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)

$24.31\ g\ Mg = \underline{mol}\ Mg$

"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?

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:

$H: 2 \times 1.008 = 2.016$

$O: 1 \times 16.00 = 16.00$

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 of barium chloride.

Ba^{2+} Cl^-

Cl^-

$BaCl_2$

Second, find formula weight of barium chloride

$BaCl_2$ - Ba: 1 x 137.3

Cl: 2 x 35.45

208.2 g $BaCl_2$ = mol $BaCl_2$

FInally, calculate the needed mass of barium chloride.

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

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

208.2 g $BaCl_2$ = mol $BaCl_2$

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

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

These percentages should sum to 100%, within roundoff error.

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

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

← 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?

$0.0555 \text{ mol HCl} = \text{L}$

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

(11800 mL)

What if we used 6.00 M HCl?

$6.00 \text{ mol HCl} = \text{L}$

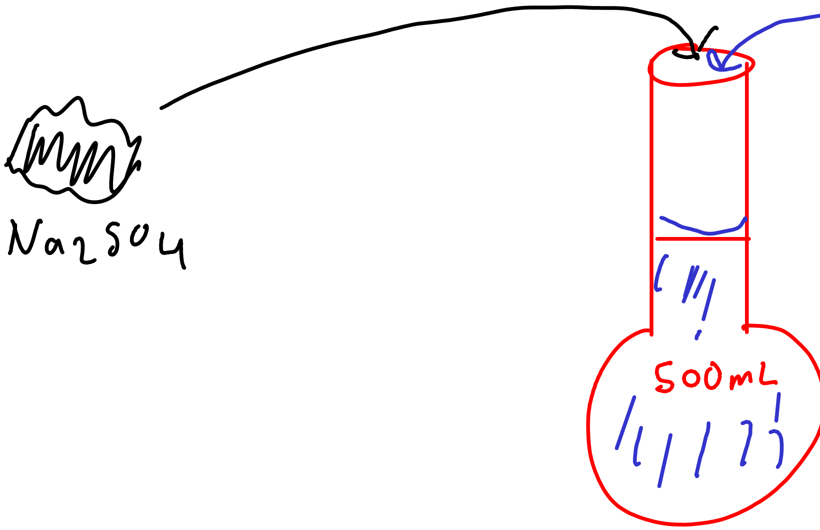
$$0.657 \text{ mol HCl} \times \frac{\text{L}}{6.00 \text{ mol HCl}} = \boxed{0.110 \text{ L}}$$

$(11\bar{0} \text{ mL})$

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.



volumetric flask

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

VOLUMETRIC FLASKS are used to prepare solutions.

We will use the VOLUME and the MOLARITY to find out how many MOLES of sodium sulfate need to be dissolved. Then, we can convert MOLES to MASS using FORMULA WEIGHT.

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

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

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

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

To make the solution, put 35.5 grams of sodium sulfate into a 500 mL volumetric flask and fill to the mark with deionized water.

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.

$$M \times V$$

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

... 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?

$$M_1V_1 = M_2V_2$$

$M_1 = 0.500\ M$ $M_2 = 0.333\ M$

$V_1 = ?$ $V_2 = 150.\ mL$

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

$$V_1 = 99.9\ mL \text{ of } 0.500\ M\ Na_2SO_4$$

Measure out 99.9 mL of 0.500 M sodium sulfate, then add enough water to get a total volume of 150. mL (could do this in a graduated cylinder!)