

"The world of chemical events is like a stage on which scene after scene is enacted in a continuous succession. The players on this stage are the elements. To each of them is assigned a characteristic role, either that of supernumerary or that of an actor playing a part." Clemens Alexander Winkler, 1897

Types of Chemical Reactions

dissolution reactions (solvent, solute)

chemical reaction where two (or more) substances form a homogeneous mixture; dispersion is on the level of individual molecules or ions; size of dispersed particles generally $< 10^{-9}$ m (nanometer)

precipitation reactions

chemical reaction where one substance exceeds its solubility in another so that it separates out of solution as a solid

acid/base reactions

"classic" Arrhenius reaction in water of a strong acid and a strong base reacting to form a salt and water

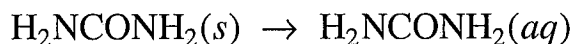
oxidation-reduction reactions

chemical reaction where electrons are transferred

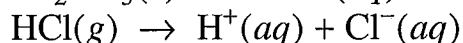
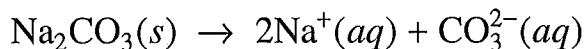
Dissolution Reactions

solubility - largest amount of substance that can dissolve in a given amount of solvent at a given T

molecular compounds in water (*e.g.*, solid urea dissolving in water)



ionic compounds in water (**dissociation, ionization**)



water is polar and often dissolves ions: "like dissolves like"

electrolytes (substances that conduct electricity better than pure water)

strong: $\text{Na}_2\text{CO}_3(aq)$, $\text{HCl}(aq)$

weak (produce less ions \Rightarrow lower conductivity): ammonia, acetic acid

nonelectrolyte: ethanol, sugar

FIG I - Dissolution of K_2SO_4 in Water FIG II - Dissolution of $NaCl$ in Water

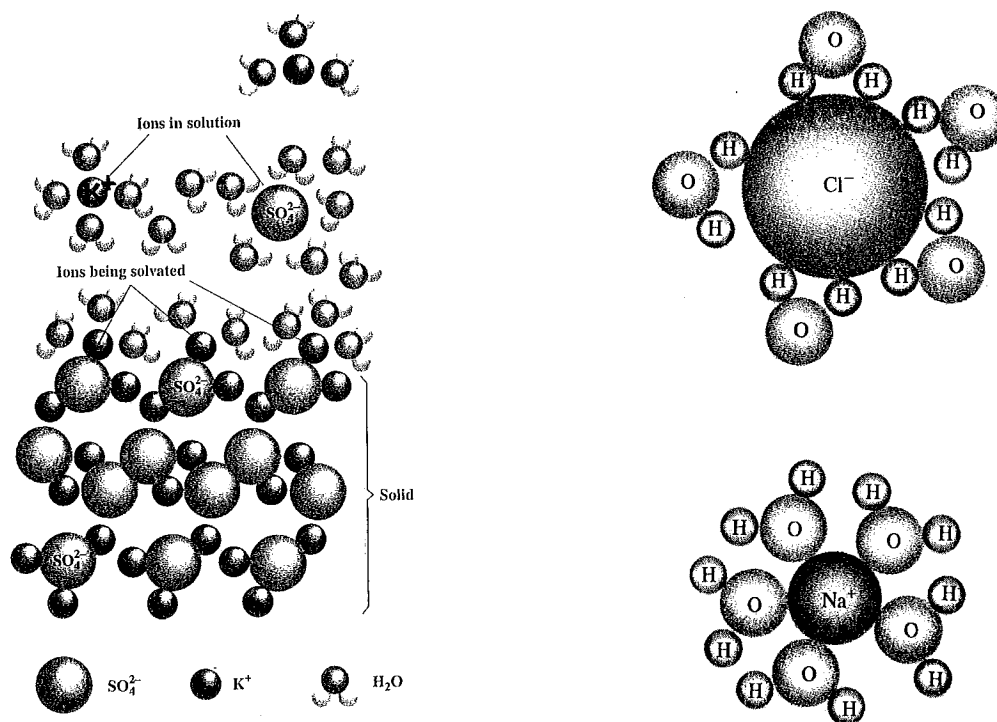


Table 4-1. Solubilities of Ionic Compounds in Water

Anion	Soluble	Slightly Soluble	Insoluble
NO_3^- (nitrate)	all		
ClO_3^- (chlorate)	all		
ClO_4^- (perchlorate)	most	$KClO_4$	
CH_3COO^- (acetate)	most		$Be(CH_3COO)_2$
F^- (fluoride)	Group I , AgF , BeF_2	SrF_2 , BaF_2 , PbF_2	MgF_2 , CaF_2
Cl^- (chloride)	most	$PbCl_2$	$AgCl$, Hg_2Cl_2
Br^- (bromide)	most	$PbBr_2$, $HgBr_2$	$AgBr$, Hg_2Br_2
I^- (iodide)	most		AgI , Hg_2I_2 , PbI_2 , HgI_2
SO_4^{2-} (sulfate)	most	$CaSO_4$, Ag_2SO_4 , Hg_2SO_4	$SrSO_4$, $BaSO_4$, $PbSO_4$
S^{2-} (sulfide)	Groups I and II , $(NH_4)_2S$		most
CO_3^{2-} (carbonate)	Group I , $(NH_4)_2CO_3$		most
SO_3^{2-} (sulfite)	Group I , $(NH_4)_2SO_3$		most
PO_4^{3-} (phosphate)	Group I , $(NH_4)_3PO_4$	Li_3PO_4	most
OH^- (hydroxide)	Group I , $Ba(OH)_2$	$Sr(OH)_2$, $Ca(OH)_2$	most

in 100 g of water: **soluble**, > 1 g; **slightly soluble**, 0.01 to 1 g; **insoluble**, < 0.01 g

Precipitation Reactions

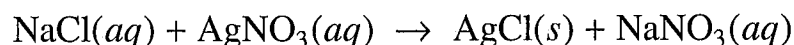
(or **WHY YOU NEED TO KNOW YOUR IONS**)

STRATEGY

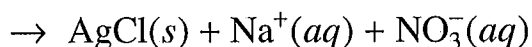
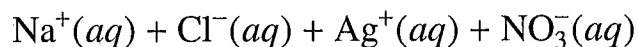
- write down formulas of reactants
- identify nature of reactants in solution (if ionic, what ions are in solution)
- consult solubility table for any combination of cations/anions that will ppt
- write balanced equation
- write **total ionic equation**
- write **net ionic equation** - omits **spectator ions**

for example: if aqueous solutions of sodium chloride and silver nitrate were mixed, the solubility table identifies silver chloride as an insoluble species so

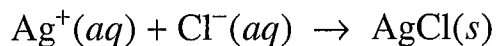
balanced equation:



total ionic equation:



net ionic equation (**contains the CHEMISTRY**):

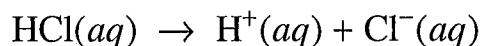


EX 1. Aqueous solutions of iron(III) bromide and potassium sulfide are mixed. Write a net ionic equation for the reaction.

EX 2. Aqueous solutions of sodium hydroxide and magnesium chloride are mixed. Write a net ionic equation for the reaction.

Properties of Acids and Bases

Arrhenius acids deliver $\text{H}^+(aq)$ ions to the solution upon dissolution in water

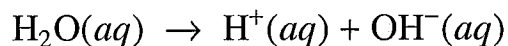


Arrhenius bases deliver $\text{OH}^-(aq)$ ions to the solution upon dissolution in water



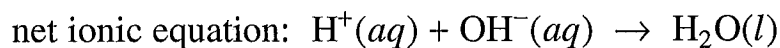
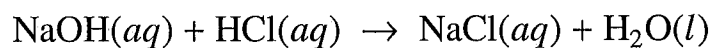
seven strong acids to know		soluble strong bases to know	
hydrochloric acid	HCl	lithium hydroxide	LiOH
hydrobromic acid	HBr	sodium hydroxide	NaOH
hydroiodic acid	HI	potassium hydroxide	KOH
perchloric acid	HClO_4	rubidium hydroxide	RbOH
chloric acid	HClO_3	cesium hydroxide	CsOH
sulfuric acid	H_2SO_4	barium hydroxide	$\text{Ba}(\text{OH})_2$
nitric acid	HNO_3		

Arrhenius definition works since pure water ionizes to a very small extent in a process called **autoionization**



so water is both an Arrhenius acid and an Arrhenius base. A substance having both acidic and basic properties is called **amphoteric**.

neutralization - reaction of an Arrhenius acid with an Arrhenius base to form a **salt (ionic compound not containing OH^-)** and water; driving force is the formation of stable, low energy water



weak acids are not strong electrolytes like the strong acids, *e.g.*, organic acids (contain COOH group) like acetic $\text{CH}_3\text{COOH}(aq)$ though they neutralize strong bases - leave H undissociated when writing

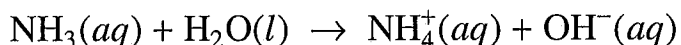
Naming Nonmetallic Compounds Containing Hydrogen¹

Compounds Containing Hydrogen	
H-Nonmetal	H-Oxoanion
<p>Rule 1: (without the presence of H₂O) hydrogen _ide</p> <p>Examples: HCl hydrogen chloride HF hydrogen fluoride H₂S hydrogen sulfide H₂Se hydrogen selenide</p> <p>Rule 2: (H acids) (when dissolved in H₂O) hydro_ic acid</p> <p>Examples: HCl hydrochloric acid HF hydrofluoric acid H₂S hydrosulfuric acid H₂Se hydroselenic acid</p> <p>Comment: (a) These H-containing compounds are named as if they were ionic. b) Often the (aq) in the formulas of the acids is omitted when it is obvious from the context that they are acids.</p>	<p>Rule 1: (without the presence of H₂O) like ionic compounds: cation + anion hydrogen hypo_ite hydrogen _ite hydrogen _ate hydrogen per_ate</p> <p>Rule 2: (HO acids) (when dissolved in H₂O) hypo_ous acid _ous acid _ic acid per_ic acid</p> <p>Examples: HClO hypochlorous acid HClO₂ chlorous acid HClO₃ chloric acid HClO₄ perchloric acid HNO₂ nitrous acid HNO₃ nitric acid H₂SO₃ sulfurous acid H₂SO₄ sulfuric acid H₃PO₄ phosphoric acid</p> <p>Comment: The (aq) is usually omitted.</p>

¹adapted from Gerhard Lind, *Journal of Chemical Education*, **69**, 613 (1992)

What is to be done with ammonia which neutralizes acids but does not contain OH⁻? ... modify the definition

Arrhenius bases (modified definition) - increase concentration of OH⁻ above that present in pure water by reacting with water; so for ammonia



Arrhenius acids (modified definition) - increase concentration of H⁺ above that present in pure water by reacting with water