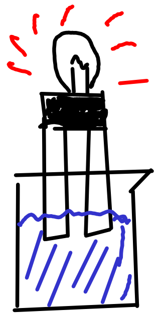
Ionic theory experiment



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

SOME PURE COMPOUNDS (MOLECULAR AND IONIC)

DISTILLED WATER

No light. Pure water is a NONCONDUCTOR. In other words, it's unable to carry an appreciable electric current.

SOLID SODIUM CHLORIDE

No light. Solid sodium chloride is a nonconductor. There ARE potential charge carriers, but they're stuck in the solid structure.

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

Like water, solid sucrose is a NONCONDUCTOR. This is typical behavior for molecular substances.

MOLECULAR AND IONIC SOLUTIONS

SODIUM CHLORIDE + WATER

Bright light. Sodium chloride (like all soluble ionic compounds) is a STRONG ELECTROLYTE that breaks apart in water to form free ions.

SUCROSE + WATER

No light. Sucrose is a NONELECTROLYTE - since its solution does not carry a current. When sucrose dissolves, it remains in the molecular form. This is typical molecule behavior.

ACIDS

PURE (GLACIAL) ACETIC ACID

No light. Like water, this molecular substance does not conduct electricity in the liquid state, since there are no charge carriers (ions) that can move around.

ACETIC ACID + WATER

Dim light. Acetic acid is a WEAK ELECTROLYTE - meaning that SOME (but not all) acetic acid molecules break apart into ions in water.

2M ACETIC ACID (AQUEOUS)

Somewhat dim light. So, acetic acid is a WEAK ELECTROLYTE - it lights up much less brightly than for 2M HCl (the same concentration)

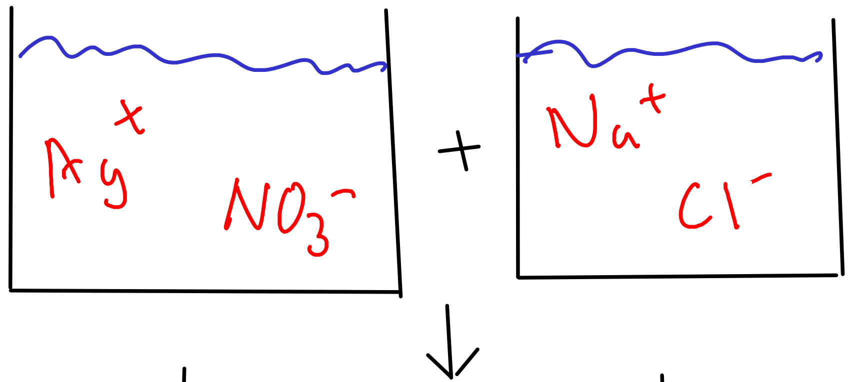
2M HYDROCHLORIC ACID (AQUEOUS)

Bright light. Hydrochloric acid is a STRONG ELECTROLYTE (or at least, it's a stronger eloectrolyte than acetic acid is!)

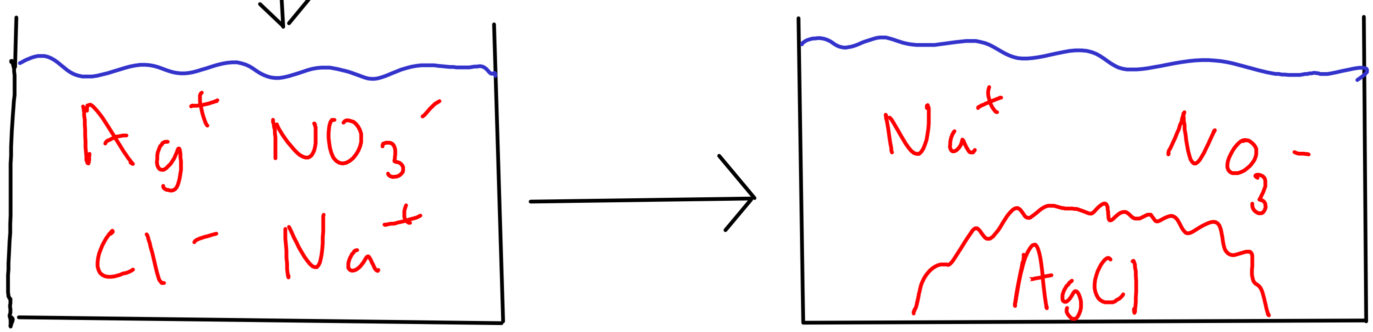
- What good is ionic theory?

- provides an easy-to-understand MECHANISM for certain kinds of chemical reactions.
    - "Exchange" reactions. (a.k.a "double replacement" reactions)

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



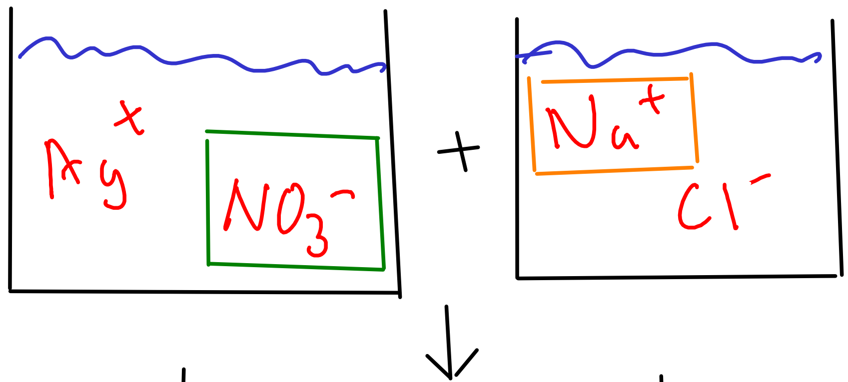
These free ions mix and can interact with each other!



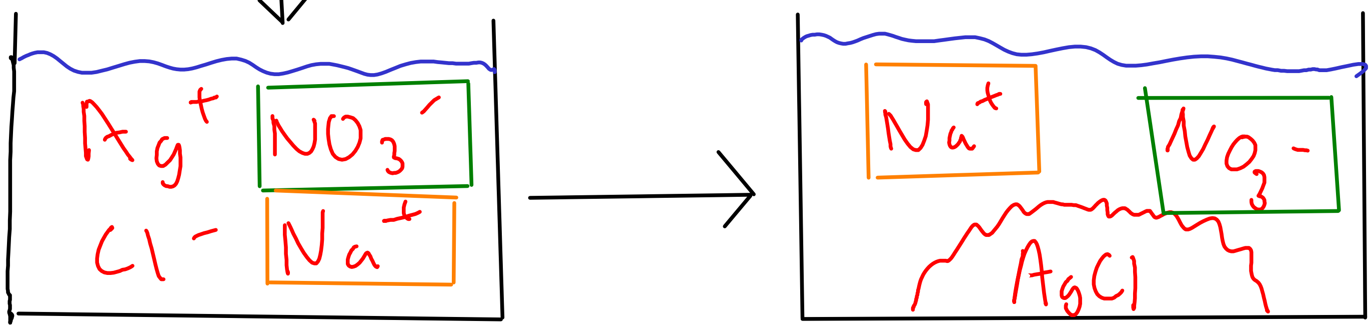
"ion soup"!

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.

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

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

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

* 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.

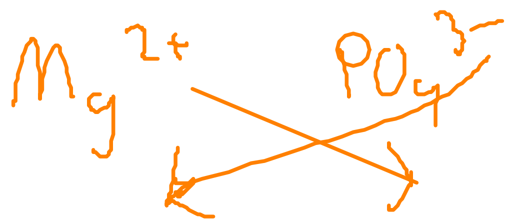
$$3MgCl_2(aq) + 2Na_3PO_4(aq) \rightarrow 6NaCl(aq) + Mg_3(PO_4)_2(s)$$

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

Potential products: $NaCl$

$Mg_3(PO_4)_2$

The formation of INSOLUBLE magnesium phosphate drives this 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.

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

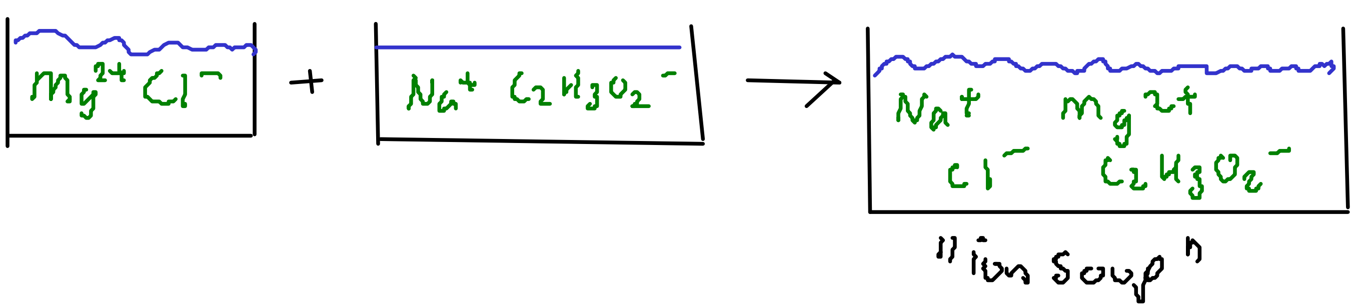
ions: Mg^{2+} Cl^- Na^+ $C_2H_3O_2^-$

"exchange"

$Mg(C_2H_3O_2)_2$ ... dissolves in water

$NaCl$ ... dissolves in water

So, no solid forms here. All possible combinations of these four ions result in compounds that dissolve readily in water.



NO CHANGE, therefore NO DRIVING FORCE, and NO REACTION

* We will learn about other driving forces than the formation of solid, but these driving forces do not apply to this reaction

ACID/BASE REACTIONS (also called NEUTRALIZATION REACTIONS)

- There are several stable molecules that may be formed in double replacement reactions, but the most common is WATER!

- Double replacement reactions that form water are also called "neutralizations"

$$HA + BOH \rightarrow H_2O + BA$$

acid (HA), base (BOH), salt (BA) ← ionic compound

$H^+ A^-$ $B^+ OH^-$

H^+ and OH^- → H_2O "HOH"; B^+ and A^- → BA

* To make water (H_2O), you need a source of hydrogen ion (H^+) and hydroxide ion (OH^-)

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$$

This is the NET IONIC EQUATION for many neutralizations

... assumes you're reacting STRONG acid with STRONG base!

ACIDS

- compounds that release hydrogen ion (H^+), when dissolved in water.

Properties of acids:

- Corrosive: React with most metals to give off hydrogen gas
- Cause chemical burns on contact
- Taste sour (like citrus - citric acid!)
- Changes litmus indicator to RED

BASES

- Substances that release hydroxide ion (OH^-) when dissolved in water

Properties of bases:

- Caustic: Attack and dissolve organic matter (think lye, which is NaOH)
- Cause skin/eye damage on contact
- Taste bitter
- changes litmus indicator to BLUE

Due to the dissolving action of base on your skin, bases will feel "slippery". The base ITSELF is not particularly slippery, but what's left of your skin IS!

ACID/BASE or NEUTRALIZATION reactions continued

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

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$$ Net ionic equation

$H^+(aq)$: From the acid

$OH^-(aq)$: From the base

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

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

Potential products: Na_2SO_4, H_2O

Formation of water moecules drives this reaction!

- How can this reaction be detected?
  - pH detector (indicator paper, etc.)
  - do the products have similar chemical properties to the reactants?
  - release of heat!

... formation of water is usually accompanied by a release of heat