Solution

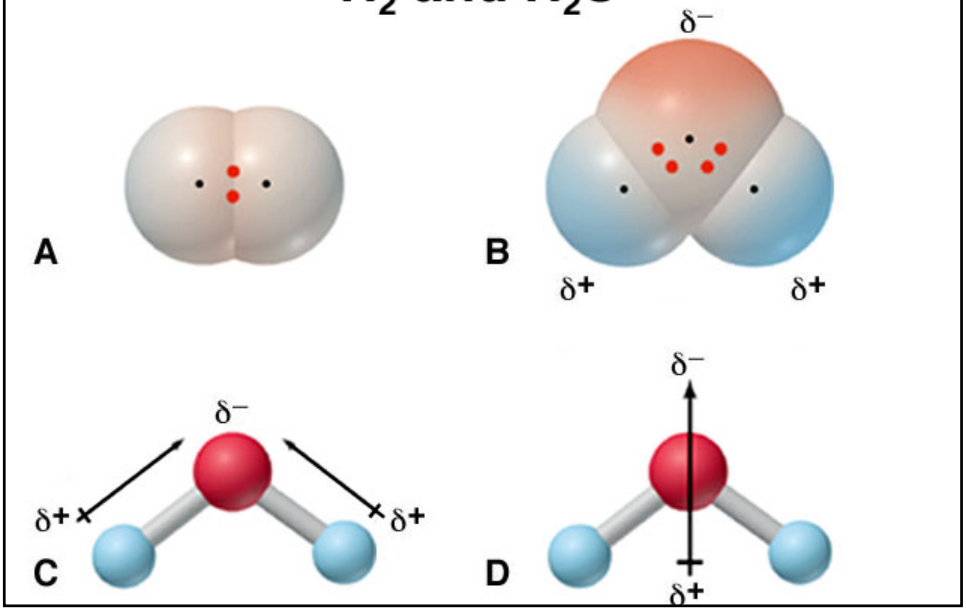
- Solvent and one or more solutes dissolved in the solvent
- Interested in aqueous solutions, where the solvent is water

When ionic compounds (salts) dissolve in water, ions dissociate

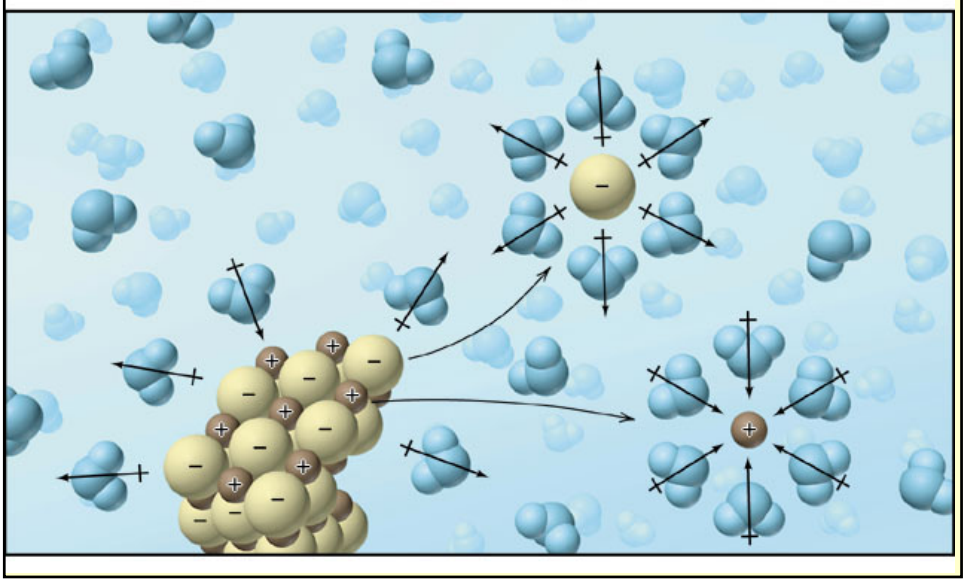
- Surrounded by H_2O molecules
- $NaCl(s) \xrightarrow{water} Na^+(aq) + Cl^-(aq)$

  (s) = solid; (aq) = aqueous solution

Electron Distribution in Molecules of H_2 and H_2O



The Dissolution of an Ionic Compound



- An aqueous solution of NaCl conducts electricity
  - Ions are free to move
- Substances that form ions in solution are called electrolytes
- NaCl is a strong electrolyte because it completely dissociates to form ions

- In a weak electrolyte, only a small amount that dissolves (< 5%) dissociates to form ions
- The rest stays in molecular form
- Acetic acid
  $H_3CCOOH \leftrightarrows H^+ + H_3CCOO^-$
- Nonelectrolytes – dissolve in H_2O but don't produce ions, e.g. sucrose, ethyl alcohol
  - Polar molecules soluble

- Precipitation Reactions – two solutions are mixed and a precipitate forms

  $BaCl_2(aq) + Na_2CO_3(aq) \rightarrow BaCO_3(s) + 2\ NaCl(aq)$

- Molecular equation
  - $BaCl_2(aq)$ actually $Ba^{2+}(aq)$ and $2Cl^-(aq)$
  - $BaCO_3(s)$ insoluble
  - Precipitates from solution as solid

- The dividing line between soluble and insoluble is approximately 0.01 M, i.e., in the range of 1 to 10 g/L
- If more than this dissolves, the salt is soluble

Table 4.1 Solubility Rules for Ionic Compounds in Water

Soluble Ionic Compounds	Insoluble Ionic Compounds
1. All common compounds of Group 1A(1) ions (Li^+, Na^+, K^+, etc.) and ammonium ion (NH_4^+) are soluble.	1. All common metal hydroxides are insoluble, *except* those of Group 1A(1) and the larger members of Group 2A(2) (beginning with Ca^{2+}).
2. All common nitrates (NO_3^-), acetates (CH_3COO^-), and most perchlorates (ClO_4^-) are soluble.	2. All common carbonates (CO_3^{2-}) and phosphates (PO_4^{3-}) are insoluble, *except* those of Group 1A(1) and NH_4^+.
3. All common chlorides (Cl^-), bromides (Br^-), and iodides (I^-) are soluble, *except* those of Ag^+, Pb^{2+}, Cu^+, and Hg_2^{2+}.	3. All common sulfides are insoluble, *except* those of Group 1A(1), Group 2A(2), and NH_4^+.
4. All common sulfates (SO_4^{2-}) are soluble, *except* those of Ca^{2+}, Sr^{2+}, Ba^{2+}, and Pb^{2+}.	

- Total ionic equation

  $Ba^{2+}(aq) + 2Cl^-(aq) + 2Na^+(aq) + CO_3^{2-}(aq) \rightarrow BaCO_3(s) + 2Na^+(aq) + 2Cl^-(aq)$

- CO_3^{2-} is a polyatomic ion

- Na^+ and Cl^- are spectator ions

- Omit these ions when writing net ionic equation:

  $Ba^{2+}(aq) + CO_3^{2-}(aq) \rightarrow BaCO_3(s)$

Table 2.5 Common Polyatomic Ions*

Formula	Name	Formula	Name
Cations			
NH_4^+	**ammonium**		
H_3O^+	**hydronium**		
Anions		**Anions** (cont.)	
CH_3COO^- (or **$C_2H_3O_2^-$**)	**acetate**	CrO_4^{2-}	chromate
CN^-	cyanide	**$Cr_2O_7^{2-}$**	**dichromate**
OH^-	**hydroxide**	O_2^{2-}	peroxide
ClO^-	hypochlorite	**PO_4^{3-}**	**phosphate**
ClO_2^-	chlorite	HPO_4^{2-}	hydrogen phosphate
ClO_3^-	**chlorate**	$H_2PO_4^-$	dihydrogen phosphate
ClO_4^-	**perchlorate**	SO_3^{2-}	sulfite
NO_2^-	nitrite	**SO_4^{2-}**	**sulfate**
NO_3^-	**nitrate**	HSO_4^-	hydrogen sulfate (or bisulfate)
MnO_4^-	**permanganate**		
CO_3^{2-}	**carbonate**		
HCO_3^-	**hydrogen carbonate** (or **bicarbonate**)		

*Boldface ions are most common.

- Balance the reaction and write net ionic equation:

  $ZnCl_2 + KOH \rightarrow KCl + Zn(OH)_2$

- Balance:

  $ZnCl_2 + 2KOH \rightarrow 2KCl + Zn(OH)_2$

- Determine which are soluble and which are insoluble

  $ZnCl_2(aq) + 2\ KOH(aq) \rightarrow$
  $2KCl(aq) + Zn(OH)_2(s)$

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- This is a molecular equation
- Write total ionic equation:

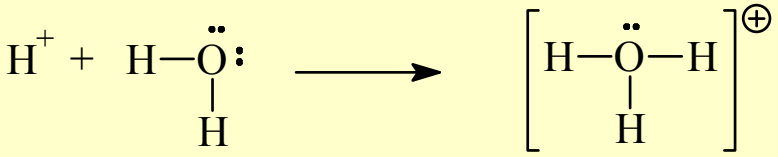
  $Zn^{2+}(aq) + 2Cl^-(aq) + 2K^+(aq) + 2OH^-(aq) \rightarrow 2K^+(aq) + 2Cl^-(aq) + Zn(OH)_2(s)$

- Write net ionic equation:

  $Zn^{2+}(aq) + 2OH^-(aq) \rightarrow Zn(OH)_2(s)$

Acid – Base Reactions

- Commonly define <u>acid</u> as substance that produces H^+
- In H_2O, H^+ attached to H_2O molecule to produce hydronium ion



- $HCl(aq) \rightarrow H^+(aq) + Cl^-(aq)$
- Arrow points only in forward direction because reaction goes to completion
- $CH_3COOH(aq) \leftrightarrows H^+(aq) + CH_3COO^-(aq)$
  acetic acid acetate
- Arrows both ways because only a small amount of CH_3COOH dissociates, reaches equilibrium
- HCl – strong acid
- CH_3COOH – weak acid

- Base – produces OH^- in H_2O

  $NaOH(s) \xrightarrow{water} Na^+(aq) + OH^-(aq)$

  $NH_3(aq) + H_2O(l) \leftrightarrows NH_4^+(aq) + OH^-(aq)$

- Only a small amount of NH_3 is converted to NH_4^+
- NaOH – strong base
- NH_3 – weak base

Table 4.2 Selected Acids and Bases

Acids
Strong
Hydrochloric acid, HCl
Hydrobromic acid, HBr
Hydriodic acid, HI
Nitric acid, HNO_3
Sulfuric acid, H_2SO_4
Perchloric acid, $HClO_4$
Weak
Hydrofluoric acid, HF
Phosphoric acid, H_3PO_4
Acetic acid, CH_3COOH (or $HC_2H_3O_2$)
Bases
Strong
Sodium hydroxide, NaOH
Potassium hydroxide, KOH
Calcium hydroxide, $Ca(OH)_2$
Strontium hydroxide, $Sr(OH)_2$
Barium hydroxide, $Ba(OH)_2$
Weak
Ammonia, NH_3

- Neutralization reaction

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

- H_2O very stable, reaction goes to completion

- $HX + MOH \rightarrow MX + H_2O$
  acid base salt

M = "+" ion, cation X = "-" ion, anion

- $2HNO_3(aq) + Ca(OH)_2(aq) \rightarrow Ca(NO_3)_2(aq) + 2H_2O\ (l)$

- Total ionic:
  $2H^+(aq) + 2NO_3^-(aq) + Ca^{2+}(aq) + 2OH^-(aq) \rightarrow Ca^{2+}(aq) + 2NO_3^-(aq) + 2H_2O\ (l)$

- Net ionic:
  $2H^+(aq) + 2OH^-(aq) \rightarrow 2H_2O\ (l)$

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

- Acids will react with several salts to produce a gas that leaves the solution

  $2HNO_3(aq) + Na_2CO_3(aq) \rightarrow 2NaNO_3(aq) + H_2CO_3(aq)$

- $H_2CO_3(aq) \rightarrow CO_2(g) + H_2O\ (l)$
- Net ionic:
- $2H^+(aq) + CO_3^{2-}(aq) \rightarrow CO_2(g) + H_2O\ (l)$

In order for a reaction to occur, something must happen that is irreversible

1) Two soluble ions $\rightarrow$ insoluble salt (precipitation)

2) $H^+ + OH^- \rightarrow H_2O$ (acid – base, neutralization)

3) Reaction produces an insoluble gas, e.g. CO_2, that leaves the solution

- $H_2SO_4(aq) + KOH(aq) \rightarrow$

  $2H^+ + SO_4^{2-} + K^+ + OH^- \rightarrow$

- Exchange partners, double KOH

  $\rightarrow 2K^+ + SO_4^{2-} + 2H_2O$

- Net ionic:

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

<u>Strong acids</u>

Hydrohalic acids HCl, HBr and HI
Oxoacids HNO_3, H_2SO_4, and $HClO_4$

<u>Weak acids</u>
Hydrohalic acids HF
HCN and H_2S
Oxoacids such as HClO, HNO_2 and H_3PO_4

<u>Strong bases</u>
M_2O or MOH, where M is Group 1A
MO or $M(OH)_2$, where M is Group 2A

<u>Weak bases</u>
Ammonia
$CH_3CH_2NH_2$