Chemical and Physical Properties

- Physical properties
  - Observations about a substance
  - changes that do not involve a change in the arrangement of the atoms in the substance.
    - Density
    - Hardness
    - Melting and boiling point

- Chemical Properties
  - Atomic rearrangement to make new substance(s).
    - Burning wood (combustion)
    - Iron rusting (oxidation - reduction)
    - Gunpowder exploding
Chemical Equations

- Consider the reaction $A + B \rightarrow C + D$
  - $A$, $B$ are reactants
    - amount of $A$ and $B$ decreases as the reaction progresses.
  - $C$, $D$ are products
    - amount of $C$ and $D$ increases as the reaction progresses.
  - $$\rightarrow$$ similar to equal sign in mathematical equation.

Formation of Water

Balancing Chemical Equations

- Balancing chemical equations involve the rearrangement of atoms.
- Must insure the same number of each type of atom appears on each side of the equation.
- Can ONLY manipulate coefficients in front of the atom/molecule.
Balancing Chemical Equations

- Final values for these molecular/atomic coefficients.
- Must be whole numbers, not fractions.
- Cannot have a fractional amount of a molecule or a part of an atom!
- Should represent the smallest whole number ratio that is possible.

Balancing Chemical Equations

- Tips
  - You **must** be able to count atoms!
  - For $4\text{Al}(\text{SO}_4)_3$
    - 8 Al, 12 S, 48 O
  - Start with an element in only one place on each side of the equation.
  - Finish with any substance in elemental form.
  - Balance polyatomic ions as a unit.
  - Put in fractions; then multiply to eliminate.

Symbols in Chemical Equations

<table>
<thead>
<tr>
<th>Table 13.2: Common Symbols in Chemical Equations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Symbol</strong></td>
</tr>
<tr>
<td>+</td>
</tr>
<tr>
<td>→</td>
</tr>
<tr>
<td>(g)</td>
</tr>
<tr>
<td>(l)</td>
</tr>
<tr>
<td>(s)</td>
</tr>
<tr>
<td>(aq)</td>
</tr>
<tr>
<td>NH₂O₂</td>
</tr>
<tr>
<td>⇋</td>
</tr>
</tbody>
</table>
Balancing Chemical Equations

- **Examples**
  - \( \text{H}_2 + \text{O}_2 \rightarrow \text{H}_2\text{O} \)
  - \( \text{KClO}_3 \rightarrow \text{KCl} + \text{O}_2 \)
  - \( \text{Mg} + \text{O}_2 \rightarrow \text{MgO} \)
  - \( \text{C}_2\text{H}_4 + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O} \)

- **Types of Reactions**
  - Combination
  - Decomposition
  - Combustion

Combination and Decomposition Reactions

- **Combination Reaction**
  - Rapid exothermic reaction with oxygen.
  - Hydrocarbons
    - Compounds containing only carbon and hydrogen
    - Gasoline, natural gas, oils
  - Product of combustion reaction with hydrocarbons is \( \text{CO}_2 + \text{H}_2\text{O} \)
  - Reactions are all exothermic.
Balancing Chemical Equations

- Learning Goals
  - Distinguish between chemical and physical changes
  - Balance chemical equations
  - Identify combination, decomposition, and hydrocarbon combustion reactions
- Questions: 2 - 10
- Exercises: 1 - 5 odd

Energy and Reaction Rates

- All reactions include a change in energy.
  - Exothermic - Energy is released.
  - Endothermic - Energy is absorbed.
- Activation Energy
  - Energy required to start a reaction.
  - Car pushed up over a small hill to coast to the bottom of a large hill

Exothermic Process
Endothermic Reaction

For a reaction to occur, molecules/atoms must collide with sufficient energy in the proper orientation.

Increase in temperature increases the rate of a reaction
- increased temp increases the average kinetic energy of the molecules
- leads to more ‘effective’ collisions
Reaction Rates

- Reaction rates usually increase with an increase in the concentration of the reactant(s).
  - More chances for a collision.
- Rate increases with increase in surface area.
  - Grain elevator explosions.

Reaction Rates

- Catalysts
  - Increase the rate of a reaction without being permanently changed.
  - Catalytic converter on car.
  - Works by lowering the activation energy.
    - Go around the small hill rather than over.
- Enzymes
  - Biochemical catalysts

Energetics of Catalysts
Energy and Reaction Rates

- Learning Goals
  - Describe the role of energy in chemical reactions.
  - State the factors that affect the rate of a reaction.
- Questions: 11 - 20
- Exercise: 7

Acids and Bases

- Acids
  - Conduct electricity
  - Change litmus from blue to red
  - Sour
  - Neutralize properties of a base
  - Reacts with active metals to produce H₂
- Bases
  - Conduct electricity
  - Change litmus from red to blue
  - Bitter

Chemical Equilibrium

- Consider the reaction A + B → C + D
  - A, B are reactants
    - Amount of A and B decreases as the reaction progresses.
  - C, D are products
    - Amount of C and D increases as the reaction progresses.
Chemical Equilibrium

- Consider \( C + D \rightarrow A + B \)
  - Reverse of previous process
  - If both reactions occur (to a significant extent) we have a ‘reversible’ reaction.
  - Written \( A + B \leftrightarrow C + D \)
  - the double arrow (\( \leftrightarrow \)) indicates the reversible reaction
  - Every reaction is somewhat reversible; double arrow indicates significant amounts of all products and reactants at equilibrium.

Chemical Equilibrium

- Occurs when the rate of the forward process is equal to the rate of the reverse process.
  - Consider \( A + B \rightarrow C + D \)
  - At equilibrium, for every set of \( A \) and \( B \) molecules that reacts to form a set of \( C \) and \( D \) molecules, another set of \( C \) and \( D \) molecules reacts to form a set of \( A \) and \( B \) molecules.

Arrhenius

- Acid - reacts in water to give \( H^+ \) ions.
  - Strong acid - all molecules react (\( \text{HCl}_{aq} \))
  - Weak acid - only some react (\( \text{HC}_2\text{H}_3\text{O}_2 \))
  - Equilibrium process
  - Many industrial/food uses
- Base - reacts in water to give \( \text{OH}^- \) ions.
  - Strong base - soluble hydroxides
  - Weak base - molecules containing \( N \)
  - Also an equilibrium process
**pH scale**
- Measure of concentration of $H^+$
  - logarithmic scale
  - Several common pH values shown below

**Acid / Base Reaction**
- $HCl + NaOH \rightarrow H_2O + NaCl$
  - Products are water and a 'salt'
    - salt is a generic term for an ionic compound.
    - Any cation except $H^+$
    - Any anion except $OH$

**Salts**
- Salts may be hydrated or anhydrous
  - $Cu(SO_4)(H_2O)_6$ - hydrated salt (Blue)
  - $CuSO_4$ - anhydrous - white
Carbonates

- Carbonates are salts containing $\text{CO}_3^{2-}$
- Products of acidic reaction with carbonates:
  - $\text{H}_2\text{O}$
  - salt
  - $\text{CO}_2$
- Baking soda
  - reaction with $\text{NaHCO}_3$ causes $\text{CO}_2$ to form.
  - products 'rise'

Double Replacement Reaction

- $\text{AB} + \text{CD} \rightarrow \text{AD} + \text{CB}$

  Precipitate
  - insoluble solid
  - typically insoluble salt
  - Soluble salts
    - Nitrate, acetate, ammonium, alkali metal ions.

Acids and Bases

- Learning Goals
  - Describe the properties of acids and bases.
  - Write chemical reactions for double replacement reactions.
- Questions: 21 - 31
- Exercises: 9, 11
Single Replacement Reactions

- Species reacts with oxygen.
  - Oxidation
  - Now defined as reaction when electron(s) are lost.
- Reacts to remove oxygen - reduction
  - $2 \text{Fe}_2\text{O}_3 + 3\text{C} \rightarrow 4\text{Fe} + 3\text{CO}_2$
    - Iron is reduced
    - Carbon is oxidized
    - Reduction = gain of electrons

Oxidation-Reduction Reactions

- Redox for short
  - Cannot have oxidation without reduction.
  - Do not need oxygen at all!
  - $2\text{Na} + \text{Cl}_2 \rightarrow 2\text{NaCl}$
    - Na is oxidized
    - Cl$_2$ is reduced
    - No oxygen required!
- Most combination/decomposition reactions are redox reactions.

Single Replacement Reaction

Zinc metal + Copper(II) sulfate $\rightarrow$ Copper metal + Zinc sulfate
Activity Series

- Used to predict whether a single replacement reaction will occur.
  - $A + BC \rightarrow AC + B$
  - If A is above B then reaction will occur.
  - Metals above H will produce $H_2$
  - Table 13.5

Single Replacement Reactions

- Reaction types summarized in Table 13.6
- Learning Goals:
  - Define the terms oxidation and reduction.
  - Write equations for single replacement reactions.
- Questions: 32 - 35
- Exercises: 13, 15

Avagadro’s Number

- Number of ‘things’ in one mole
  - Atoms
  - Molecules
  - Electrons...
  - $6.022 \times 10^{23}$
- Allows atomic mass in amu to correlate to molar mass in g
Avagadro’s Number

- For the reaction Na⁺ + e⁻ → Na
  - 96,485 C of charge to make 23.0 g (1 mole) of sodium
    - Charge on one electron = 1.6022 × 10⁻¹⁹ C
    - 2 mole e⁻ = 1 mole Na
    - (96,485 C)/(1.6022 × 10⁻¹⁹ C/electron)
    - = 6.022 × 10²³ electrons

Molarity

- Ratio of reacting particles present to volume of solution
  - Moles / liters (moles per liter)
  - Symbol is $M$
- Since reactions based on number of molecules, this is a convenient measurement for concentration!

Example

- What is the molarity of sucrose when 0.400 mol of the sugar is dissolved to give 1.80 L of solution?
  - Moles of solute: 0.400
  - Liters of solution: 1.80 L
  - Molarity = 0.400 mol / 1.80 L
  - Molarity = 0.222 $M$
Avagadro’s Number

- Learning Goal
  - State the relationship among mole, mass, and Avagadro’s number.
  - Explain the concept of molarity.
- Questions: 36, 37
- Exercises: 17 – 21
- Key Terms; Matching, Multiple Choice, and Fill-in-the-Blank Questions; Visual Connection and Applying your Knowledge

General Physical Science

Chapter 13
Chemical Reactions