

Reactions in Aqueous Solutions

Chapter 7

Sodium Reacting with Water.

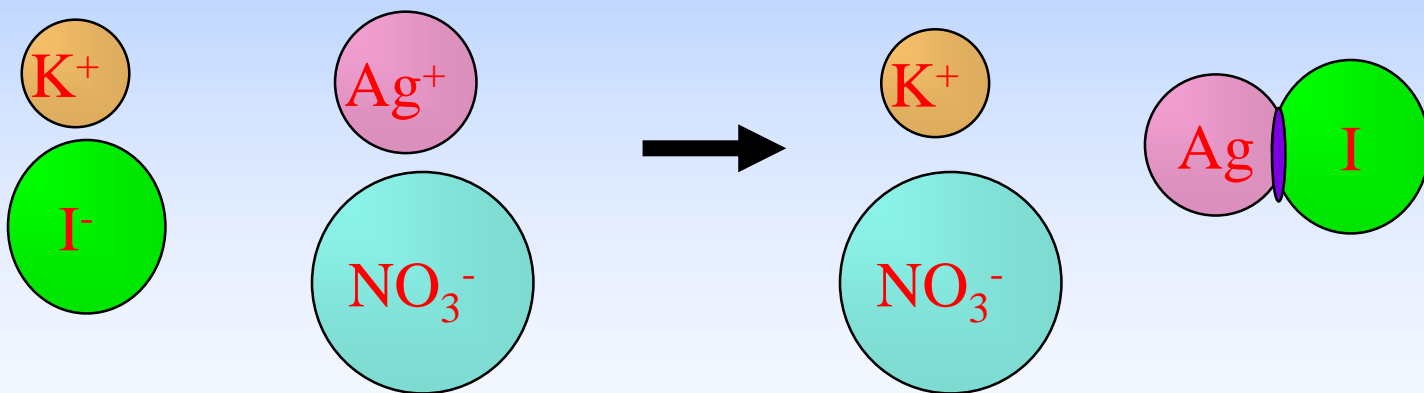
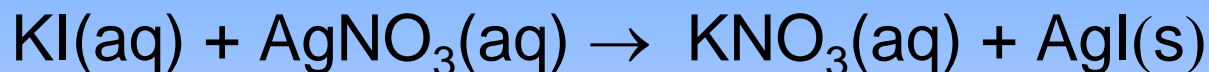


Predicting Whether a Reaction Will Occur

- “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

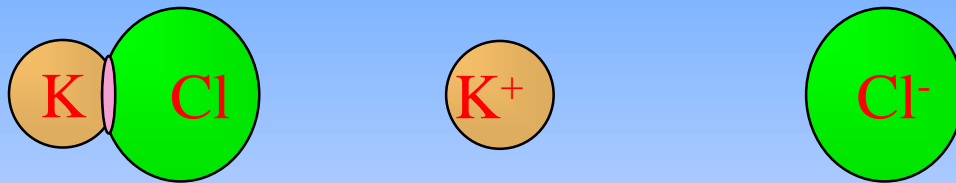


Dissociation

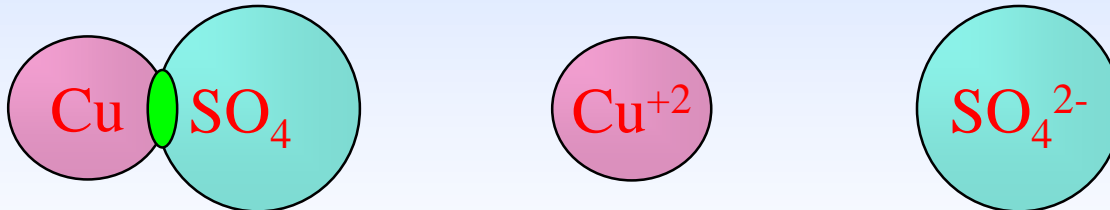
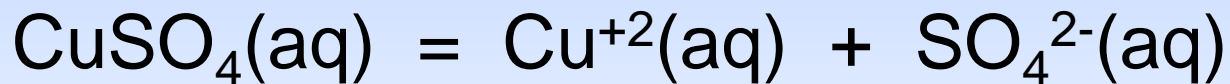
- ionic compounds
 - metal + nonmetal (Type I & II)
 - metal + polyatomic anion
 - polyatomic cation + anion
- when ionic compounds dissolve in water the anions and cations are separated from each other; this is called **dissociation**
- we know that ionic compounds dissociate when they dissolve in water because the solution conducts electricity

Dissociation

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

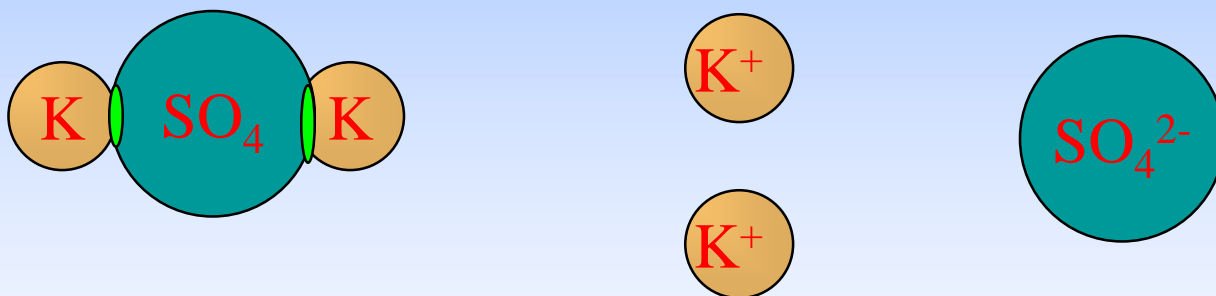


- copper(II) sulfate dissociates in water into copper(II) cations and sulfate anions



Dissociation

- 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

Solubility Rules

- Most compounds that contain NO_3^- ions are soluble
- Most compounds that contain Na^+ , K^+ , or NH_4^+ ions are soluble
- Most compounds that contain Cl^- ions are soluble, except AgCl , PbCl_2 , and Hg_2Cl_2
- Most compounds that contain SO_4^{2-} ions are soluble, except BaSO_4 , PbSO_4 , CaSO_4
- Most compounds that contain OH^- ions are slightly soluble (will precipitate), except NaOH , KOH , are soluble and $\text{Ba}(\text{OH})_2$, $\text{Ca}(\text{OH})_2$ are moderately soluble
- Most compounds that contain S^{2-} , CO_3^{2-} , or PO_4^{3-} ions are slightly soluble (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.

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

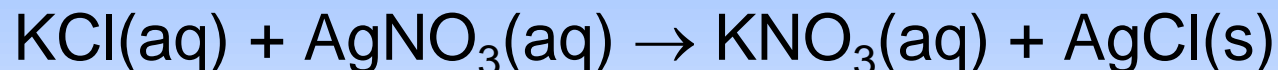
S^{2-} , CO_3^{2-} , PO_4^{3-} salts

OH^- salts

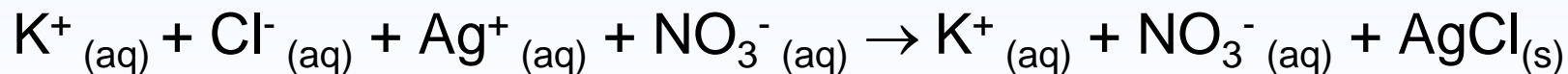
Except for those containing Na^+ , K^+ , Ca^{2+} , Ba^{2+}

Ionic Equations

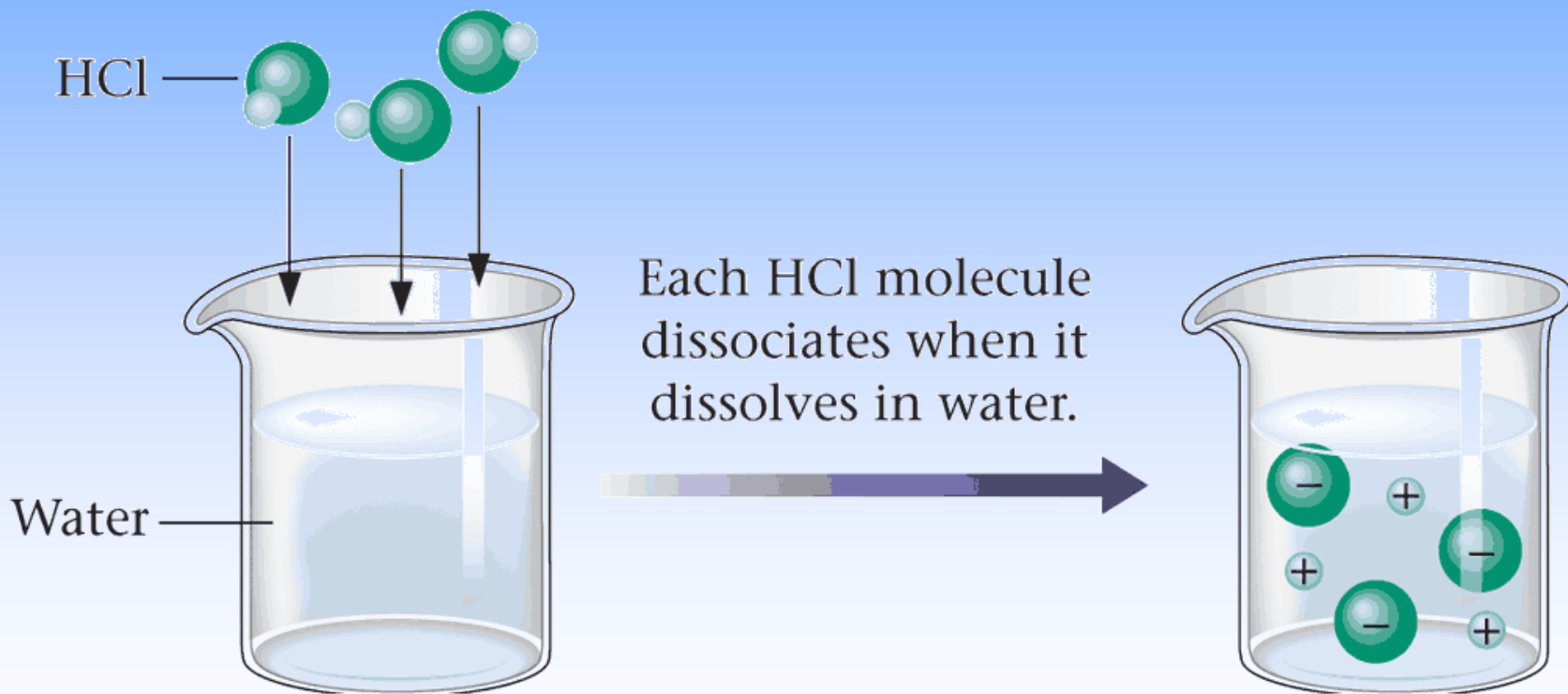
- equations which describe the chemicals put into the water and the product molecules are called **molecular equations**



- equations which describe the actual ions and molecules in the solutions as well as the molecules of solid, liquid and gas not dissolved are called **ionic equations**

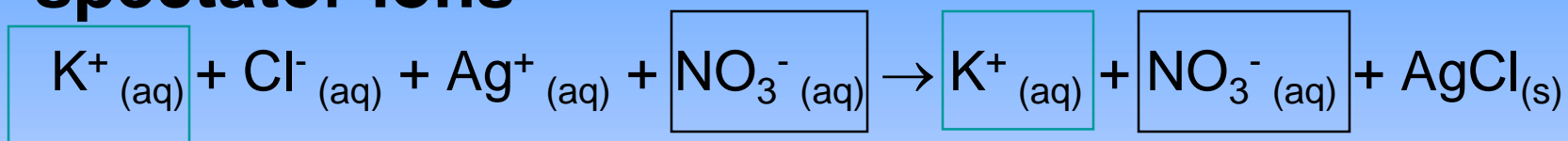


When gaseous HCl is dissolved in water, each molecule dissociates to produce H^+ and Cl^- ions.

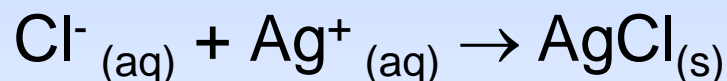


Ionic Equations

- ions that are both reactants and products are called **spectator ions**



- an ionic equation in which the spectator ions are dropped is called a **net ionic equation**



Electrolytes

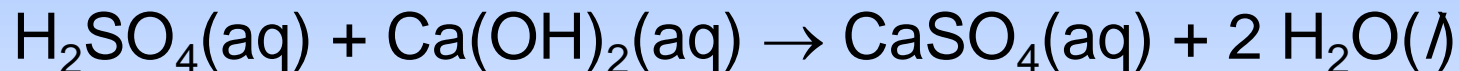
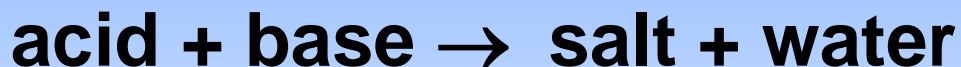
- electrolytes are substances whose aqueous solution is a conductor of electricity
- all electrolytes have ions dissolved in water
- in **strong** electrolytes, virtually **all** the molecules are dissociated into ions
- in **nonelectrolytes**, **none** of the molecules are dissociated into ions
- in **weak** electrolytes, a **small percentage** of the molecules are dissociated into ions

Reactions that Form Water: Acids + Bases

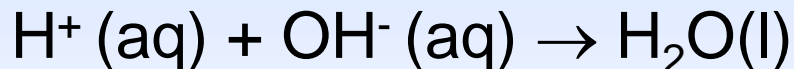
- Acids all contain H^+ cations and an anion
- Bases all contain OH^- anions and a cation
- when acids dissociate in water they release H^+ ions and their anions
- when bases dissociate in water they release OH^- ions and their cations

Acid-Base Reactions

- in the reaction of an acid with a base, the H^+ from the acid combines with the OH^- from the base to make water
- the cation from the base combines with the anion from the acid to make the salt



- the net ionic equation for an Acid-Base reaction is always



Reactions of Metals with Nonmetals (Oxidation-Reduction)

- The metal loses electrons and becomes a cation
 - We call this process **oxidation**
- The nonmetal gains electrons and becomes an anion
 - We call this process **reduction**
- In the reaction, electrons are transferred from the metal to the nonmetal

Oxidation-Reduction Reactions

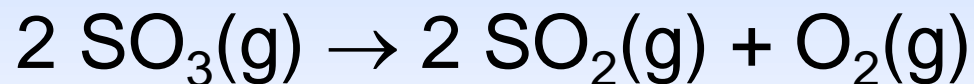
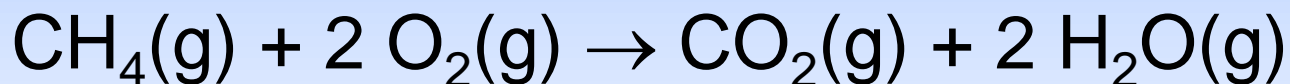
- All reactions that involve a transfer of one or more electrons are called **oxidation-reduction reactions**
- We say that the substance that loses electrons in the reaction is **oxidized** and the substance that gains electrons in the reaction is **reduced**.

Predicting Products of Metal + Nonmetal Reactions

- metal + nonmetal \rightarrow ionic compound
 - ionic compounds always solids unless dissolved in water
- in the ionic compound the metal is now a cation
- in the ionic compound the nonmetal is now an anion
- to predict direct synthesis of metal + nonmetal
 - ★ determine the charges on the cation and anion
 - from their position on the Periodic Table
 - ★ determine numbers of cations and anions needed to have charges cancel
 - ★ balance the equation

Another Kind of Oxidation-Reduction Reaction

- Some reactions between two non-metals are also oxidation-reduction reaction
- Any reaction in which O_2 is a reactant or a product will be an oxidation-reduction reaction



Ways to Classify Reactions

- Reactions that involve solid formation are called **precipitation reactions**
- Reactions that involve water formation are called **acid-base reactions**
- Both precipitation reactions and acid-base reactions involve compounds exchanging ions, ion exchange reactions are called **double displacement reactions**

Double Displacement Reactions

- two ionic compounds exchange ions
- $X^{\oplus}Y^{-}(\text{aq}) + A^{\oplus}B^{-}(\text{aq}) \rightarrow XB + AY$
- reaction will not occur unless one of the products either (1) precipitates, (2) or is water

Ways to Classify Reactions

- Reactions that involve electron transfer are called **oxidation-reduction reactions**
 - Metals + Nonmetal
 - O₂ as a reactant or product
- Reactions that occur in aqueous solution because one of the products is a gas are called **gas forming reactions**



Ways to Classify Reactions

- Reactions that involve one ion being transferred from one cation to another are called **single replacement reaction**

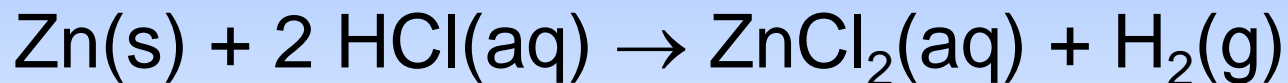
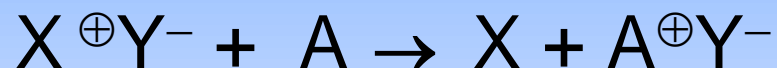
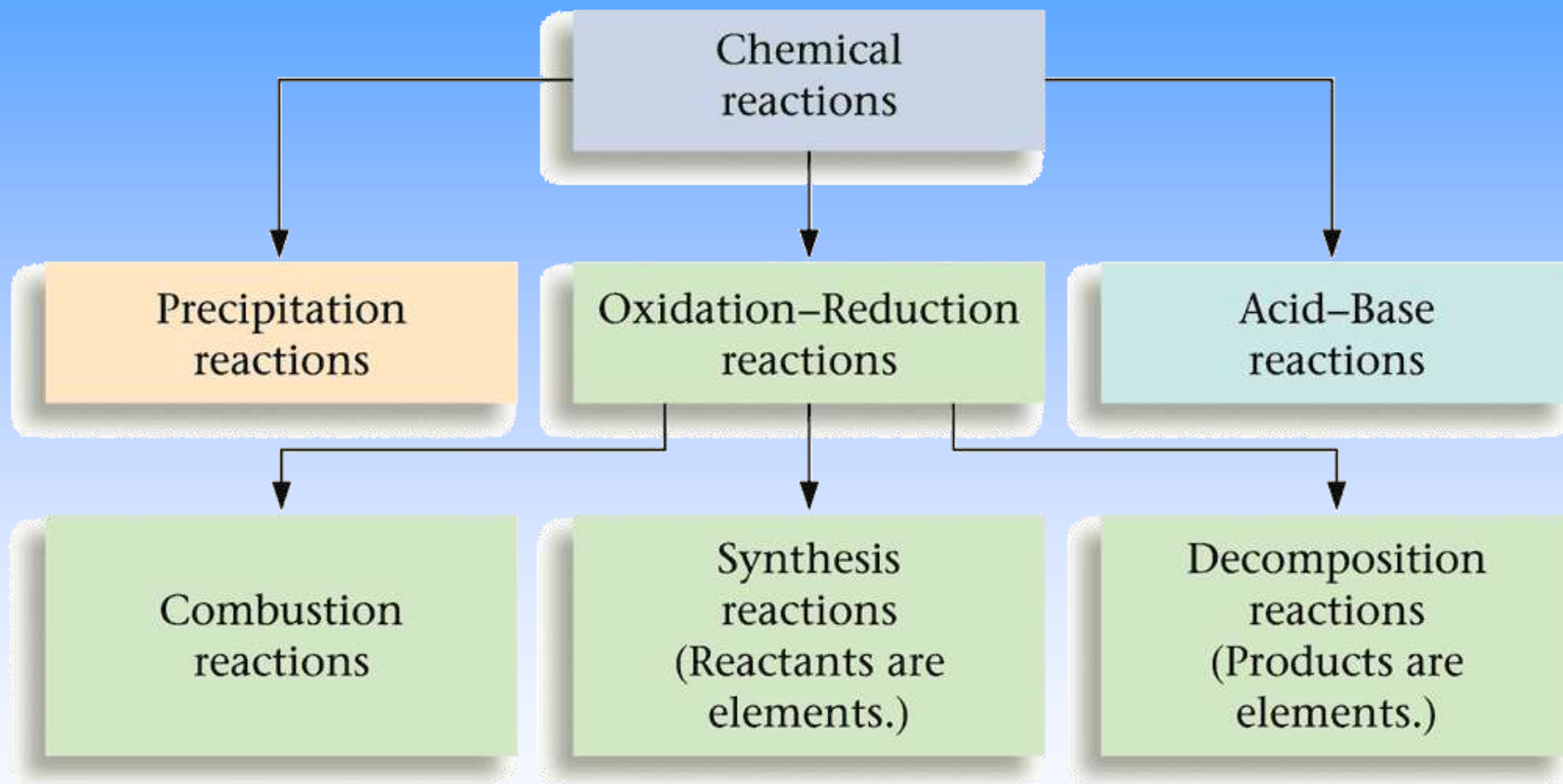
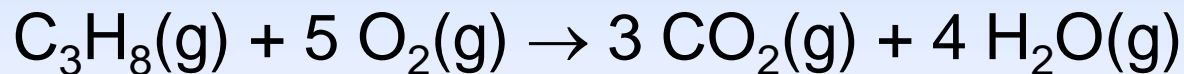


Figure 7.12: Summary of classes of reactions.



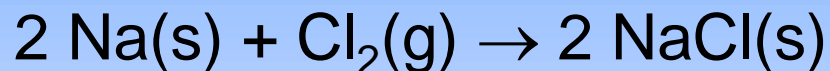
Other Ways to Classify Reactions

- Reactions in which $O_2(g)$ is reacted with a carbon compound are called **Combustion Reactions**
- Combustion reactions release a lot of energy
- Combustion reactions are a subclass of Oxidation-Reduction reactions
- Combustion of carbon compounds produces $CO_2(g)$
- Combustion of compounds that contain hydrogen produces $H_2O(g)$

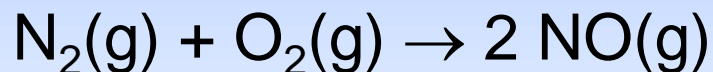


Other Ways to Classify Reactions

- Reactions in which chemicals combine to make *one product* are called **Synthesis Reactions**
- Metal + Nonmetal reactions can be classified as Synthesis Reactions



- Reactions of Metals or Nonmetals with O_2 can be classified as Synthesis Reactions



- These two types of Synthesis Reactions are also subclasses of Oxidation-Reduction Reactions

Other Ways to Classify Reactions

- Reactions in which *one reactant* breaks down into smaller molecules are called **Decomposition Reactions**
- Generally initiated by addition of energy
 - Addition of electric current or heat
- Opposite of a Synthesis Reaction



electric
current