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?

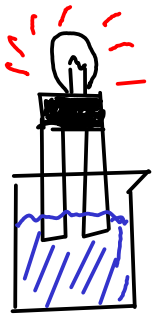
- Soluble ionic compounds
- Acids (strong AND weak)
- Bases (strong AND weak)

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.

Ionic theory experiment



Simple conductivity tester: The stronger the electrolyte, the brighter the light.

SOME PURE COMPOUNDS (MOLECULAR AND IONIC)

DISTILLED WATER

Pure water is a NONCONDUCTOR. We expect this for molecules, since there are no charge carriers.

SOLID SODIUM CHLORIDE

Pure sodium chloride is a nonconductor in the solid state, since its ions are not free to move!

SOLID SUCROSE $C_{12}H_{22}O_{11}$

Like water, sucrose molecules are unable to carry a charge. And like NaCl solid, the molecules aren't free to move!

MOLECULAR AND IONIC SOLUTIONS

SODIUM CHLORIDE + WATER

Bright light. Sodium chloride is an electrolyte - which dissociates in water to form free ions. These ions allow the salt water solution to conduct electricity very well. Typical for ionic substances.

SUCROSE + WATER

No light. Sucrose is a NONELECTROLYTE. When sucrose dissolves, it does not react with the water and break into ions. This is typical behavior for molecular substances.

ACIDS

PURE (GLACIAL) ACETIC ACID

Pure acetic acid is a nonconductor. (So that means it's a MOLECULAR substance like water is!)

ACETIC ACID + WATER

The light bulb lights, but more dimly than the NaCl experiment we did earlier. Acetic acid is an electrolyte, and we suspect it's a WEAK ELECTROLYTE.

2M ACETIC ACID (AQUEOUS)

The light bulb lights up less brightly than the 2M HCl, so acetic acid must be a WEAK ELECTROLYTE.

2M HYDROCHLORIC ACID (AQUEOUS)

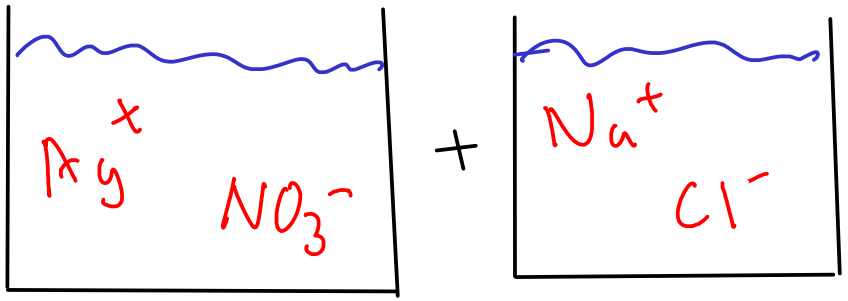
Lights up more brightly than 2M acetic acid, so it's a stronger electrolyte than acetic acid it. (HCl is a strong electrolyte, but we didn't prove it with this experiment...)

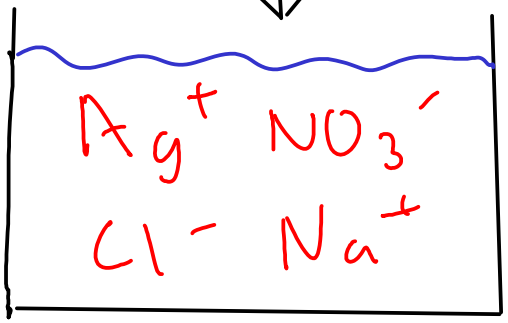
- What good is ionic theory?

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

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

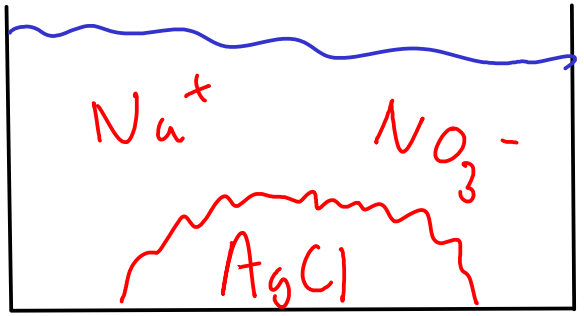
$$AgNO_3(aq) + NaCl(aq) \longrightarrow AgCl(s) + NaNO_3(aq)$$





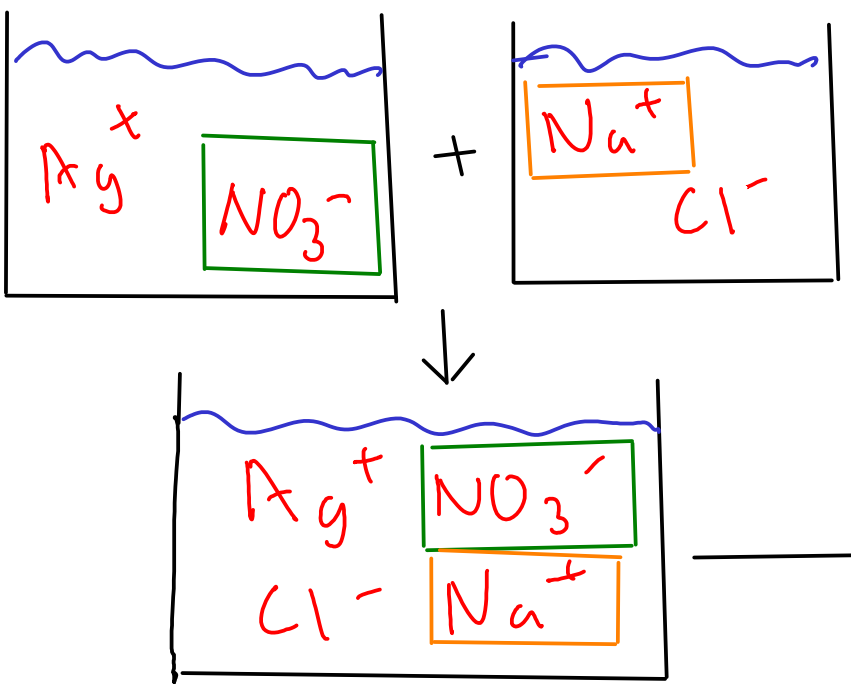
These free ions mix and can interact with each other!

"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 call 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.

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

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

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

* You can get from the complete ionic equation to the net ionic equation by crossing out the spectator ions on both sides.

"Undissolved ionic compounds":

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

- consult experimental data: "solubility rules"!

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

See p 129 9th edition (10th ed: p131)

... or see the web site for a solubility chart.

$Fe(OH)_3$

#8 - hydroxides generally insoiluble, except Group IA, ammonium, calcium strontium, barium

Conclusion: iron(III) hydroxide is insoluble.

$Ca(C_2H_3O_2)_2$

#2 - acetates are soluble, no common exceptions.

Conclusion: calcium acetate is soluble.

AgI

#3 - Iodides usually dissolve, exceptions are silver, mercury, lead

Conclusion: silver(I) iodide is INSOLUBLE

$BaCO_3$

#5 - Most carbonates are insoluble

Conclusion - barium carbonate is insoluble.

Exchange Chemistry

- Three kinds of exchange chemistry.

1. PRECIPITATION

2. ACID/BASE or NEUTRALIZATION

3. GAS FORMATION (formation of unstable molecules)
   - SOME (but not all) reactions that form gases are examples of exchange chemistry.

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 REACTIONS

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

$3MgCl_{2(aq)} + 2Na_3PO_{4(aq)} \rightarrow 6NaCl_{(aq)} + Mg_3(PO_4)_{2(s)}$

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

Mg^{2+} PO_4^{3-}

Formation of SOLID magnesium phosphate DRIVES this PRECIPITATION reaction!

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 aqueous.
4. Balance the overall equation.