SINGLE REPLACEMENT REACTIONS

$$A + BC \longrightarrow AC + B$$

One element, usually a metal, replaces another element in a compound. This forms a new compound and leaves behind a new free element!

example: $\underset{0}{Cu}(s) + 2\,\underset{+1}{Ag}NO_3(aq) \longrightarrow \underset{+2}{Cu}(NO_3)_2(aq) + 2\,\underset{0}{Ag}(s)$

Copper loses electrons, goes from 0 charge to +2 charge!

Silver gains electrons, goes from +1 charge to 0 charge!

... but just because you combine an element and a compound doesn't mean that a reaction will occur. Some combinations react, some don't!

- Whether a reaction occurs depends on how easily the replacing and replaced elements lose electrons. An atom that loses electrons more easily will end up in IONIC form (in other words, in the compound). An atom that loses electrons less easily will end up as a free element.

- We say that an atom that loses elecrons more easily that another is MORE ACTIVE than the other element. But how would you get information about ACTIVITY?

A single replacement reaction is an example of a reaction where ELECTRON TRANSFER is a driving force. Electron transfer reactions are generally called OXIDATION-REDUCTION reactions.

ACTIVITY SERIES

- comes from experiental data. It's a list of elements in order of their ACTIVITY - more active elements are higher in the series!

A sample activity series

Activity

Sodium Na^+

Magnesium Mg^{2+}

Aluminum Al^{3+}

Zinc Zn^{2+}

Iron Fe^{2+}

Lead Pb^{2+}

Hydrogen H^+

Copper Cu^{2+}

Silver Ag^+

Gold Au^{3+}

Very active metals will replace hydrogen in acids AND in water!

Metals more active than hydrogen will replace hydrogen in acids!

These metals are unreactive to most acids!

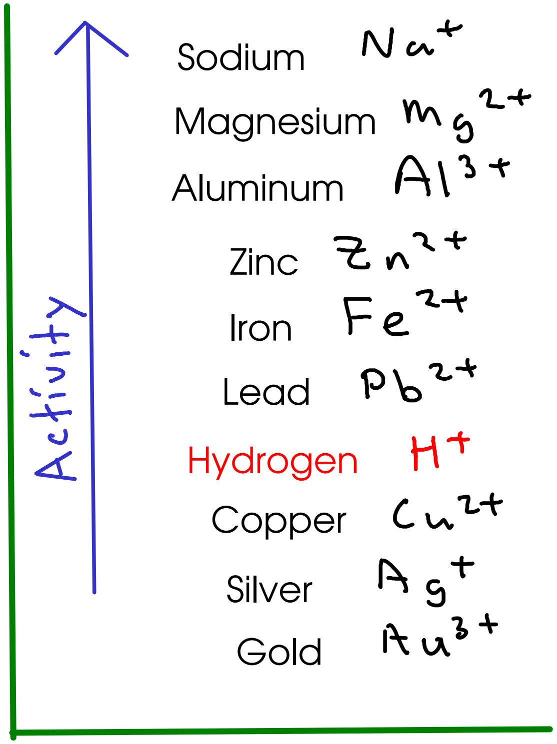
PREDICTING SINGLE REPLACEMENT REACTIONS

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

Since LEAD is more active than hydrogen, we expect it to replace H in HCl.

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

Since ZINC is more active than LEAD, the reaction will proceed. Zn will replace Pb in the compound!



Sodium	Na^+
Magnesium	Mg^{2+}
Aluminum	Al^{3+}
Zinc	Zn^{2+}
Iron	Fe^{2+}
Lead	Pb^{2+}
Hydrogen	H^+
Copper	Cu^{2+}
Silver	Ag^+
Gold	Au^{3+}

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

Since SILVER is NOT more active than HYDROGEN, no reaction will occur.

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

Since MAGNESIUM is more active than ZINC, a reaction occurs!

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

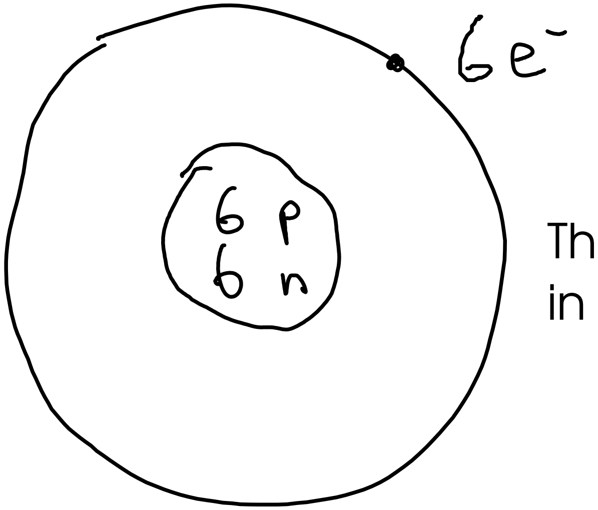
... so how do we relate atoms and molecules with things we routinely measure in lab - like grams and milliliters?

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.

$$\mathrm{Mg} : 24.31 \quad \Big| \quad 24.31\ \mathrm{g\ Mg} = \mathrm{mol\ Mg}$$

"mol" is the abbreviation for "mole"

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

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

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

Note: Atomic weights are measured numbers, so they DO have significant figures.

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

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

WHAT ABOUT COMPOUNDS? FORMULA WEIGHT

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

(H_2O)

H_2O

$$\begin{aligned} H &: 2 \times 1.008 = 2.016 \\ O &: \underline{1 \times 16,00 = 16,00} \\ & \qquad\qquad\quad 18,016 \end{aligned}$$

FORMULA WEIGHT of water

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

$$18.016\,g\,H_2O = mol\,H_2O$$

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

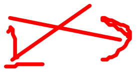
Formula weight goes by several names:

- 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?

First, we need the chemical formula of ammonium carbonate:

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



$(NH_4)_2CO_3$

Now that we have the formula, find the formula weight:

N: 2 x 14.01

H: 8 x 1.008

C: 1 x 12.01

O: 3 x 16.00

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

Convert moles to mass:

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