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 = 1 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

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

ATOMIC WEIGHT is a MEASURED number - in other words, it has significant figures. Usually we can find atomic weights with more significant figures if necessary.

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

Fe: 55.85

$55.85\text{ g Fe} = \text{mol Fe}$

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

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.

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

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

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 ammonium carbonate do we need to weigh out to get 3.65 moles of ammonium carbonate?

First, find the formula of ammonium carbonate!

$$NH_4^+ \quad CO_3^{2-}$$

$$NH_4^+$$

$$(NH_4)_2CO_3$$

Then, find the formula weight of ammonium carbonate:

N : 2×14.01

H : $8 \times 1,008$

C : 1×12.01

O : 3×16.00

$$96.094\,g\,(NH_4)_2CO_3 = mol\,(NH_4)_2CO_3$$

Now, convert moles to mass:

$$3.65\,\cancel{mol\,(NH_4)_2CO_3} \times \frac{96.094\,g\,(NH_4)_2CO_3}{\cancel{mol\,(NH_4)_2CO_3}} = \boxed{351\,g\,(NH_4)_2CO_3}$$

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 ammonium nitrate.

NH_4NO_3 : N: $2 \times 14.01 = 28.02$

H: $4 \times 1.008 = 4.032$

O: $3 \times 16.00 = 48.00$

$80.052 \text{ g } NH_4NO_3 = \text{mol } NH_4NO_3$

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

$$\%N = \frac{28.02 \text{ g N}}{80.052 \text{ g total}} \times 100\% = 35.00\% \text{ N}$$

$$\%H = \frac{4.032 \text{ g H}}{80.052 \text{ g total}} \times 100\% = 5.04\% \text{ H}$$

$$\%O = \frac{48.00 \text{ g O}}{80.052 \text{ g total}} \times 100\% = 59.96\% \text{ O}$$

All 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 <u>M</u> 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

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

*See SECTIONS 4.7 - 4.10 for more information about MOLARITY and solution calculations (p 154 - 162 - 9th edition) (p 156-164 - 10th edition)

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

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

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

$11800\ \text{mL}$

This is much too large of a volume for typical lab-scale work. Use a more concentrated solutio!

What if we used 6.00 M HCl?

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

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

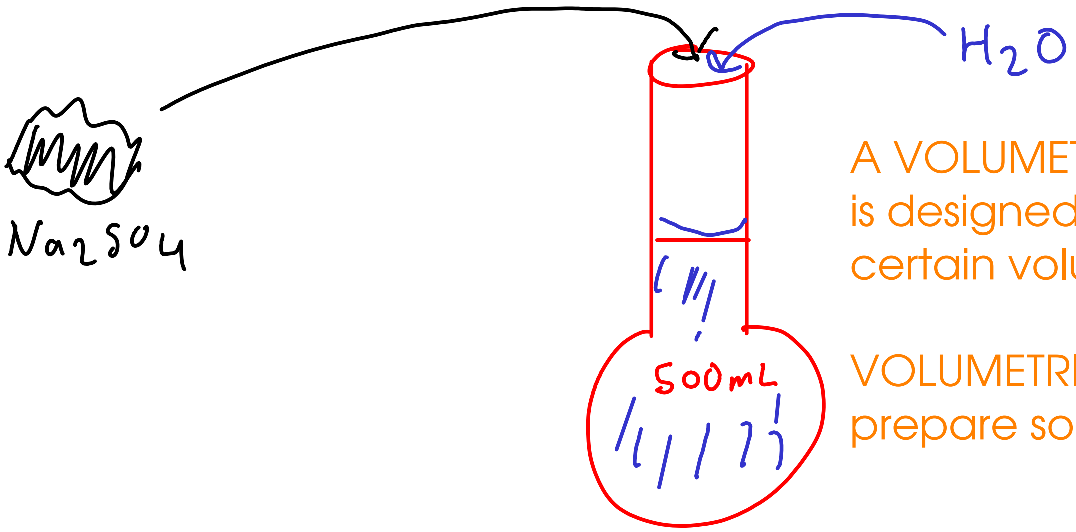
$11\bar{0}\ \text{mL}$

This volume is easy to measure with our lab glassware!

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

Given that we need 0.500 M sodium sulfate (concentraiton) and we need 500 mL (volume), we can calculate the MOLES OF SODIUM SULFATE REQUIRED. Then, convert the moles sodium sulfate to MASS using the formula weight.

$0.500\ mol\ Na_2SO_4 = L$ | $mL = 10^{-3}\ L$ | $142.05\ g\ Na_2SO_4 = mol\ Na_2SO_4$

$$500.\,\cancel{mL} \times \frac{10^{-3}\,\cancel{L}}{\cancel{mL}} \times \frac{0.500\ mol\ \cancel{Na_2SO_4}}{\cancel{L}} \times \frac{142.05\ g\ Na_2SO_4}{mol\ \cancel{Na_2SO_4}} = \boxed{35.5\ g\ Na_2SO_4}$$

To make the solution, weigh out 35.5 grams sodium sulfate, put into a 500 mL volumetric flask, and add water to the mark.