

Chem 101

Reactions in Aqueous Solutions

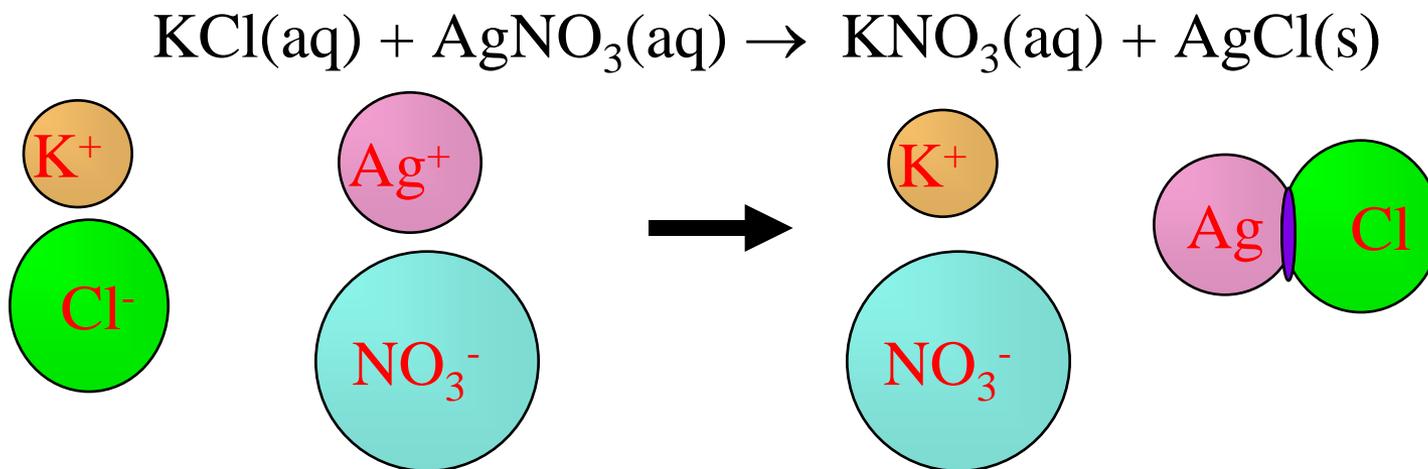
Lectures 15 and 16

Predicting Whether a Reaction Will Occur

- “Forces” that drive a reaction
 - Formation of a solid
 - Formation of water
 - Transfer of electrons
 - Formation of a gas
- When chemicals (dissolved in water) are mixed and one of these 4 things can occur, the reaction will generally happen.

Precipitation Reactions

- In all precipitation reactions, the ions of one substance are exchanged with the ions of another substance when their aqueous solutions are mixed.
- At least one of the products formed is insoluble in water.

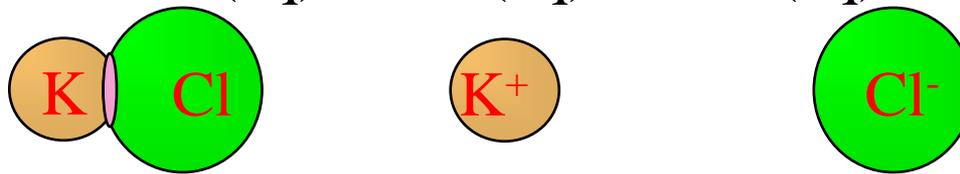
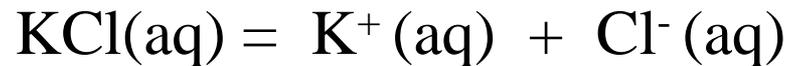


Dissociation

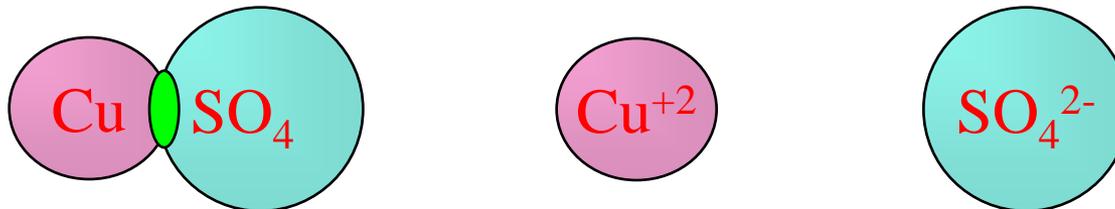
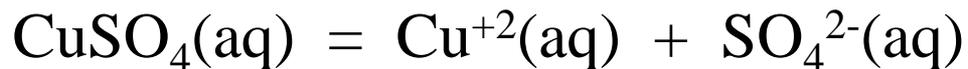
- Ionic compounds
 - Metal + nonmetal (Type I & II)
 - Metal + polyatomic anion
 - Polyatomic cation + anion
- **Dissociation:** when ionic compounds dissolve in water the anions and cations are separated from each other
- We know that ionic compounds dissociate when they dissolve in water because the solution conducts electricity.

Dissociation (cont.)

- Potassium chloride dissociates in water into potassium cations and chloride anions.

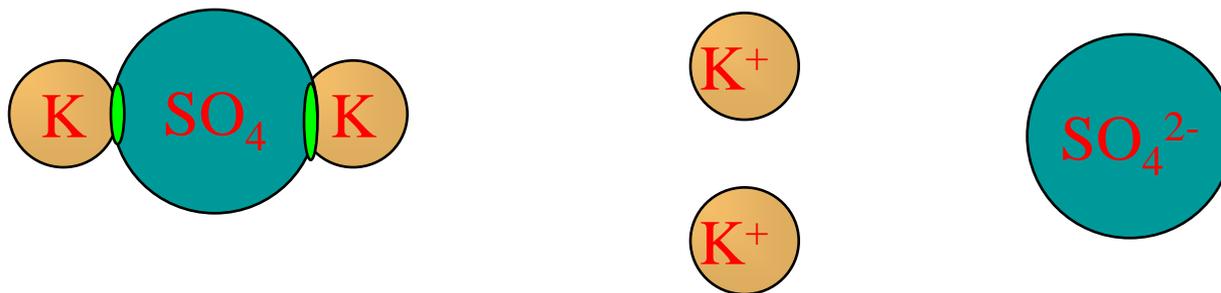
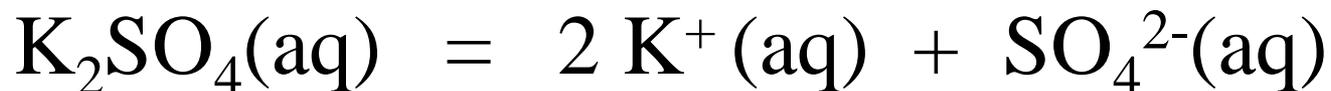


- Copper(II) sulfate dissociates in water into copper(II) cations and sulfate anions.



Dissociation (cont.)

- Potassium sulfate dissociates in water into potassium cations and sulfate anions.



Process for Predicting the Products of a Precipitation Reaction

- Determine what ions each aqueous reactant has
- Exchange ions
 - (+) ion from one reactant with (-) ion from other
- Balance charges of combined ions to get formula of each product
- Balance the equation
 - Count atoms
- Determine solubility of each product in water
 - Solubility rules
 - If product is insoluble or slightly soluble, it will precipitate.

Table 7.1 General Rules for Solubility of Ionic Compounds (Salts) in Water at 25 °C

1. Most nitrate (NO_3^-) salts are soluble.
2. Most salts of Na^+ , K^+ , and NH_4^+ are soluble.
3. Most chloride salts are soluble. Notable exceptions are AgCl , PbCl_2 , and Hg_2Cl_2 .
4. Most sulfate salts are soluble. Notable exceptions are BaSO_4 , PbSO_4 , and CaSO_4 .
5. Most hydroxide compounds are only slightly soluble.* The important exceptions are NaOH and KOH . $\text{Ba}(\text{OH})_2$ and $\text{Ca}(\text{OH})_2$ are only moderately soluble.
6. Most sulfide (S^{2-}), carbonate (CO_3^{2-}), and phosphate (PO_4^{3-}) salts are only slightly soluble.*

*The terms *insoluble* and *slightly soluble* really mean the same thing: such a tiny amount dissolves that it is not possible to detect it with the naked eye.

Figure 7.3: Solubilities of common compounds.

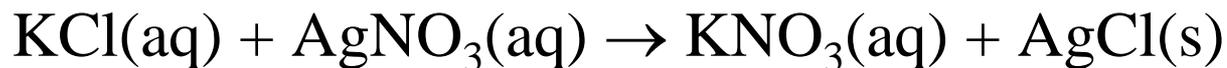
(a) Soluble compounds	
NO_3^- salts	
Na^+ , K^+ , NH_4^+ salts	
Cl^- , Br^- , I^- salts	Except for those containing Ag^+ , Hg_2^{2+} , Pb^{2+}
SO_4^{2-} salts	Except for those containing Ba^{2+} , Pb^{2+} , Ca^{2+}
(b) Insoluble compounds	
S^{2-} , CO_3^{2-} , PO_4^{3-} salts	
OH^- salts	Except for those containing Na^+ , K^+ , Ca^{2+} , Ba^{2+}

Practice Solubility Worksheet

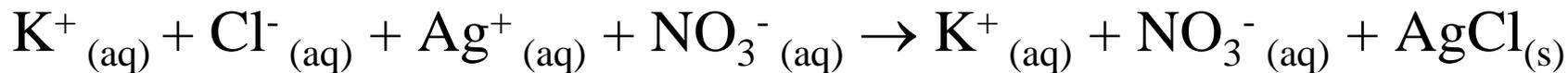
Ionic substance	Formula	Water Soluble?
Aluminum nitrate		
Magnesium chloride		
Nickel (II) hydroxide		
Potassium fluoride		
Calcium carbonate		
Silver phosphate		
Calcium nitrate		
Phosphoric acid		
Barium sulfate		
Sodium hydroxide		

Ionic Equations

- **Molecular equations:** equations that describe the chemicals put into the water and the product molecules

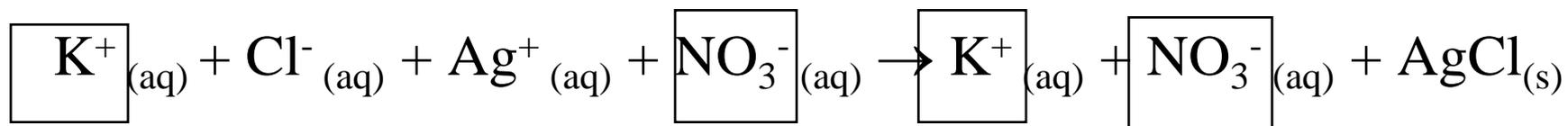


- **Ionic equations:** equations that describe the actual ions and molecules in the solutions, as well as the molecules of solid, liquid, and gas not dissolved

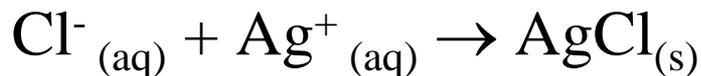


Ionic Equations (cont.)

- **Spectator ions:** ions that are both reactants and products



- **Net ionic equation:** an ionic equation in which the spectator ions are dropped

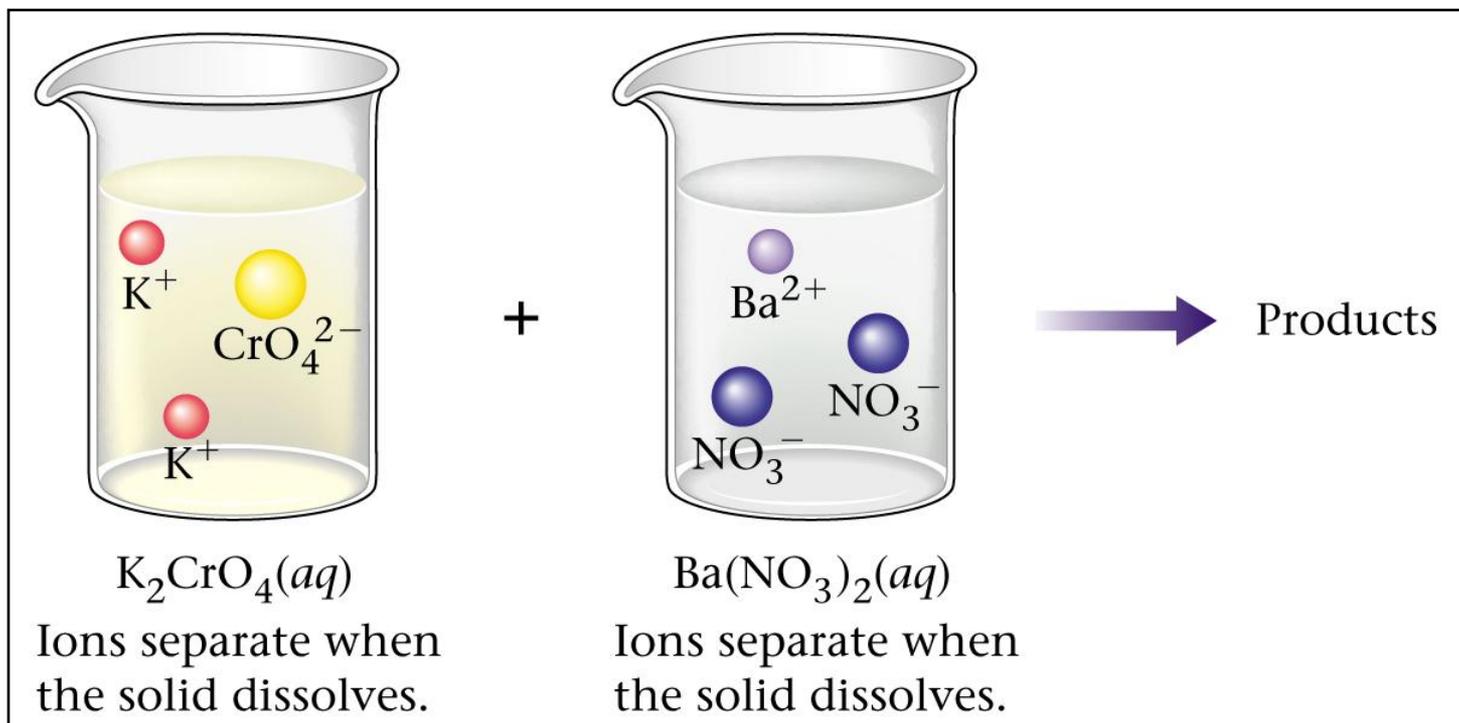


The precipitation reaction that occurs when yellow potassium chromate, $\text{K}_2\text{CrO}_4(aq)$, is mixed with a colorless barium nitrate solution, $\text{Ba}(\text{NO}_3)_2(aq)$

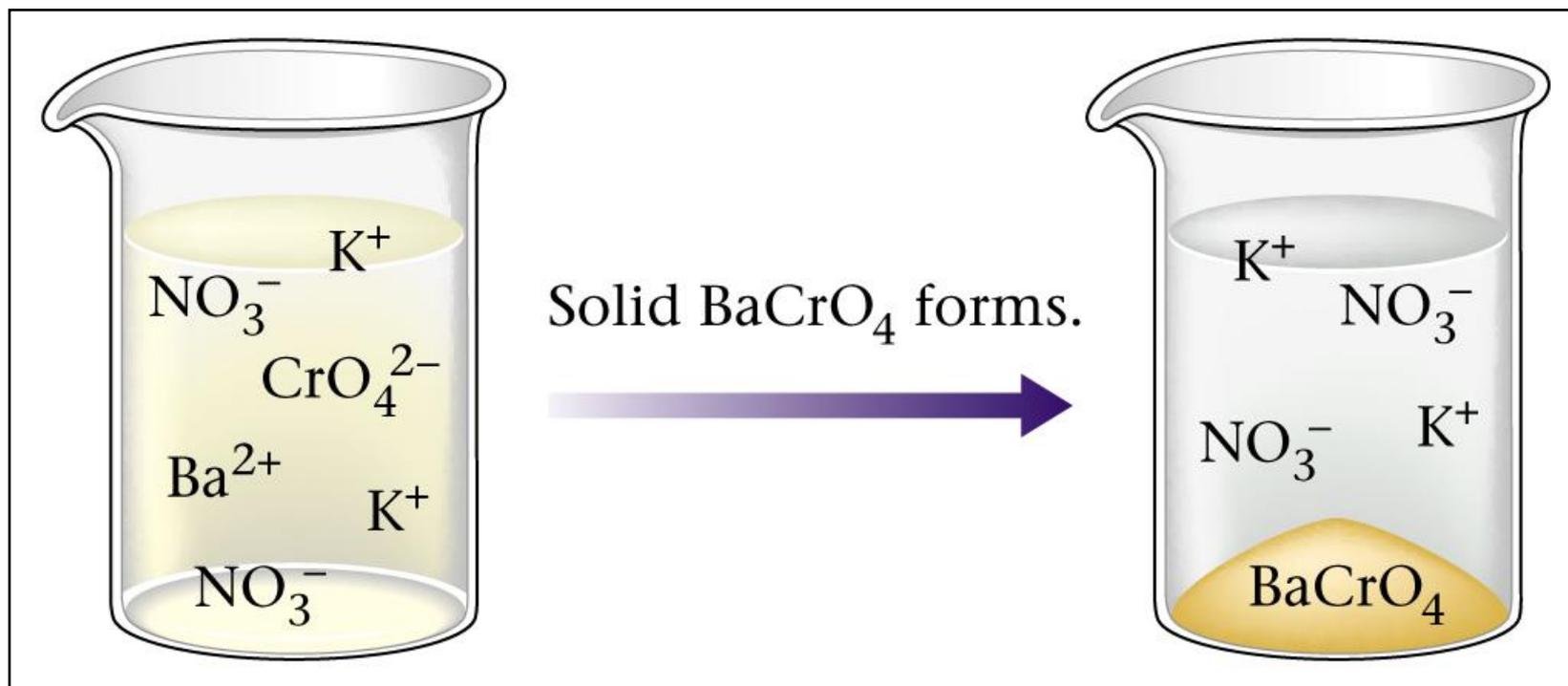


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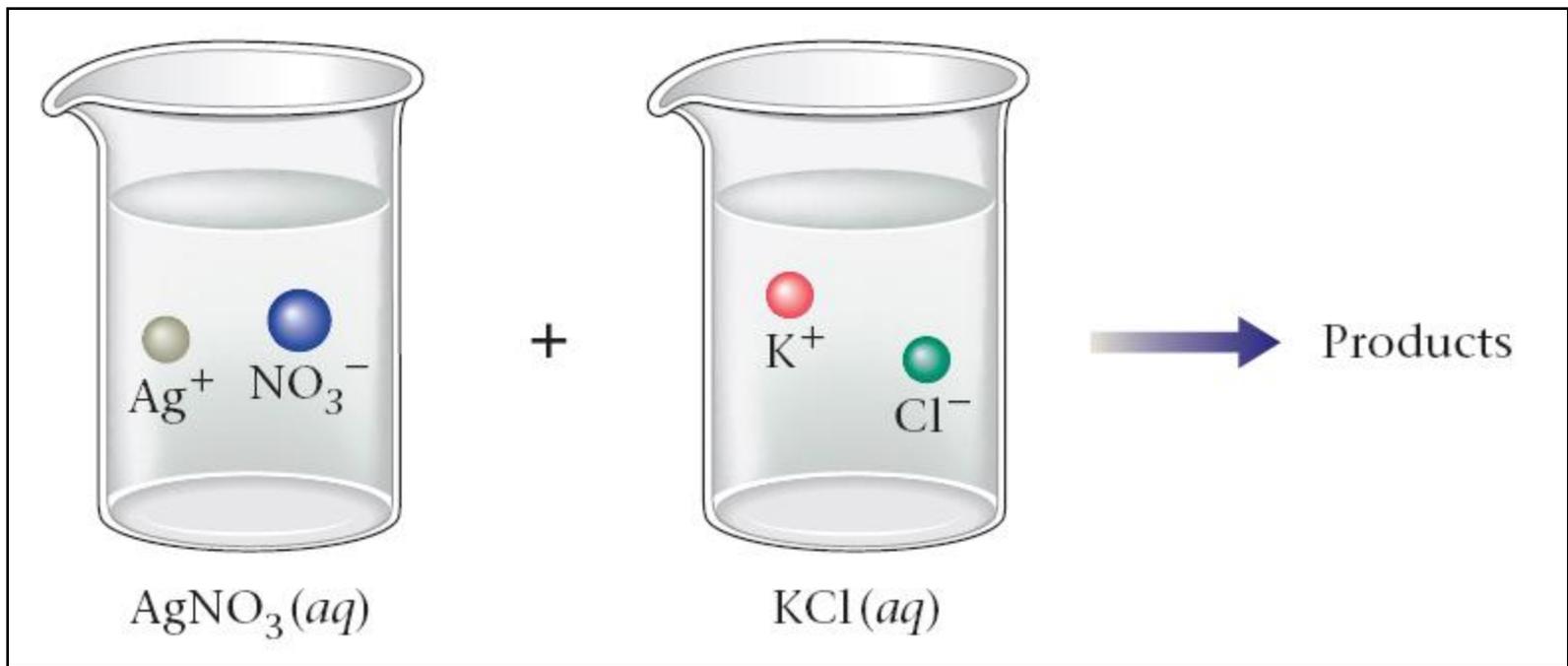
When ionic solids are dissolved, their ions separate in the solution.



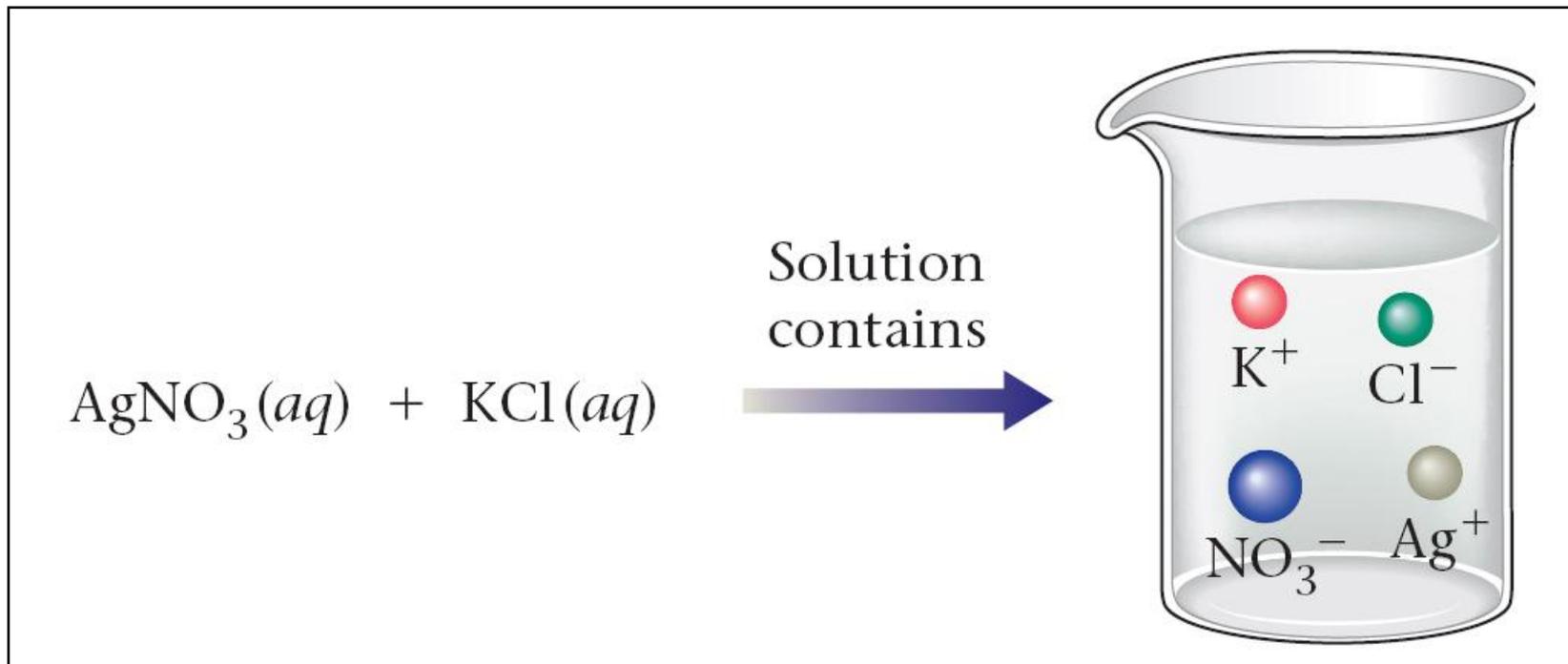
An example of a precipitation reaction: the formation of BaCrO_4



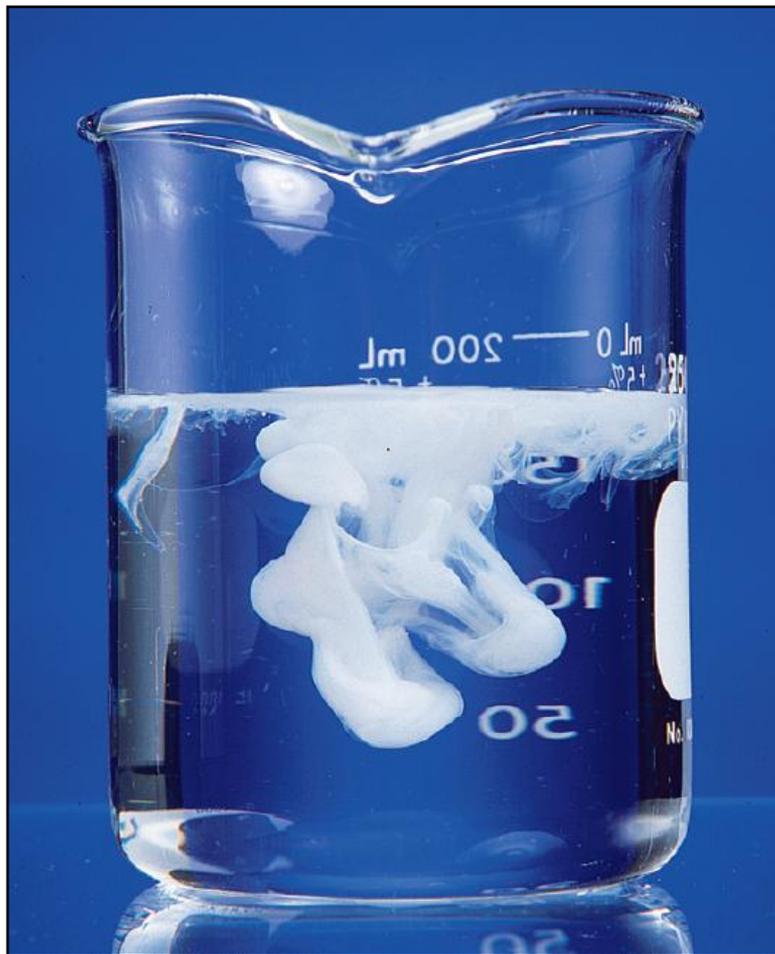
When ionic substances dissolve in water, their ions separate.



What are the possible solid products of this solution?

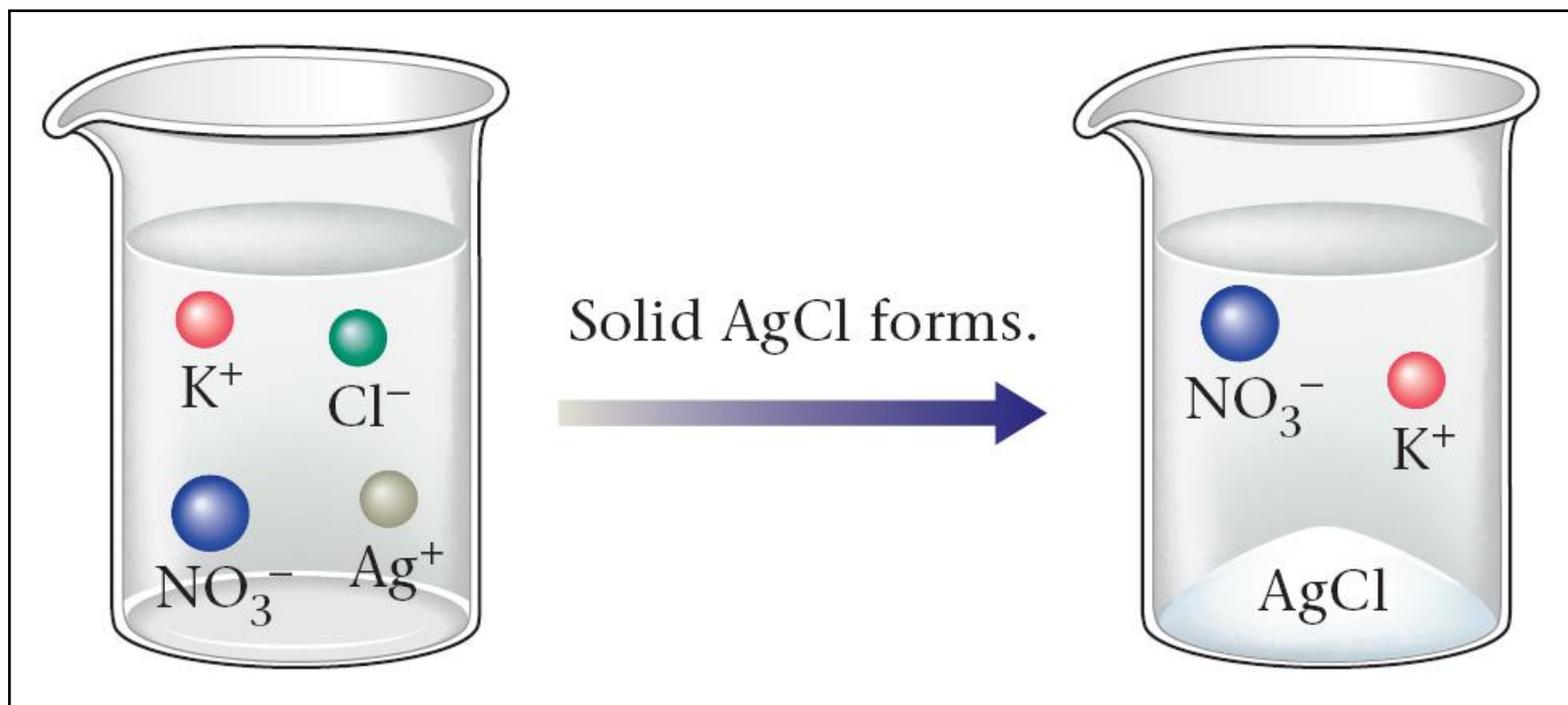


Precipitation of silver chloride occurs when solutions of silver nitrate and potassium chloride are mixed.

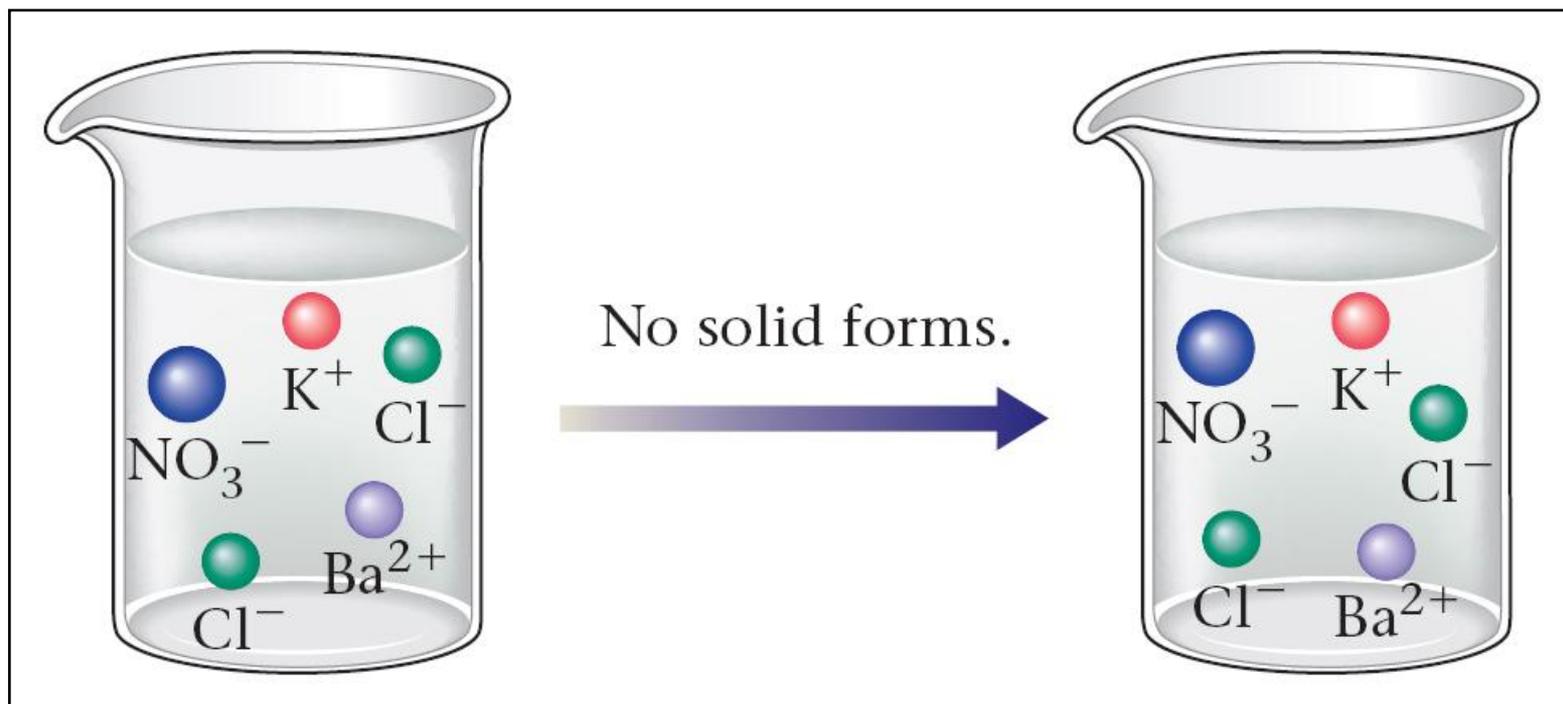


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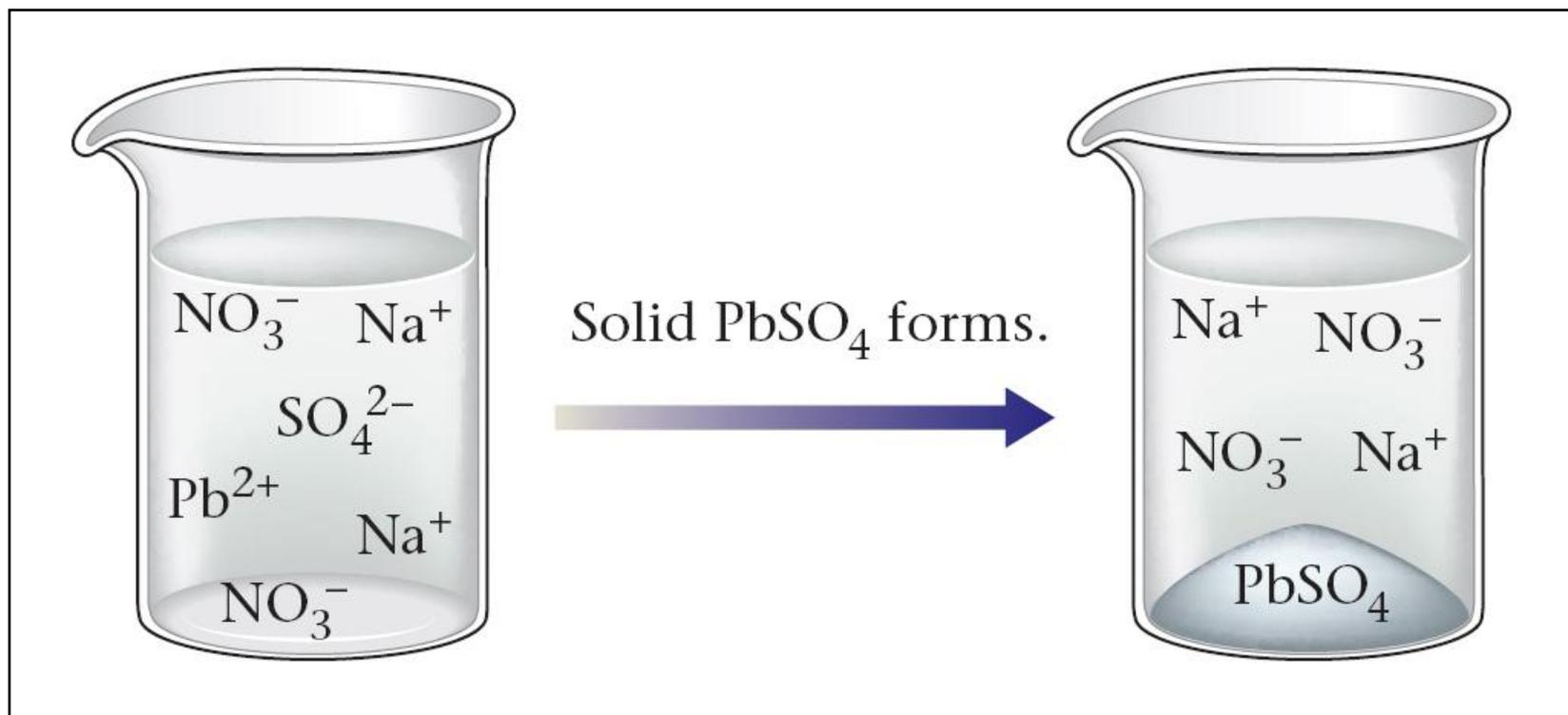
Formation of solid AgCl through a precipitation reaction.



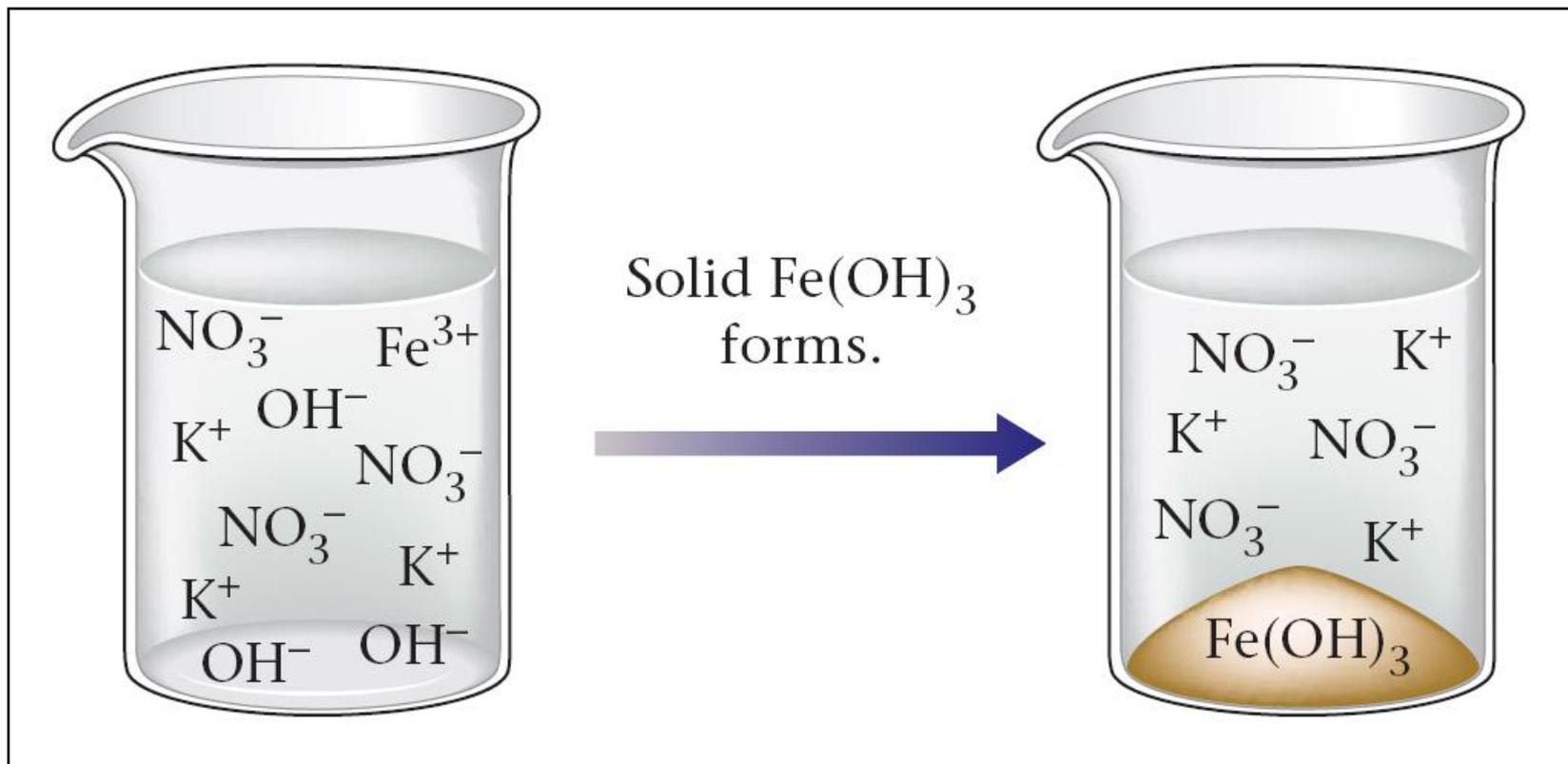
All the dissolved ions remain in solution. No reaction takes place. That is, no chemical change takes place.



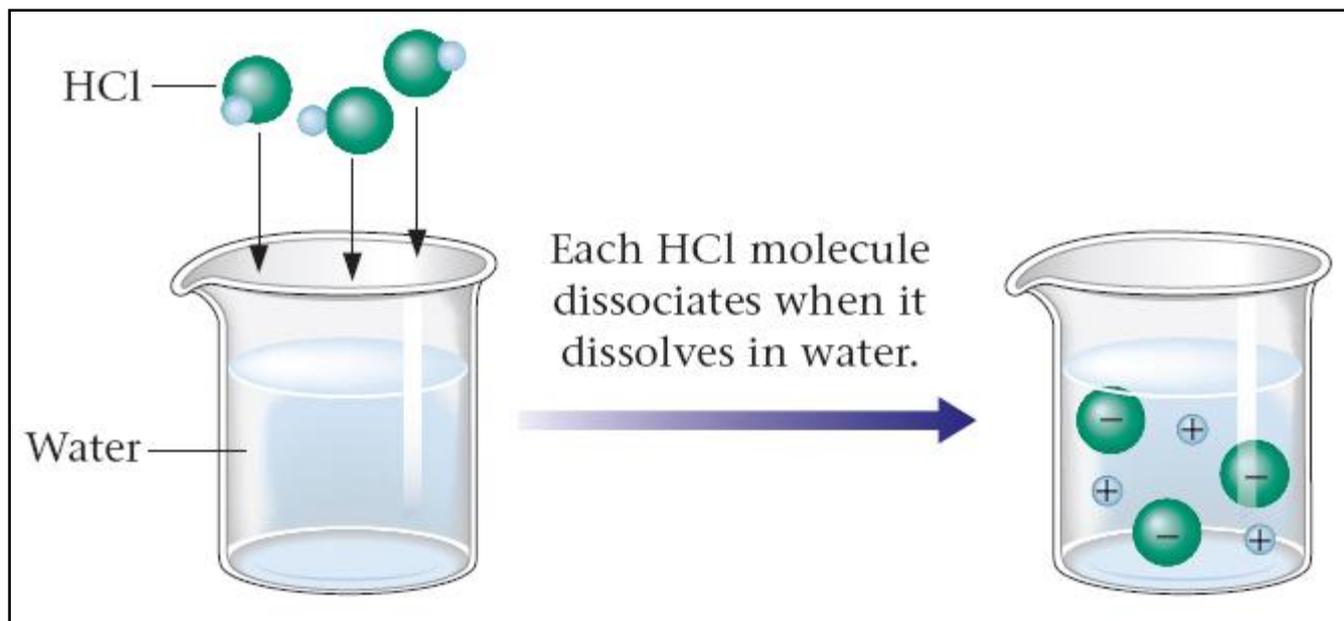
Formation of solid PbSO_4 through precipitation.



Formation of solid $\text{Fe}(\text{OH})_3$ through precipitation.

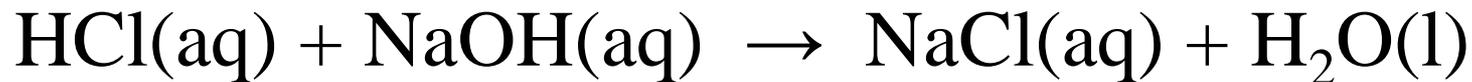


When gaseous HCl is dissolved in water, each molecule dissociates to form H^+ and Cl^- ions. That is, HCl behaves as a strong electrolyte.

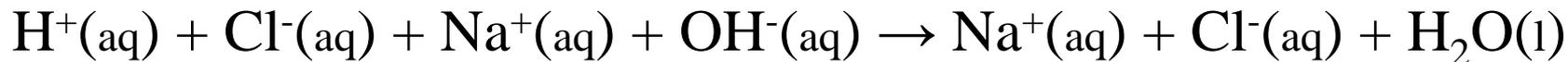


Molecular to Total Ionic Equation

Molecular Equation:



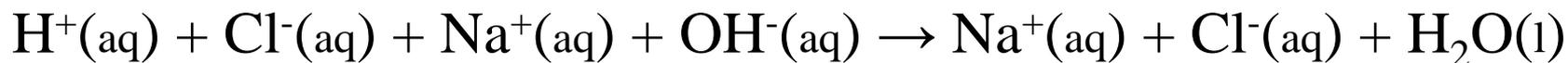
Strong acids, strong bases, and soluble ionic compounds can be written as ions:



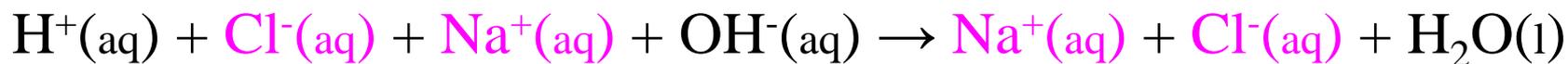
This is the Total Ionic Equation. Each species is written as it predominantly exists in solution.

Total Ionic to Net Ionic Equation

Total Ionic Equation:

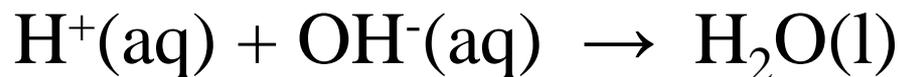


Na^+ and Cl^- appear on both sides of the equation. They are spectator ions. Spectator ions are in the solution, but do not participate in the overall reaction.

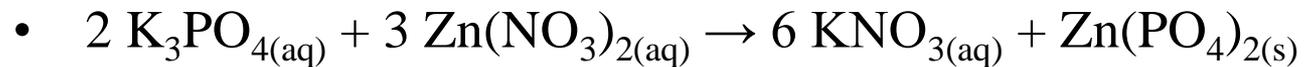


Cancel out the spectator ions to get the net ionic equation.

The Net Ionic Equation is:



Write the total ionic and net ionic equations



Write the molecular, total ionic and net ionic equations

- Barium chloride and sodium sulfate

Review

- Complete and balance the molecular chemical equation.
- Convert the molecular equation into the total ionic equation.
 - a) Write aqueous solutions in the ionized form.
 - b) Write solids, liquids, and gases in the non-ionized form.
- Cancel all the spectator ions to obtain the net ionic equation.

If all species are eliminated, there is no reaction.