

Chapter 4

Chemical Reactions

I) Ions in Aqueous Solution

many reactions take place in water
form ions in solution

aq solution = solute + solvent

solute: substance being dissolved and present in lesser amount

solvent: substance doing the dissolving and present in greater amount

In aqueous solutions the solvent is Water

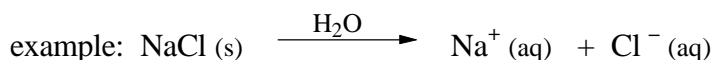
A) Solutes in aqueous solutions

2 categories

1) **Electrolytes:** substance that conducts electricity when dissolved in water

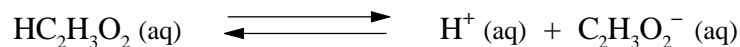
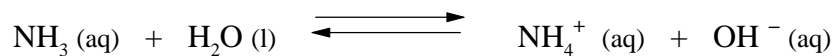
a) **Strong electrolytes**

- dissociate almost completely into ions (~100%)
- strongly conducts electricity
- only ions present in solution no molecules



b) **Weak electrolytes**

- partially dissociates into ions
- weakly conducts electricity
- mostly molecules present with a small % of ions
(mostly molecules few ions)



Note: How does an electrolyte conduct electricity?

- substance must form ions in solution
- movement of ions (charged particles) conduct the electrical current

- cation (+ ions) are attracted to the cathode (– electrode)
- anion (– ions) are attracted to the anode (+ electrode)

2) **Nonelectrolytes**

- do not conduct electricity when dissolved in water
- do not form ions; only intact molecules



B) Types of substances which form Strong electrolytes

1) Soluble Ionic Compounds

which compounds are soluble?

Check Solubility Table, Table 3.1 pg. 96 in Ebbing 5th edition

2) Strong Acids

defined in following section

3) Strong Bases

defined in the following section

Examples:

Which of the following substances will dissolve in water?

Also write a disassociation equation for the soluble substances?

NaCl

Ba(C₂H₃O₂)₂

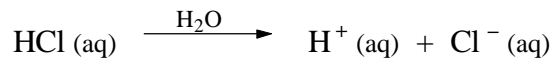
PbCl₂

CaCO₃

II) Acids and Bases

A) Defined by Arrhenius

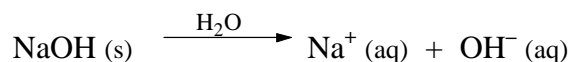
Acid: produces H^+ ions in solution when dissolved in water



Note: H^+ ion is a single proton and does not exist on its own. It will associate with a water molecule

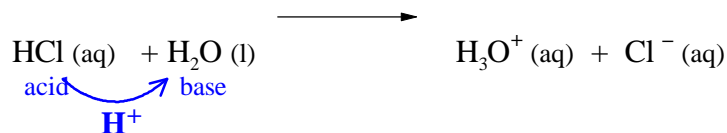


Base: produces OH^- ions in solution when dissolved in water

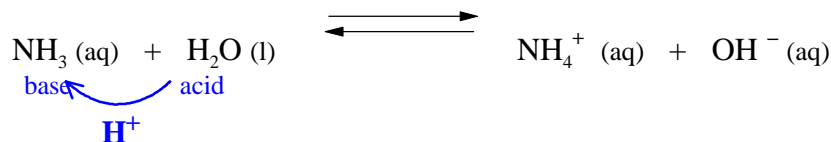


B) Defined by Brønsted and Lowry

Acid: proton donor



Base: proton acceptor



Note: In figuring out which species donated and accepted the proton compare reactants to the products

C) Properties of Acids and Bases

Properties	Acid	Base
Taste	sour	bitter
Color change with litmus paper	turns blue litmus red	turns red litmus blue
Electrolytes	strong and weak	strong and weak
Other		slippery feel
Reacts with one another	neutralization reaction acid + base \rightarrow ionic salt + water	

D) Electrolytes: Strong and weak

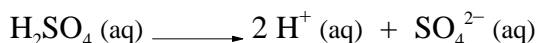
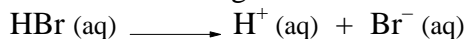
- Strong acid or base ionizes 100% into ions in solution (only ions present)
- Weak acid or base partially ionizes into ions in solution (mostly molecules and few ions)

Which acid and which bases are strong (or weak)

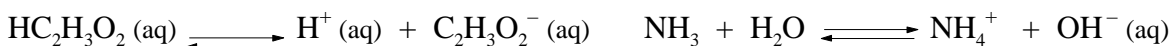
There are six strong acids and six strong soluble bases, the rest are weak.

Six Strong Acids		Six Strong Soluble Bases	
HCl	hydrochloric acid	LiOH	lithium hydroxide
HBr	hydrobromic acid	NaOH	sodium hydroxide
HI	hydroiodic acid	KOH	potassium hydroxide
HNO ₃	nitric acid	RbOH	rubidium hydroxide
H ₂ SO ₄	sulfuric acid	CsOH	cesium hydroxide
HClO ₄	perchloric acid	Ba(OH) ₂	barium hydroxide

Ionization of a strong acid or base



Ionization of a weak acid or base



III) Writing Net Ionic Equations

In a chemical equation, It is important to know which species are partaking in the actual reaction and which ones are spectators (just watching and not participating).

A) Molecular equations

In a molecular equation, all the species are written as if they were molecules or whole units.

e.g.



B) Complete ionic equation

A complete ionic equation represents all soluble ionic compound, strong acids and strong bases as ions. Weak acids or bases are written as molecules, as well as solids, liquids, weak electrolytes or nonelectrolytes.

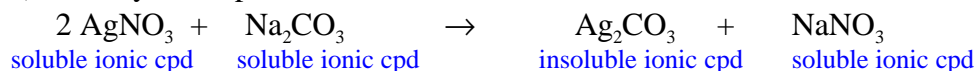
One approach to writing a complete ionic equation, look at each species in the molecular equation. If the species is a soluble ionic compound, a strong acid or a strong base, write these species as ions, otherwise leave the substance together as a molecule.

A few tools are needed:

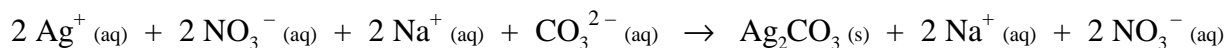
- 1) being able to identify an ionic compound
Ionic compound consist of a metal and a nonmetal or possible a polyatomic ion.
- 2) using a solubility table to identify if the ionic compound is soluble in solution.
A solubility table can be found on page 96 in the 6th edition of General Chemistry by Ebbing.
- 3) being able to identify which compounds are acids and which are bases.
Most acid have a H^+ ion as the cation and most bases have a OH^- ions as the anion. Acids: HF , HNO_3 , H_2CO_3 . Bases: $\text{Mg}(\text{OH})_2$, $\text{Al}(\text{OH})_3$, NH_3
- 4) having memorized the six strong acids and the six strong soluble bases.
The acids or bases that do not appear in these two list are either weak or insoluble in solution and written as molecules in the complete ionic equation.

e.g. Using the above molecular equation example, write complete ionic equation.

a) identify each species in the reaction



b) write the soluble ionic cpds, strong acids and strong bases as ions.



This is the complete ionic equation for this reaction.

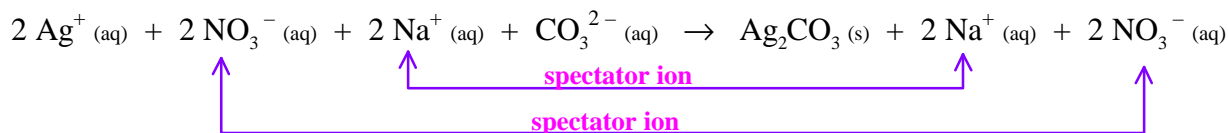
C) Net ionic equation

The net ionic equation is the complete ionic equation without the spectator ions. A spectator ion is the species which appears on both the reactant side and product side of the arrow.

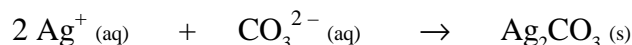
Why is the net ionic equation important? This equation shows which species are actually partaking in the chemical reaction. Knowing this information, a more expensive substance can be substituted with a cheaper one and save a company money.

e.g. write the net ionic equation for the above complete ionic equation.

a) identify the spectator ions

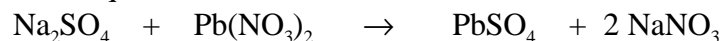


b) write the net ionic equation

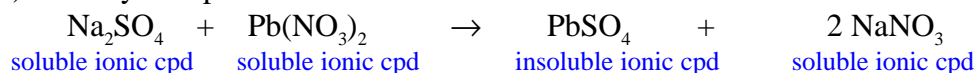


D) Try writing net ionic equations from a molecular equation

1) Molecular equation



a) identify the species



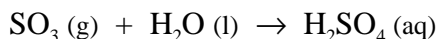
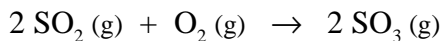
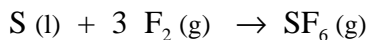
IV) Types of Reactions

A) Combination reaction

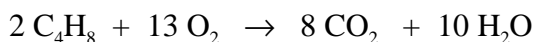
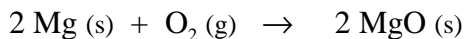
Two or more substances combine to form one substance



examples:



A special type of combination reaction is a combustion reaction (burning with oxygen)



(In this reaction oxygen combines with both carbon and hydrogen to form carbon dioxide and water, respectively.)

B) Decomposition reaction

A reactant breaks down into 2 or more products. This reaction is the reverse of the combination reaction.



examples:

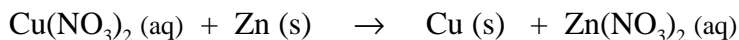


C) Single displacement reaction

An atom or ion in a compound is replaced with another atom or ion of another element.



examples:

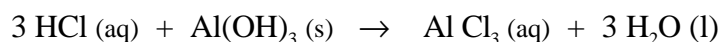
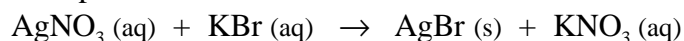


D) Double displacement reaction (metathesis)

exchange of either the cations or anions



examples:

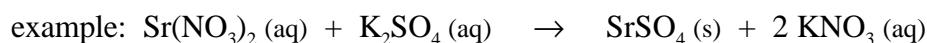


V) Reactions in Aqueous Solutions

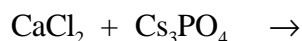
Double displacement reactions

A) precipitation reaction

- an insoluble solid product forms in solution
- this reaction is used to remove ions from solution

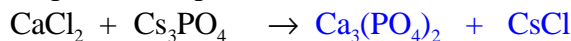


Predict whether a precipitate (ppt) will form given two reactants and write the net ionic equation.

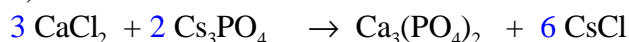


1) write the molecular equation

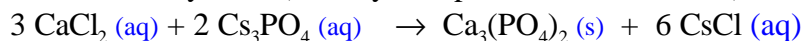
a) predict the product (with the correct chemical formula)



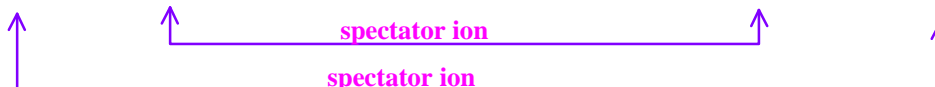
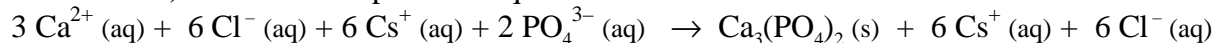
b) balance the reaction



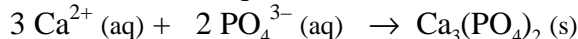
2) check solubility table (identify the species in the reactions)



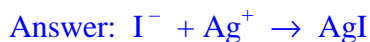
3) write the complete ion equation



4) write the net ionic equation

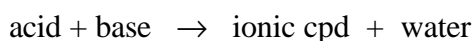


Practice:

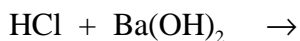


B) Neutralization reaction

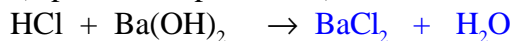
- forms an ionic compound and water as the products
- an ionic compound is sometimes referred to as a salt in this reaction
- In the ionic compound, the cation comes from the base and the anions comes from the acid



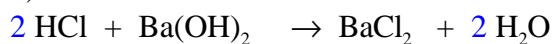
Predict the product and write the net ionic equation for the following reaction.



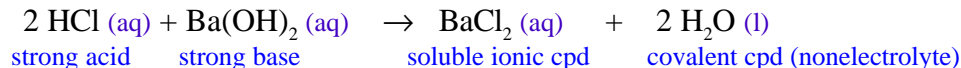
- 1) write the molecular equation
 - a) predict the product (with the correct chemical formula)



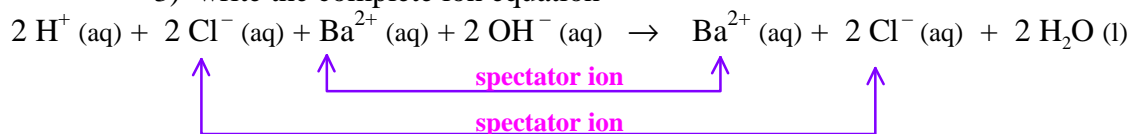
- b) balance the reaction



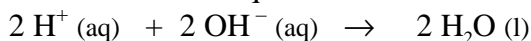
- 2) check solubility table (identify the species in the reactions)



- 3) write the complete ion equation



- 4) write the net ionic equation



Practice:



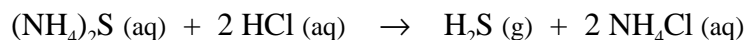
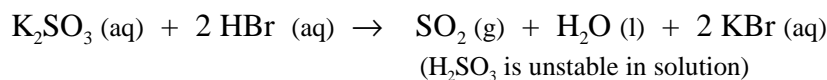
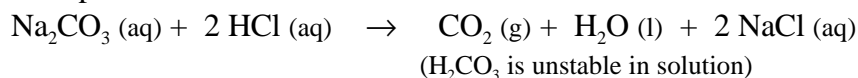
C) Gas formation reaction

- one product is unstable and decomposes into a gas
- removes ions from solution
- the anion in the reagent must be either carbonate (CO_3^{2-}), sulfite (SO_3^{2-}) or sulfide (S^{2-})

ionic cpd + acid \rightarrow new ionic cpd + gas (+ water)



examples:



Example:

Predict the product and write the net ionic equation for the following reaction.

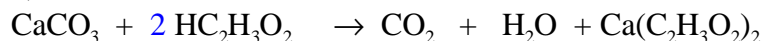


1) write the molecular equation

a) predict the product (with the correct chemical formula)



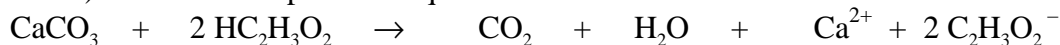
b) balance the reaction



2) check solubility table (identify the species in the reactions)

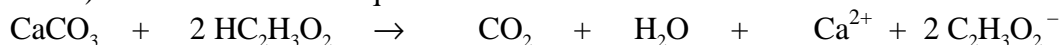


3) write the complete ion equation

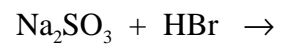


No spectator ions are present

4) write the net ionic equation



Practice:



VI) Oxidation/Reduction Reactions (redox rxn)

Oxidation/reduction reaction involves the transfer of e^- from one species to another

To monitor which atoms lose e^- charge and which gain it during a chemical reaction, chemist devised a "book keeping" system known as oxidation numbers. An oxidation number is a mental tool used to conceptually tally the electron charge. It is not a real charge. Each atom in a compound is assigned an oxidation number.

Note: For an ionic charge, the sign follows the number (2+).

For an oxidation number, the sign precedes the number (+2).

Rules for determining oxidation number (ox. num.)

1) For free elements: ox. num. = 0



2) Ions composed of 1 atom: ox. num. = charge on the ion

<u>ion</u>	<u>ox. num.</u>
Li^+	+1
O^{2-}	-2
I^-	-1

3) Oxygen-containing compounds: ox. num. of oxygen = -2

exception: hydrogen peroxide H_2O_2 ox. num. for oxygen = -1

4) Hydrogen-containing compounds: ox. num. of H = +1

exception: when hydrogen is bonded to a metal (e.g. NaH)

ox. num. for hydrogen = -1

5) In neutral compounds: the sum of ox. num. must equal zero

in polyatomic ions: sum of the ox. num. must equal the net charge on the ion.

examples: determine the ox. num. of each atom in the following compounds.



Since this compound is composed of ions, the oxidation number of each atom is the same as the ionic charge of the ion.

The ox. num. for Al^{3+} = +3 and the ox. num. for each Cl^- atom = -1

The sum of the ox. num. should equal zero. One atom of Al with ox. num. = +3 plus three atoms of Cl each with an ox. num. = -1.

$$1(+3) + 3(-1) = 0$$



Start assigning oxidation numbers with oxygen.

Ox. num. for oxygen = -2 (rule #3)

In this polyatomic ion the sum of the ox. num. will equal -2

therefore the sum of the ox. num. of 1 sulfur atom and 4 oxygen atoms should = -2

worksheet: $1(x) + 4(-2) = -2$

$$x + -8 = -2$$

$$x = +6$$

The ox. num. of sulfur = $+6$



Since this is an element the oxidation number of hydrogen = 0



ox. num. of Na = $+1$

ox. num. of O = -2

ox. num. of N = $+5$

check sum of ox. num.

$$1(+1) + 1(+5) + 3(-2) = 0$$

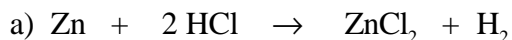
Oxidation/Reduction reaction involves the transfer of electrons between species in which atoms change oxidation number. (The same atom on the reactant side and the product side of the reaction have different oxidation numbers.) If oxidation occurs in a reaction, so must reduction. One can not appear without the other.

Oxidation reaction involves a loss of electrons (or an increase in the oxidation number)

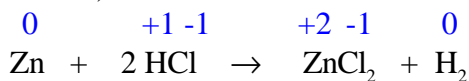
Reduction reaction involves a gain of electrons (or a decrease in the oxidation number)

To determine which species in a reaction is undergoing oxidation, reduction or not changing, the oxidation number of an atom on the reactant side of the equation is compared to the oxidation number of the same atom on the product side of the reaction.

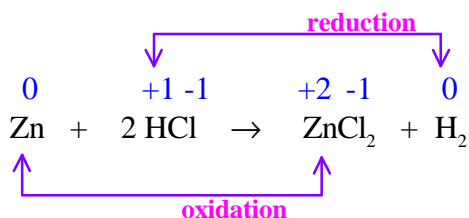
for example in the following chemical equation, determine which species is undergoing oxidation and which is undergoing reduction.



1) Determine the oxidation number of each atom on both sides of the reaction

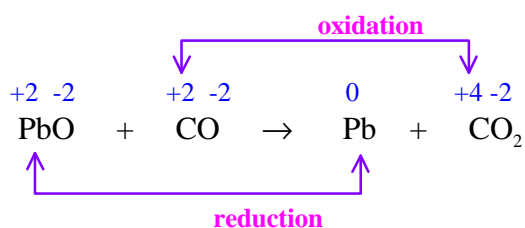
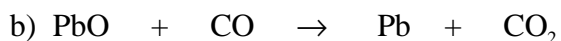


2) Which atom is losing e^- and which is gaining e^- ?



Zn started with an ox. num. = 0 on the reactant side and then increased to an ox. num. = +2 on the product side. (oxidation)

H started with an ox. num. = +1 on the reactant side and was reduced to an ox. num. = 0 on the product side. (reduction)



lead is being reduced and carbon is being oxidized

In a redox reaction, reactants can be identified as either a reducing agent or an oxidizing agent. A **reducing agent** is doing the reducing and it itself is undergoing oxidation, whereas an **oxidizing agent** is doing the oxidizing and it itself is undergoing reduction.

Identify the oxidizing agent and the reducing agent in chemical reaction b above.

Lead is undergoing reduction and it is oxidizing carbon, therefore PbO is the oxidizing agent. Because carbon is undergoing oxidation and is reducing the lead, CO is the reducing agent.

For good practice at home

Write a balance molecular equation for each of the following problems.

- 1) Gallium metal is heated in oxygen gas, it melts and forms solid gallium(III) oxide.
- 2) When solutions of calcium chloride and sodium phosphate are mixed, solid calcium phosphate forms and sodium chloride remains in solution.
- 3) Liquid disilicon hexachloride reacts with water to form solid silicon dioxide, hydrogen chloride gas and hydrogen gas.