00 = 16.00

18.016 ← FORMULA WEIGHT of water

FORMULA WEIGHT is the mass of one mole of either an element OR a compound.

$18.016 \text{ g } H_2O = \text{mol } H_2O$

$$25.0 \text{ g } H_2O \times \frac{\text{mol } H_2O}{18.016 \text{ g } H_2O} = 1.39 \text{ mol } H_2O$$

Formula weight goes by several names:

- For atoms, it's the same thing as ATOMIC WEIGHT
- For molecules, it's called MOLECULAR WEIGHT
- Also called "MOLAR MASS"

Example: How many grams of barium chloride do we need to weigh out to get 3.65 moles of barium chloride?

First, find out the formula for barium chloride:

(ionic, begins with metal)

Ba^{2+} Cl^-

Cl^-

$BaCl_2$

Second, find the formula weight:

Ba : 1 x 137.3 = 137.3

Cl : 2 x 35.45 = 70.90

208.2 g $BaCl_2$ = mol $BaCl_2$

FInally, convert mass barium chloride to moles.

$$3.65 \text{ mol } BaCl_2 \times \frac{208.2 \text{ g } BaCl_2}{\text{mol } BaCl_2} = 76\bar{0} \text{ g } BaCl_2$$

PERCENTAGE COMPOSITION

- sometimes called "percent composition" or "percent composition by mass"
- the percentage of each element in a compound, expressed in terms of mass

Example: Find the percentage composition of barium chloride.

$BaCl_2$: Ba : 1 x 137.3 = 137.3
Cl : 2 x 35.45 = 70.90

These numbers are the masses of each element in a mole of the compound!

208.2 g $BaCl_2$ = mol $BaCl_2$

Ba: $\frac{137.3 \text{ g Ba}}{208.2 \text{ g } BaCl_2} \times 100 = 65.95\%$ Ba

Cl: $\frac{70.90 \text{ g Cl}}{208.2 \text{ g } BaCl_2} \times 100 = 34.05\%$ Cl

So far, we have

- 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

$$M = \text{molarity} = \frac{\text{moles of SOLUTE}}{\text{L SOLUTION}}$$

(SOLUTE ← dissolved substance)

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

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

6.0 mol HCl = L

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

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

0.0555 mol HCl = L

$$0.657\ \text{mol HCl} \times \frac{\text{L}}{0.0555\ \text{mol HCl}} = 11.8\ \text{L}$$

(11800 mL)

What if we used 6.00 M HCl?

6.00 mol HCl = L

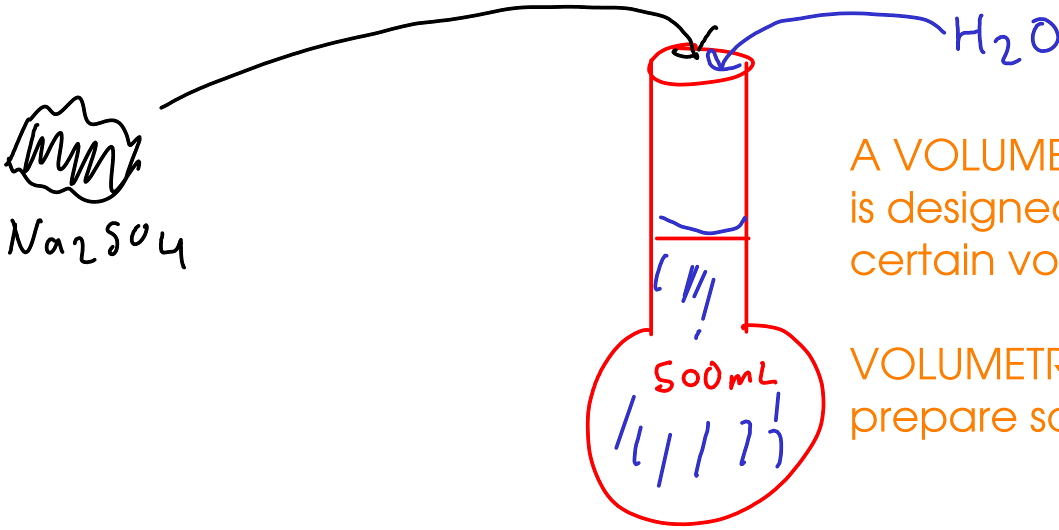
$$0.657\ \text{mol HCl} \times \frac{\text{L}}{6.00\ \text{mol HCl}} = 0.110\ \text{L}$$

(11$\bar{0}$ mL)

Example: How would we prepare 500. mL of 0.500 M sodium sulfate in water?

Na_2SO_4 : 142.05 g/mol

Dissolve the appropriate amount of sodium sulfate into enough water to make 500. mL of solution.



A VOLUMETRIC FLASK is a flask that is designed to precisely contain a certain volume of liquid.

VOLUMETRIC FLASKS are used to prepare solutions.

volumetric flask

First, let's find out how many moles of sodium sulfate we'll need. Start with volume and molarity.

$0.500 \text{ mol } Na_2SO_4 = L \qquad mL = 10^{-3} L$

$$500.\ mL \times \frac{10^{-3}\ L}{mL} \times \frac{0.500 \text{ mol } Na_2SO_4}{L} = 0.250 \text{ mol } Na_2SO_4$$

Next, convert the moles of sodium sulfate to mass. Use FORMULA WEIGHT.

$142.05 \text{ g } Na_2SO_4 = \text{mol } Na_2SO_4$

$$0.250 \text{ mol } Na_2SO_4 \times \frac{142.05 \text{ g } Na_2SO_4}{\text{mol } Na_2SO_4} = 35.5 \text{ g } Na_2SO_4$$

Weigh out 35.5 grams of sodium sulfate into a 500 mL volumetric flask, then add water to the mark!

More on MOLARITY

To prepare a solution of a given molarity, you generally have two options:

1. Weigh out the appropriate amount of solute, then dilute to the desired volume with solvent (usually water)

2. Take a previously prepared solution ("stock solution") of known concentration and DILUTE it with solvent to form a new solution

   - Use DILUTION EQUATION

The dilution equation is easy to derive with simple algebra.

$$M \times V$$

$$\frac{\text{mol}}{\text{L}} \times \text{L} = \text{moles solute}$$

... but when you dilute a solution, the number of moles of solute REMAINS CONSTANT. (After all, you're adding only SOLVENT)

$$M_1 V_1 = M_2 V_2$$

before diution — after dilution

Since the number of moles of solute stays the same, this equality must be true!

$$M_1V_1 = M_2V_2$$ ... the "DILUTION EQUATION"

M_1 = molarity of concentrated solution

V_1 = volume of concentrated solution

M_2 = molarity of dilute solution

V_2 = volume of dilute solution (total volume, not volume of added solvent!)

The volumes don't HAVE to be in liters, as long as you use the same volume UNIT for both volumes!

Example: Take the 0.500 M sodium sulfate we discussed in the previous example and dilute it to make 150. mL of 0.333 M solution. How many mL of the original solution will we need to dilute?

$$M_1V_1 = M_2V_2$$

$$(0.500\ M)V_1 = (0.333\ M)(150.\ mL)$$

$$V_1 = 99.9\ mL \text{ of } 0.500\ M \text{ stock}$$

$M_1 = 0.500\ M$

$V_1 = ?$

$M_2 = 0.333\ M$

$V_2 = 150.\ mL$

Take 99.9 mL of 0.500 M sodium sulfate, then add water until the total volume equals 150. mL.

CHEMICAL EQUATIONS

- are the "recipes" in chemistry
- show the substances going into a reaction, substances coming out of the reaction, and give other information about the process

"yields"

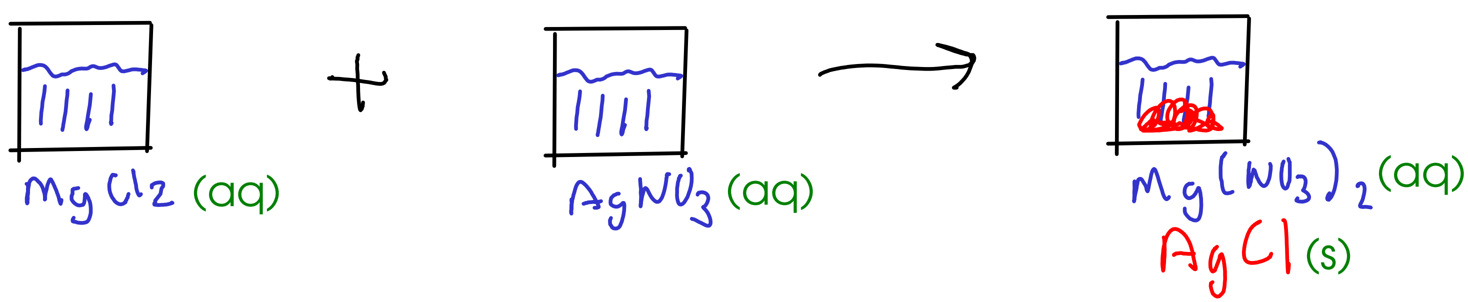
$$MgCl_2(aq) + 2AgNO_3(aq) \longrightarrow 2AgCl(s) + Mg(NO_3)_2(aq)$$

REACTANTS - materials that are needed fot a reaction

PRODUCTS - materials that are formed in a reaction

COEFFICIENTS - give the ratio of molecules/atoms of one substance to the others

PHASE LABELS - give the physical state of a substance:
(s) -solid
(l) - liquid
(g) - gas
(aq) - aqueous. In other words, dissolved in water



CHEMICAL EQUATIONS

$$2\,Mg(s) + O_2(g) \xrightarrow{\Delta} 2\,MgO(s)$$

REACTION CONDITIONS - give conditions necessary for chemical reaction to occur. May be:

- Δ apply heat
- catalysts - substances that will help reaction proceed faster
- other conditions, such as required temperatures

- Reaction conditions are usually written above the arrow, but may also be written below if the reaction requires several steps or several different conditions

COEFFICIENTS

- Experimentally, we can usually determine the reactants and products of a reaction

- We can determine the proper ratios of reactants and products WITHOUT further experiments, using a process called BALANCING

  - BALANCING a chemical equation is making sure the same number of atoms of each element go into a reaction as come out of it.

- A properly balanced chemical equation has the smallest whole number ratio of reactants and products.

- There are several ways to do this, but we will use a modified trial-and-error procedure.

BALANCING

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$$

~~2~~ 10 | 6 + 4 = 10

1. Pick an element. Avoid (if possible) elements that appear in more than one substance on each side of the equation.

2. Change the coefficients on substances containing this element so that the same number of atoms of the element are present on each side. CHANGE AS LITTLE AS POSSIBLE!

3. Repeat 1-2 until all elements are done.

4. Go back and quickly VERIFY that you have the same number of atoms of each element on each side, If you used any fractional coefficients, multiply each coefficient by the DENOMIMATOR of your fraction.

Use SMALLEST WHOLE NUMBER RATIOS!

BALANCING

$$3MgCl_2 + 2Na_3PO_4 \longrightarrow Mg_3(PO_4)_2 + 6NaCl$$ ✓

$$C_2H_2 + 2\tfrac{1}{2}O_2 \longrightarrow 2CO_2 + H_2O$$

~~4~~ 5 | 4 + 1 = 5

We had to use a coefficient of 2 1/2 for oxygen to balance the number of oxygen atoms going in. To make that coefficient into a whole number, multiply it by two - which you can do ONLY if you multiply all the other coefficents by 2!

$$2C_2H_2 + 5O_2 \longrightarrow 4CO_2 + 2H_2O$$ ✓

$$H_2SO_4 + 2NaOH \longrightarrow Na_2SO_4 + 2H_2O$$

1) Avoid H (shows up twice on the left), balance S.
2) Avoid O (shows up in all four compounds), balance Na.
3) Balance H
4) Balance O (it's already done!)