Examples of acid-base chemistry:

When a neutralization reaction occurs, energy is released. There will be a temperature increase!

$H_2SO_4(aq) + 2NaOH(aq) \longrightarrow 2H_2O(l) + Na_2SO_4(aq)$ ✓

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

Potential products:

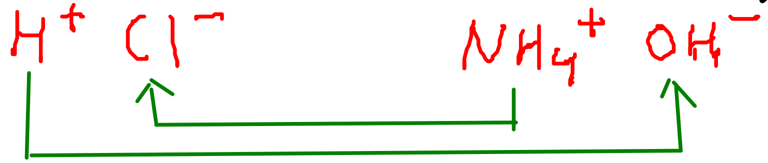
$\dfrac{H^+ \ OH^-}{H_2O}$

$\dfrac{Na^+ \ SO_4^{2-} \\ Na^+}{Na_2SO_4}$

Why "neutralization?

*The products of the reaction (water and a "salt") do not have any of the characteristic properties of acids and bases. These properties can be said to be "neutralized".

$HCl(aq) + NH_4OH(aq) \longrightarrow H_2O(l) + NH_4Cl(aq)$ ✓



H^+ Cl^- NH_4^+ OH^-

DOUBLE REPLACEMENTS THAT FORM GASES

① Formation of hydrogen sulfide: H_2S

- need an ACID (source of hydrogen ion) and a SULFIDE

$$H_2SO_4(aq) + Na_2S(aq) \longrightarrow Na_2SO_4(aq) + \underline{\underline{H_2S(g)}}$$

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

Na^+ SO_4^{2-} | Na_2SO_4
Na^+

H^+ S^{2-} | H_2S
H^+

Gas with rotten-egg odor!
Observation: Odor and visible gas bubbles

② Formation of carbonic acid and carbon dioxide:

$$H_2CO_3(aq) \longrightarrow H_2O(l) + \underline{\underline{CO_2(g)}}$$

- to form carbonic acid by double replacement, you need a source of hydrogen ion (ACID) and a source of carbonate (can be CARBONATE or BICARBONATE)

CO_3^{2-} HCO_3^-

Example of a reactions that forms carbonic acid, then gas: The "baking soda volcano"!

VINEGAR

BAKING SODA

$$2HC_2H_3O_2(aq) + Na_2CO_3(aq) \longrightarrow 2NaC_2H_3O_2(aq) + \boxed{H_2CO_3}$$

$NaC_2H_3O_2$ H_2CO_3

... but carbonic acid decomposes, and we get GAS BUBBLES

$$\boxed{2HC_2H_3O_2(aq) + Na_2CO_3(aq) \longrightarrow 2NaC_2H_3O_2(aq) + H_2O(l) + CO_2(g)}$$

This is the overall process. We show carbon dioxide and water as products, since we want to show the reaction as it's actually observed -with carbonic acid broken down to water and (gaseous) carbon dioxide.

A few more double replacement / exchange examples:

See page 172 for a solubility chart

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

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

PRECIPITATION of AgCl drives this reaction!

*Note: In exchange reactions, transition metal ions do not change their charge!

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

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

Formation of WATER drives this reaction. It's a NEUTRALIZATION.

Detect this reaction by release of heat!

$KCl(aq) + NaNO_3(aq) \longrightarrow$ ~~$KNO_3(aq) + NaCl(aq)$~~ NO REACTION

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

NO REACTION occurs. There is no DRIVING FORCE, since both sodium chloride and potassium nitrate are both soluble ionic compounds! (They exist in water as free ions - just like the original compounds.)

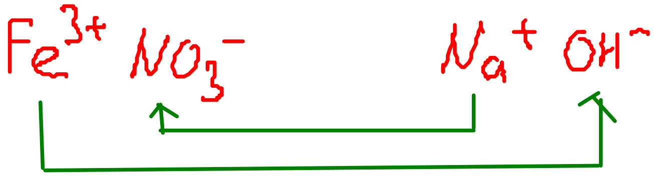
$H_2SO_4(aq) + 2NaHCO_3(aq) \longrightarrow Na_2SO_4(aq) + 2H_2CO_3$

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

CARBONIC ACID decomposes when formed to make water and carbon dioxide gas (which escapes as bubbles!)

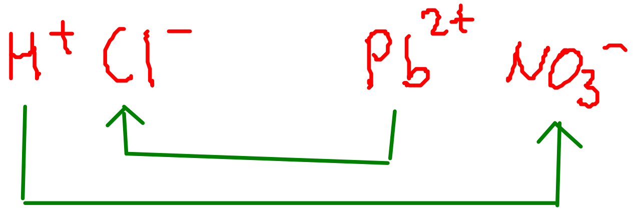
$H_2SO_4(aq) + 2NaHCO_3(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l) + 2CO_2(g)$

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



Formation of insoluble iron(III) hydroxide drives this reaction!

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



Formation of insoluble lead(II) chloride drives this reaction!

Reactions involving an acid or a base will sometimes be precipitations - check the products!

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.

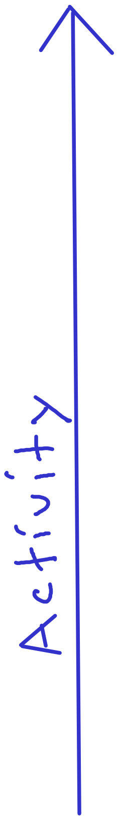
- We say that an atom that loses elecrons more easily that another is MORE ACTIVE than the other element. But how would you get information about ACTIVITY?

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

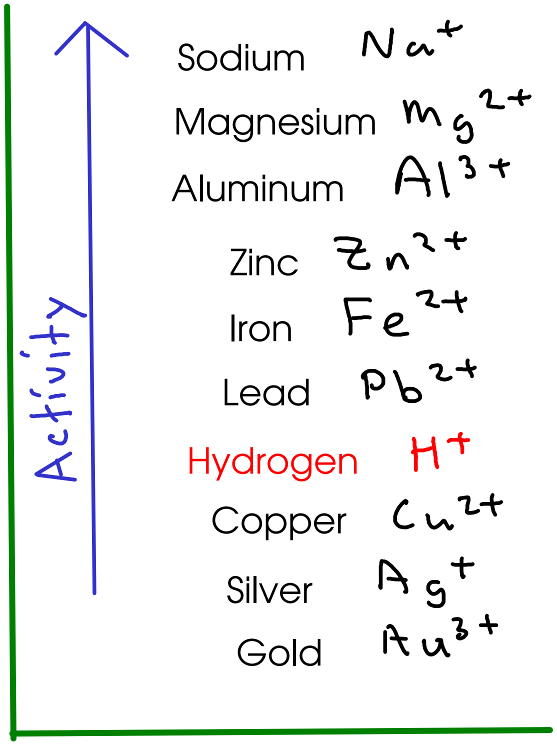
- comes from experiental data. It's a list of elements in order of their ACTIVITY - more active elements are higher in the series!

A sample activity series



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



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+}

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

Lead is MORE ACTIVE than hydrogen, so we would expect lead to replace hydrogen in this reaction.

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

Zinc is MORE ACTIVE than lead, so we expect zinc to replace lead.

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

Silver is LESS ACTIVE than hydrogen, so we do not expect silver to transfer electrons to hydrogen.

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

Magnesium is MORE ACTIVE than zinc, so we expect magnesium to give electrons to zinc and replace it in the compound.

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

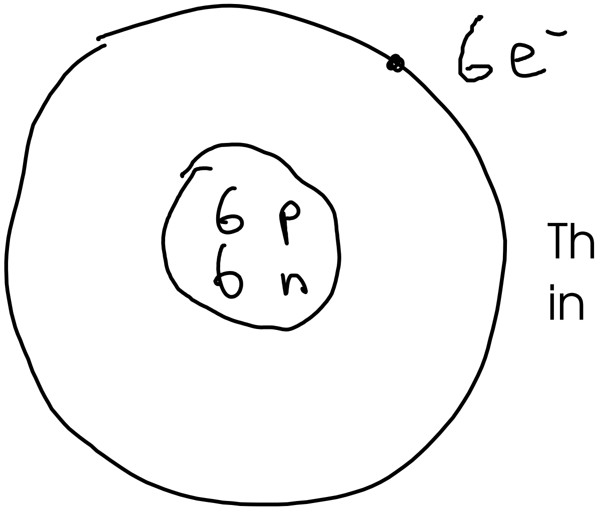
... so how do we relate atoms and molecules with things we routinely measure in lab - like grams and milliliters?

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 ~~am~~u → $\boxed{12.01\ g}$

↓

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!