PREDICTING SINGLE REPLACEMENT REACTIONS

$Ag(s) + H_2SO_4(aq) \rightarrow$ NO REACTION

Silver is LESS ACTIVE than hydrogen, so we would expect no reaction to occur. The more active element has ALREADY lost electrons.

$Mg(s) + ZnSO_4(aq) \rightarrow MgSO_4(aq) + Zn(s)$

Magnesium is MORE ACTIVE than zinc, so we would expect that magnesium will replace the zinc from zinc(II) sulfate.

$Pb(s) + 2HCl(aq) \rightarrow PbCl_2(s) + H_2(g)$

Lead is MORE active than hydrogen, so we would expect lead to replace the hydrogen in hydrochloric acid.

$Pb(NO_3)_2(aq) + Zn(s) \rightarrow Zn(NO_3)_2(aq) + Pb(s)$

Zinc is MORE active than lead, so we would expect that zinc would replace the lead in lead(II) nitrate.

CHEMICAL CALCULATIONS - RELATING MASS AND ATOMS

$\_ Na_2CO_3 + \_ 2HCl \rightarrow \_ H_2O + \_ CO_2 + \_ 2NaCl$

Chemical equations are written and balanced in terms of ATOMS and MOLECULES

- While chemical equations are written in terms of ATOMS and MOLECULES, that's NOT how we often measure substances in lab!

- measurements are usually MASS (and sometimes VOLUME), NOT number of atoms or molecules!

Na_2CO_3 solid

HCl solution

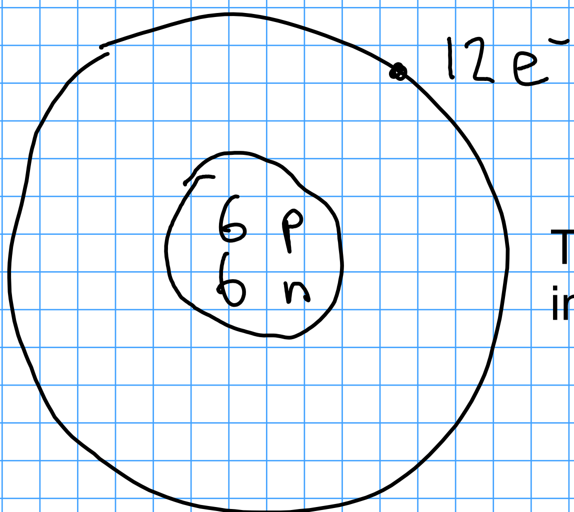
... so how do we relate atoms and molecules with things we routinely measure in lab - like grams and milliliters?

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~~ → $\boxed{12.01\ g}$ ↓

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 | 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 = 1 mol Mg

$$250.\ \cancel{g\ Mg} \times \frac{1 \text{ mol Mg}}{24.31\ \cancel{g\ Mg}} = \boxed{10.3 \text{ mol Mg}}$$

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

Use ATOMIC WEIGHT as a conversion factor. It relates MASS and MOLES.

$$55.85 \text{ g Fe} = 1 \text{ mol Fe}$$

$$1.75 \text{ mol Fe} \times \frac{55.85 \text{ g Fe}}{1 \text{ mol Fe}} = \boxed{97.7 \text{ g Fe}}$$

WHAT ABOUT COMPOUNDS? FORMULA WEIGHT

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

(H_2O)

H_2O

$$H: 2 \times 1.008 = 2.016$$
$$O: 1 \times 16.00 = 16.00$$
$$18.016$$

FORMULA WEIGHT of water

Formula weight = mass of one mole of either an element OR a compound!

$$18.016\ g\ H_2O = 1\ mol\ H_2O$$

$$25.0\ g\ H_2O \times \frac{1\ mol\ H_2O}{18.016\ g\ H_2O} = \boxed{1.39\ mol\ H_2O}$$

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?

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

NH_4^+

$(NH_4)_2CO_3$

N: 14.01 x2

H: 1.008 x8

C: 12.01 x 1

O: 16.00 x 3

96.094 Formula weight of ammonium carbonate

Use the formula weight as a conversion factor. 96.094 grams of ammonium carbonate is equal to a mole of ammonium carbonate.

$$96.094\text{ g } (NH_4)_2CO_3 = 1\text{ mol } (NH_4)_2CO_3$$

$$3.65\text{ mol } \cancel{(NH_4)_2CO_3} \times \frac{96.094\text{ g } (NH_4)_2CO_3}{1\text{ mol } \cancel{(NH_4)_2CO_3}} = \boxed{351\text{ g } (NH_4)_2CO_3}$$

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_4^+ NO_3^-

NH_4NO_3:

$N: 14.01 \times 2 = 28.02$

$H: 1.008 \times 4 = 4.032$

$O: 16.00 \times 3 = 48.00$

$80.052\text{ g } NH_4NO_3 = 1\text{ mol } NH_4NO_3$

$\%N: \dfrac{28.02\text{ g N}}{80.052\text{ g } NH_4NO_3} \times 100\% = 35.00\%\ N$

$\%H: \dfrac{4.032\text{ g H}}{80.052\text{ g } NH_4NO_3} \times 100\% = 5.04\%\ H$

$\%O: \dfrac{48.00\text{ g O}}{80.052\text{ g } NH_4NO_3} \times 100\% = 59.96\%\ O$

These percentages should sum to 100% (within rounding error)

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

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

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

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

$$6.0 \text{ mol HCl} = 1 \text{ L}$$

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