A few more double replacement / exchange examples:

$CaCl_2(aq) + 2AgNO_3(aq) \longrightarrow Ca(NO_3)_2(aq) + 2AgCl(s)$ ✓

Ca^{2+} Cl^- Ag^+ NO_3^-

PRECIPITATION of silver(I) chloride drives this reaction!

* In an exchange reaction, transition metals KEEP their charge.

$H_3PO_4(aq) + 3NaOH(aq) \longrightarrow 3\underline{H_2O(l)} + Na_3PO_4(aq)$ ✓

H^+ PO_4^{3-} Na^+ OH^-

This is a NEUTRALIZATION reaction. Water forms as a product!

$KCl(aq) + NaNO_3(aq) \longrightarrow \overset{\text{NO REACTION}}{\cancel{KNO_3(aq) + NaCl(aq)}}$

K^+ Cl^- Na^+ NO_3^-

NO REACTION occurs! There's no driving force. In other words: (1) No solid forms, (2) no stable molecule forms, (3) no gas forms ... so we observe nothing.

$H_2SO_4(aq) + 2NaHCO_3(aq) \longrightarrow Na_2SO_4(aq) + 2\underline{H_2CO_3}(aq)$

H^+ SO_4^{2-} Na^+ HCO_3^-

Carbonic acid is unstable in water - it DECOMPOSES when formed in one of these reactions

$H_2SO_4(a\ ) + 2NaHCO_3(aq) \longrightarrow Na_2SO_4(aq) + \underline{2H_2O(l) + 2CO_2(g)}$ ✓

$Fe(NO_3)_3(aq) + 3NaOH(aq) \rightarrow 3NaNO_3(aq) + \underline{Fe(OH)_3(s)}$ ✓

Fe^{3+} NO_3^- Na^+ OH^-

This is a PRECIPITATION. Formation of iron(III) hydroxide drives this reaction.

$2HCl(aq) + Pb(NO_3)_2(aq) \rightarrow 2HNO_3(aq) + \underline{PbCl_2(s)}$ ✓

H^+ Cl^- Pb^{2+} NO_3^-

This is another PRECIPITATION. The solid formed is lead(II) chloride. Most chlorides dissolve in water, but lead(II) chloride is an exception - like silver(I) chloride.

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.

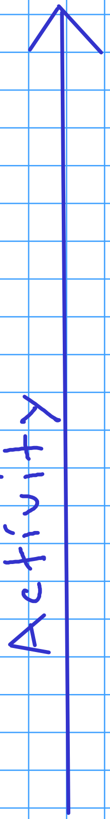
- We say that an atom that loses elecrons more easily that another is MORE ACTIVE than the other element. But how would you get information about ACTIVITY?

ACTIVITY SERIES

p164 - text

- 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



Sodium	Na^+	Very active metals will replace hydrogen in acids AND in water!
Magnesium	Mg^{2+}	
Aluminum	Al^{3+}	Metals more active than hydrogen will replace hydrogen in acids!
Zinc	Zn^{2+}	
Iron	Fe^{2+}	
Lead	Pb^{2+}	
Hydrogen	H^+	
Copper	Cu^{2+}	These metals are unreactive to most acids!
Silver	Ag^+	
Gold	Au^{3+}	

PREDICTING SINGLE REPLACEMENT REACTIONS

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

Silver is LESS active than hydrogen, so we would not expect it to REPLACE hydrogen in a compound.

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

Magnesium is MORE active than zinc. We expect that magnesium WILL REPLACE zinc!

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

Lead is MORE active than hydrogen, so we'd expect this reaction to proceed as written above!

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

Zinc is MORE active than lead, so we'd expect this reaction to proceed as written above!

DEMONSTRATION REACTIONS

$$Cu(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2(g) \ ?$$

prediction: copper is less active than hydrogen, so it will NOT replace hydrogen - NO REACTION

observation: NO REACTION

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

prediction: zinc is more active than copper, so we should see a replacement reactoin

observation: REACTION (the zinc metal turns black)

$$Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$$

prediction: reaction, since zinc is more active than hydrogen.

observation: reaction: bubbles observed

$$Zn(s) + 2AgNO_3(aq) \rightarrow Zn(NO_3)_2(aq) + 2Ag(s)$$

prediction: reaction, since zinc is more active than silver

observation: reaction. The zinc turns black almost immediately.

CHEMICAL CALCULATIONS - RELATING MASS AND ATOMS

$$\underline{\quad}\,Na_2CO_3 + \underline{2}\,HCl \rightarrow \underline{\quad}\,H_2O + \underline{\quad}\,CO_2 + \underline{2}\,NaCl$$

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

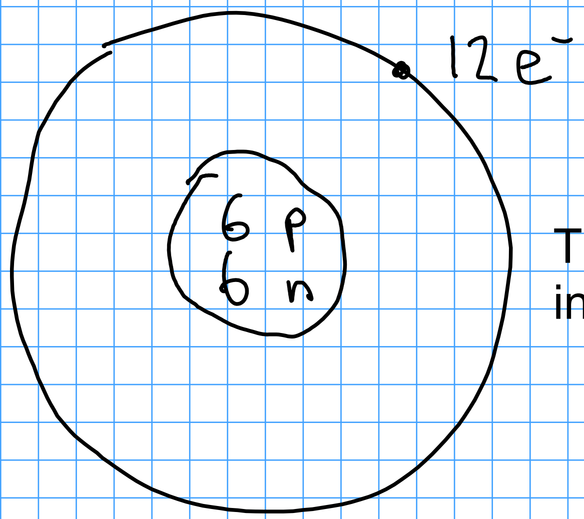
... so how do we relate atoms and molecules with things we routinely measure in lab - like grams and milliliters?

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~~ → $\boxed{12.01\text{ g}}$

↓

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.

$$\text{Mg} : 24.31 \quad \Big| \quad 24.31\ \text{g Mg} = 1\ \underline{\text{mol}}\ \text{Mg}$$

"mol" is the abbreviation for "mole"

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

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