Electrolytes and Ionic Theory

- electrolytes: substances that dissolve in water to form charge-carrying solutions

* Electrolytes form ions in solution - (ions that are mobile are able to carry charge!). These IONS can undergo certain kinds of chemistry!

IONIC THEORY

- the idea that certain compounds DISSOCIATE in water to form free IONS

What kind of compounds?

- Soluble ionic compounds
- Acids (strong AND weak)
- Bases (strong AND weak)

The ions formed may interact with each other to form NEW compounds!

Strong vs weak?

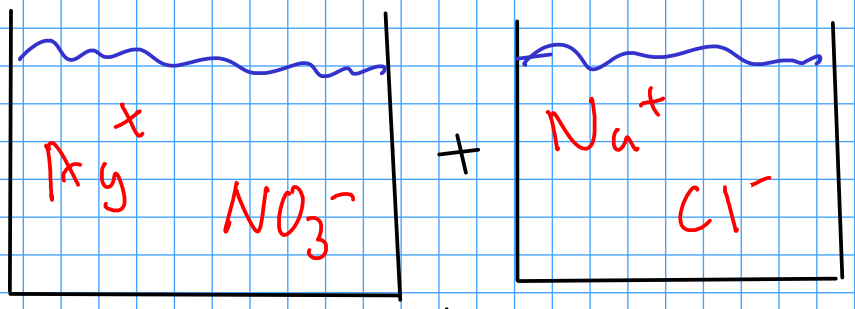
- If an electrolyte COMPLETELY IONIZES in water, it's said to be STRONG
- If an electrolyte only PARTIALLY IONIZES in water, it's said to be WEAK
- Both kinds of electrolyte undergo similar kinds of chemistry.

- What good is ionic theory?

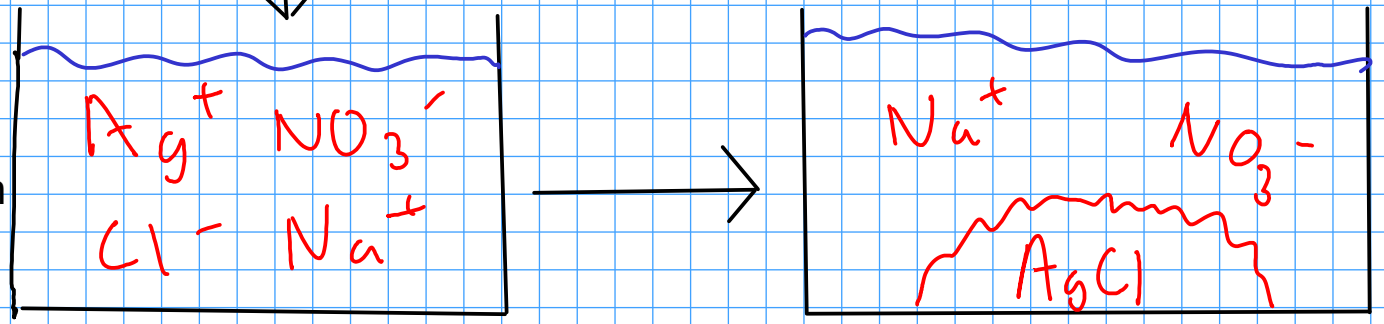
  - provides an easy-to-understand MECHANISM for certain kinds of chemical reactions.

    - "Exchange" reactions. (a.k.a "double replacement" reactions)

$$AgNO_3(aq) + NaCl(aq) \longrightarrow AgCl(s) + NaNO_3(aq)$$



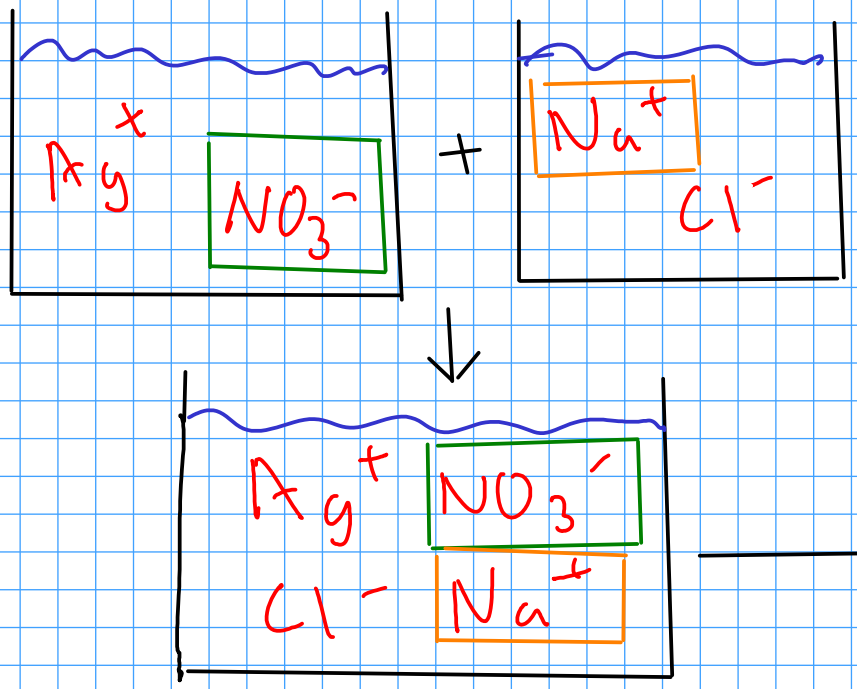
These free ions mix and can interact with each other!



"ion soup"!

Insoluble AgCl falls out of solution as it is formed - "precipitation"

Looking a bit more closely...



The nitrate and sodium ions do not really participate in this reaction. They start and end in exactly the same state. We cal them "SPECTATOR IONS".

$AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$ "Molecular equation"

$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$ "Net ionic equation"

(The net ionic equation shows only ions and substances that change during the course of the reaction!)

- The net ionic equation tells us that any source of aqueous silver and chloride ions will exhibit this same chemistry, not just silver nitrate and sodium chloride!

A bit more about molecular, ionic, and net ionic equations

- molecular equations: Represent all substances (even ionic substances) as if they were molecules. Include spectator ions, and do not show charges on ions. Traditional chemical equations.

- ionic equations: Show all free ions - including spectators - in a chemical reaction. Molecules and WEAK electrolytes are shown as molecules. STRONG electrolytes (like HCl) are shown as ions. Ions that are part of undissolved ionic compounds are shown as molecules.

- NET ionic equation: An ionic equation that leaves out spectator ions. Intended to show only things that actually change in a reaction.

$$AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$$

$$Ag^+(aq) + NO_3^-(aq) + Na^+(aq) + Cl^-(aq) \rightarrow AgCl(s) + Na^+(aq) + NO_3^-(aq)$$

$$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$$

"Undisolved ionic compounds":

How can I tell if an ionic compound dissolves in water?

- consult experimental data: "solubility rules" (p128, 8th edition)

A few of the "rules"...

- Compounds that contain a Group IA cation (or ammonium) are soluble
- Nitrates and acetates are soluble
- Carbonates phosphates, and hydroxides tend to be insoluble

Exchange Chemistry

- Three kinds of exchange chemistry.

1. PRECIPITATION
2. ACID/BASE or NEUTRALIZATION
3. GAS FORMATION (formation of unstable molecules)

- Just because you mix together two ionic compounds does NOT mean that a reaction will occur. You need a DRIVING FORCE for a reaction.

PRECIPITATION

- driving force is the formation of an insoluble ionic compound.

$$3MgCl_2(aq) + 2Na_3PO_4(aq) \rightarrow 6NaCl(aq) + \boxed{Mg_3(PO_4)_2(s)}$$

Insoluble!

ions: Mg^{2+} Cl^- Na^+ PO_4^{3-}

Possible products: $NaCl$, $Mg_3(PO_4)_2$

$$3Mg^{2+}(aq) + 2PO_4^{3-}(aq) \rightarrow Mg_3(PO_4)_2(s)$$

Net Ionic Equation

When you're trying to complete a precipitation reaction:

1. Write the IONS that form when the reactants are dissolved.
2. Make NEW compounds by pairing up cations with anions. Don't forget that the positive and negative charges must balance each other out!
3. Use the solubility rules to determine the PHASE of each new compound - solid or aqeous.
4. Balance the overall equation.

$MgCl_2(aq) + NaC_2H_3O_2(aq) \rightarrow$ NO REACTION!

~~$NaCl(aq) + Mg(C_2H_3O_2)_2(aq)$~~

Ions: Mg^{2+} Cl^- Na^+ $C_2H_3O_2^-$

Possible products: $NaCl$, $Mg(C_2H_3O_2)_2$

... but both possible products are SOLUBLE ... so has anything really happened? NO.

This "reaction" is best described as "No reaction"!

ACID/BASE or NEUTRALIZATION reactions

- the driving force of these reactions is the formation of water molecules.

$H^+(aq) + OH^-(aq) \longrightarrow H_2O(\ell)$ Net ionic equation

From the acid — From the base

Stable water molecule!

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

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

Possible products: "HOH" (H_2O), Na_2SO_4

- How can this reaction be detected?
  - pH detector
  - do the products have similar chemical properties to the reactants?
  - release of heat!

GAS FORMATION / OTHER MOLECULES

- There are a few other molecules that can be made with exchange-type chemistry.
- Most of these molecules are unstable and can break apart to form gases.

- Formation of a weak acid:
  - The formation of ANY weak acid in an exchange-type reaction can be a driving force.
  - Some weak acids are unstable and can break apart into gas molecules.

$$H_2CO_3(aq) \longrightarrow H_2O(\ell) + \boxed{CO_2(g)}$$

Gas bubbles can leave solution!

... but how would you form carbonic acid in an exchange-type reaction?

acid + carbonate CO_3^{2-}

OR

acid + bicarbonate HCO_3^-

$$H_2SO_4(aq) + 2NaHCO_3(aq) \rightarrow Na_2SO_4(aq) + \boxed{2H_2CO_3(aq)}$$

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

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

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

... but when we mix sulfuric acid and sodium bicarbonate, we observe BUBBLES. We need to write an equation that agrees with our observations. We know that carbonic acid decomposes, so we go ahead and put that into our equation.

$H_2CO_3(aq) \longrightarrow H_2O(\ell) + CO_2(g)$

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

Other molecules of interest:

H_2SO_3 : sulfurous acid - React an ACID with a SULFIDE

$H_2SO_3(aq) \rightarrow H_2O(\ell) + SO_2(g)$

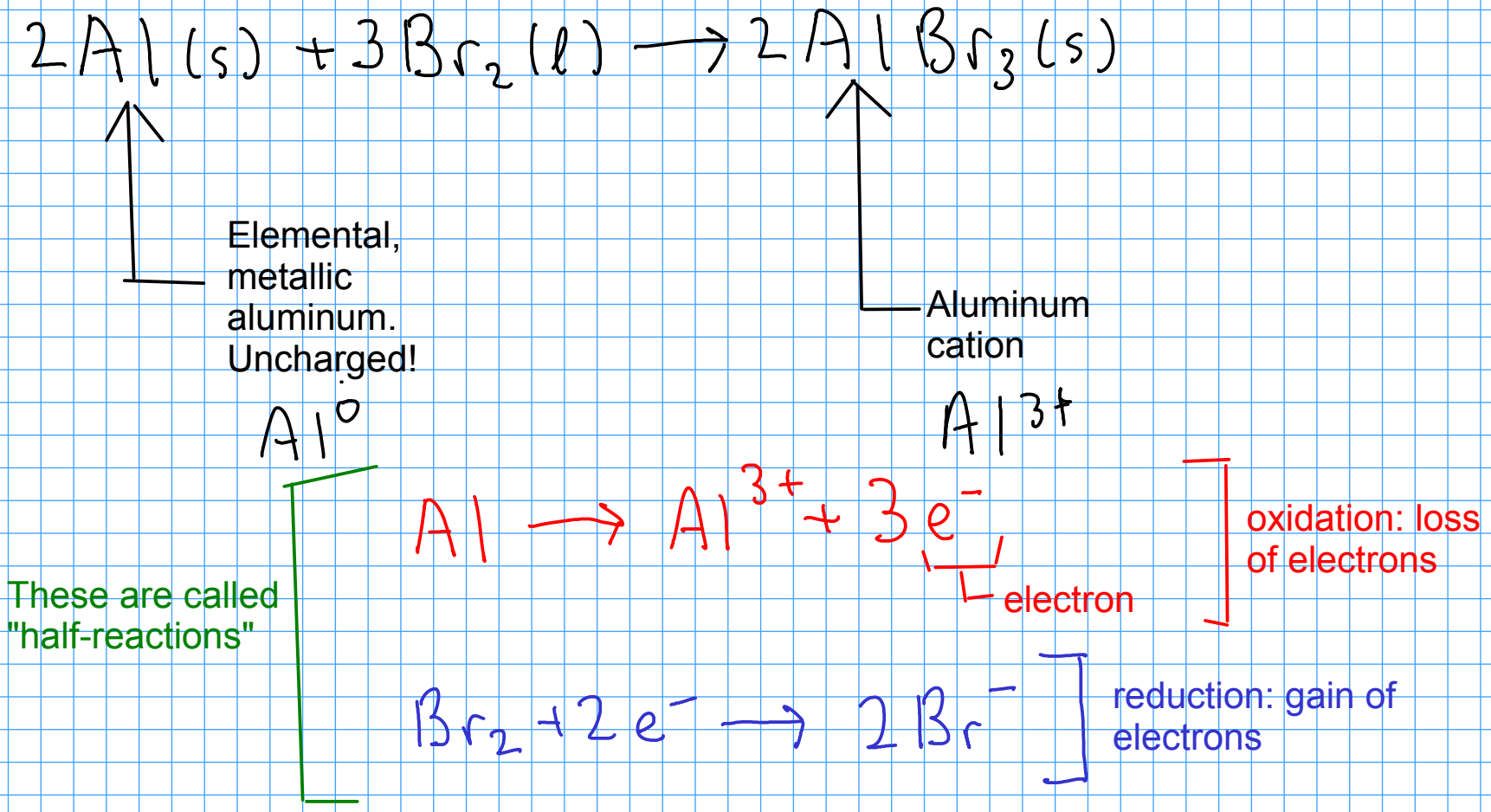
H_2S : hydrogen sulfide (gas) - React an ACID with a SULFITE

OXIDATION / REDUCTION CHEMISTRY

- Exchange reactions involve ions pairing up, but the ions themseves are not formed in exchange reactions. Exchanges start with pre-existing ions.

... but the ions have to be produced somehow - through a chemistry that involves the transfer of electrons.

- oxidation / reduction chemistry ("redox" chemistry) involves transfer of electrons and can make ions.



- oxidation and reduction always occur together. In other words, we can't just make free electrons using oxidation without giving them somewhere to go.

- Many of the five types of reactions that we learned about in previous courses are redox reactions!

  - Combinations (often but not always redox)

  - Decompositions (often redox)

  - Single replacement (always redox)

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

$$Cu \rightarrow Cu^{2+} + 2e^- \quad \text{oxidation}$$

$$2Ag^+ + 2e^- \rightarrow 2Ag(s) \quad \text{reduction}$$

$$Cu(s) + 2Ag^+(aq) \rightarrow Cu^{2+}(aq) + 2Ag(s)$$

  - Combustion

$$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$$

$$2Mg(s) \rightarrow 2Mg^{2+} + 4e^- \quad \text{oxidation}$$

$$O_2(g) + 4e^- \rightarrow 2O^{2-} \quad \text{reduction}$$