151.90 g/mol

$$10\,FeSO_4 + 2\,KMnO_4 + 8\,H_2SO_4 \rightarrow 5\,Fe_2(SO_4)_3 + 2\,MnSO_4 + K_2SO_4 + 8\,H_2O$$

How many mL of 0.250M potassium permangenate are needed to react with 3.36 g of iron(II) sulfate?

---

1 - Change the mass of iron(II) sulfate to moles using the formula weight.of iron(II) sulfate
2 - Change moles of iron(II) sulfate to moles of potassium permangenate using chemical equation
3 - Change moles of potassium permangenate to volume using concentration (0.250 mol/L)

151.90 g $FeSO_4$ = mol $FeSO_4$ | 10 mol $FeSO_4$ = 2 mol $KMnO_4$ | 0.250 mol $KMnO_4$ = L

$$3.36\text{ g } FeSO_4 \times \frac{\text{mol } FeSO_4}{151.90\text{ g } FeSO_4} \times \frac{2\text{ mol } KMnO_4}{10\text{ mol } FeSO_4} \times \frac{L}{0.250\text{ mol } KMnO_4} = 0.0177\,L$$

① ② ③

$mL = 10^{-3} L$

$$0.0177\,L \times \frac{mL}{10^{-3}\,L} =$$ **17.7 mL of 0.250 M $KMnO_4$**

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?

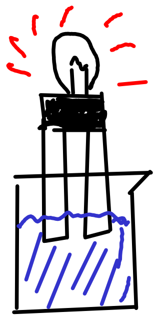
- Soluble ionic compounds
- Acids (strong AND weak)
- Bases (strong AND weak)

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

No light: Pure water is a NONELECTROLYTE

SOLID SODIUM CHLORIDE

In the solid state, ionic compounds like NaCl do not conduct electricity. Ions are NOT free to move around.

SOLID SUCROSE

Like water, solid sucrose does not conduct. $C_{12}H_{22}O_{11}$

MOLECULAR AND IONIC SOLUTIONS

SODIUM CHLORIDE + WATER

This solution conducts - sodium chloride is a STRONG ELECTROLYTE - it breaks apart in water to form free ions.

SUCROSE + WATER

The sugar water solution does not conduct - sucrose is a NONELECTROLYTE. A sucrose solution exists as dissolved sugar molecules - not ions.

ACIDS

PURE (GLACIAL) ACETIC ACID

Pure liquid acetic acid is a NONCONDUCTOR - no ions present. (If it were an ionic liquid, we would expect conductivity, so this shows acetic acid in the pure state is MOLECULAR)

ACETIC ACID + WATER

Adding water to pure acetic acid creates a solution that does conduct electricity (albeit weakly) - we conclude that some of the acetic acid forms ions in a reaction with water.

2M ACETIC ACID (AQUEOUS)

Light bulb lights, but fairly dim. WEAK ELECTROLYTE.

2M HYDROCHLORIC ACID (AQUEOUS)

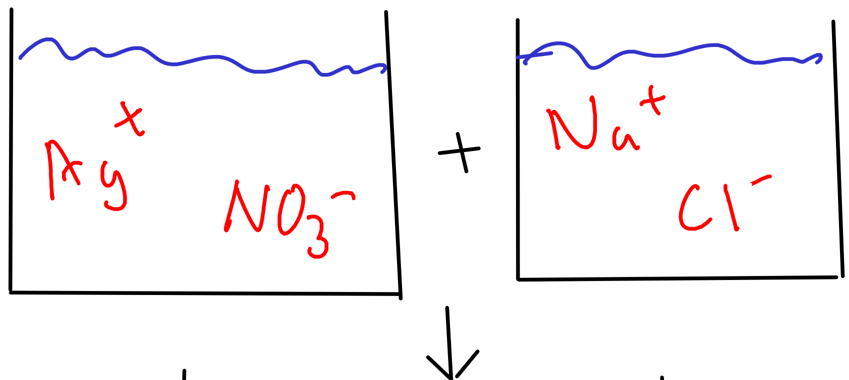
Light bulb lights up much more strongly. Hydrochloric acid is a STRONGER electrolyte than acetic acid. (In fact, HCl is considered a "strong electrolyte" just like NaCl)

- What good is ionic theory?

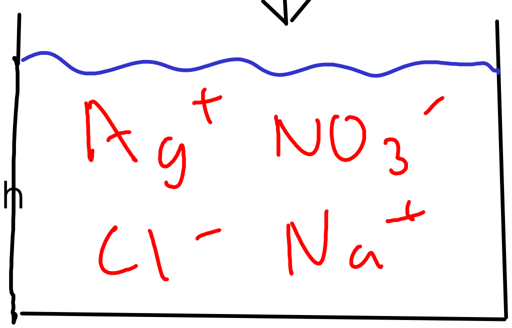
  - provides an easy-to-understand MECHANISM for certain kinds of chemical reactions.

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

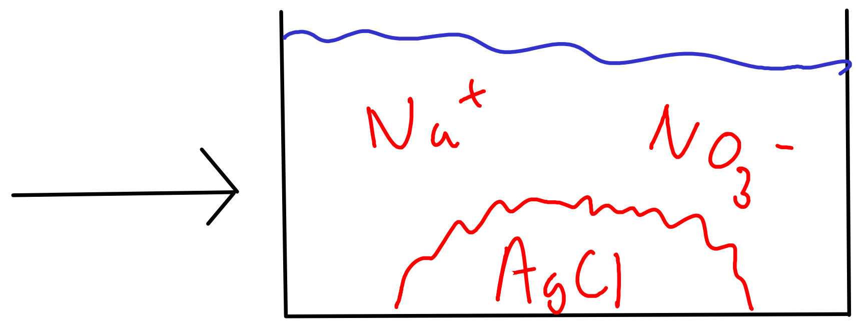
$$AgNO_3(aq) + NaCl(aq) \longrightarrow AgCl(s) + NaNO_3(aq)$$



These free ions mix and can interact with each other!

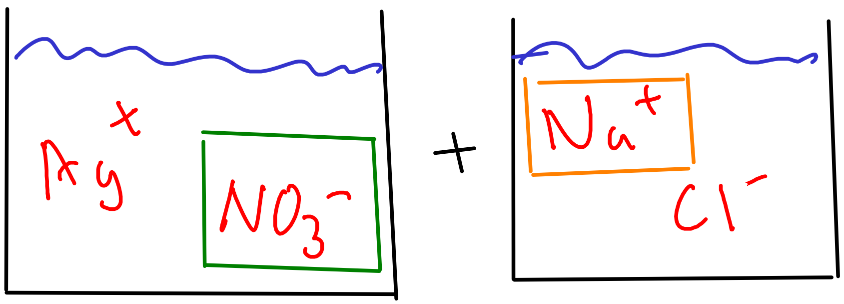


"ion soup"!

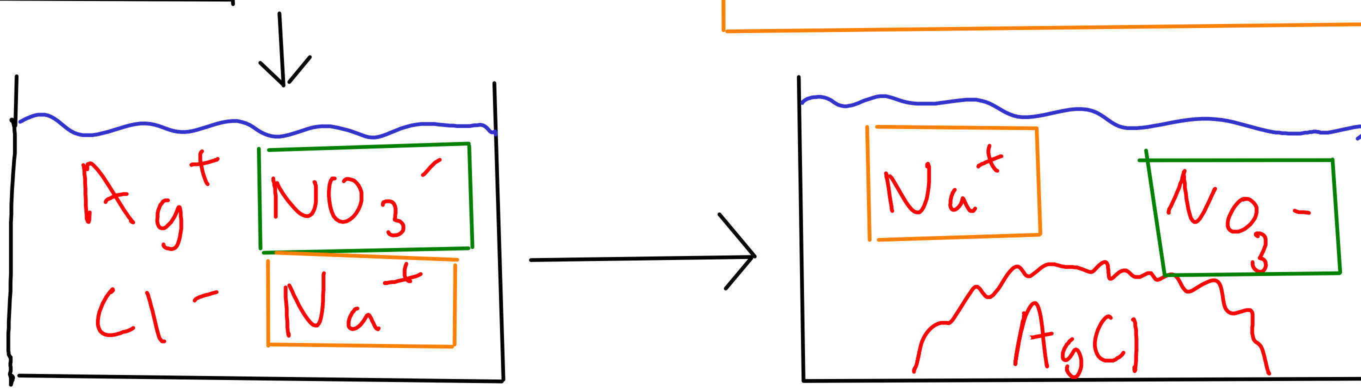


Insoluble AgCl falls out of solution as it is formed - "precipitation"

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", or use the course web site!

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

Exchange Chemistry

- Three kinds of exchange chemistry.

(1) PRECIPITATION

(2) ACID/BASE or NEUTRALIZATION

(3) GAS FORMATION (formation of unstable molecules)

↑ some gas - formers

- 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.

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

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

Potential Products:

$NaCl$

$Mg_3(PO_4)_2$

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

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

Mg^{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 aqeous.
4. Balance the overall equation.

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

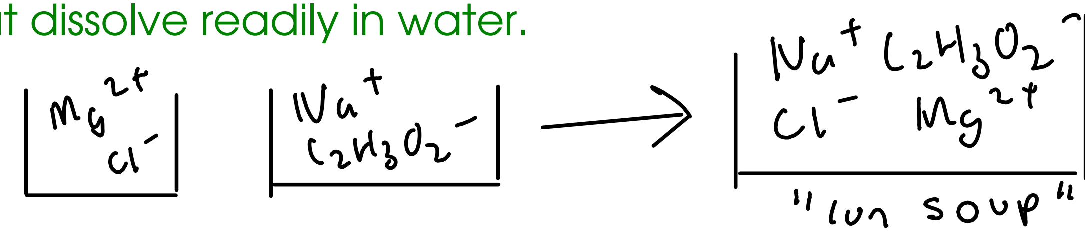
ions: Mg^{2+} Cl^- Na^+ $C_2H_3O_2^-$

"exchange"

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

$NaCl$ ... dissolves in water

So, no solid forms here. All the possible combination of ions result in compounds that dissolve readily in water.



... no change. So, NO REACTION

ACID/BASE or NEUTRALIZATION

- 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 — base — salt

"HOH"

salt: ionic compound

$$H^+ \; A^- \qquad B^+ \; OH^-$$

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

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

Net ionic equation

... 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

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

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

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

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

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

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

- 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