CHEM 1520

Course Topics and Learning Objectives

Text: R. Chang and J. Overby, *Chemistry*, McGraw-Hill, 13th Edition, 2019.

Section 1. Gases (Chapter 5: pages 175-229; 6 lectures)

1.1. Gas properties and pressure
(Reading: pages 175-180)

Properties of solids, liquids and gases.
Pressure. Atmospheric pressure. Barometer. Manometers.
Pressure units and unit conversions.

Questions you should be able to answer:
- Explain the general differences between solids, liquids and gases.
- Explain some of the physical properties of gases
- Convert between different pressure units (torr, mmHg, atm, Pa).

1.2. The gas laws
(Reading: pages 180-186)

The ideal gas model and the approximations involved
Boyle's law (p, V). Charles' law (V, T and p, T)
Combined gas law (p, V, T). Avogadro's law (V, n)

Questions you should be able to answer:
- Write, explain, and apply Boyle's law, Charles's law, Avogadro's law and the combined gas law.
- Solve quantitative or qualitative problems involving the various gas laws studied.
- Know what the STP conditions are and be able to apply this knowledge in problems.

1.3. The ideal gas law: Applications
(Reading: pages 186-197)

Derivation of the ideal gas law or the equation of state of the ideal gas ($pV=nRT$)
The ideal gas constant, R
Determination of molar masses
Determination of gas densities
Determination of molecular formulae
Stoichiometry calculations involving gases

Questions you should be able to answer:
- Know the ideal gas equation and use it for solving problems.

- Know what the constant R is and that it can be expressed in a variety of units.
- Given a set of conditions (some magnitudes changing and other remaining constant), derive the equation that applies using the ideal gas law ($pV=nRT$) and solve for the magnitude of interest.
- Apply the ideal gas law equation for determining gas densities, molar masses and molecular formulae.
- Apply the ideal gas law equation when solving stoichiometric problems when gases are involved.
- Be able to calculate the molar volume (V_m) of any gas at STP conditions.

1.4. Dalton's law of partial pressures

(Reading: pages 197-201)

Partial pressure of a gas in a mixture
Dalton's law of partial pressures
Mole fractions and partial pressures
Collecting gases over water: water vapour pressure

Questions you should be able to answer:
- Know what the Dalton's law is and be able to apply it in problems involving gas mixtures, including the collection of gases over water.
- Know what mole fractions and partial pressures are and be able to calculate them given a gas mixture.
- Be able to derive the expression $p(x) = \chi(x)\, P_T$

1.5. The kinetic molecular theory (KMT) of gases

(Reading: pages 203-208)

Postulates of the KMT
Molecular interpretation of pressure and temperature
Average kinetic energy, E_K
Relationship between temperature, E_K, and speed of molecules
Explaining the gas laws using the KMT
Molecular speeds: average, most probable and root-mean-square speeds
Effect of temperature on molecular speeds
Effect of molar masses on molecular speeds

Questions you should be able to answer:
- Know and understand the postulates of the KMT of gases.
- Explain what the ideal gas model is and the approximations involved according to the postulates of the KMT.
- Explain the gas laws studied from a molecular point of view by means of the KMT.
- Understand how the pressure of a gas relates to the frequency and strength of the collisions of its particles.
- Explain the relationship between temperature, the average kinetic energy, and the speed of molecules.
- Explain the difference between the different types of molecular speeds studied: average, most probable and root-mean-square (RMS) speeds
- Using the two expressions for calculating kinetic energy, be able to derive the equation that relates RMS speeds and molar masses, and use it in calculations.

1.6. Diffusion and effusion

(Reading: pages 208-211)

Diffusion
Effusion
Graham's laws of effusion and diffusion

Questions you should be able to answer:
- Explain what effusion and diffusion are.
- Understand how the rates of effusion and diffusion of gases relate to their molecular masses.
- Apply Graham's law of effusion and diffusion in calculations.

1.7. Deviation from ideal behaviour

(Reading: pages 211-214)

Conditions under which gases deviate from ideal behaviour
The van der Waals equation

Questions you should be able to answer:
- Explain the conditions under which gases deviate from ideal behaviour
- Explain how the pressure and volume of gases that deviate from ideal bahaviour need to be corrected making use of the van der Waals equation.

Book Exercises for Practice

Pressure Conversions/Manometer	5.14
Gas laws	5.18, 5.20, 5.22, 5.24, 5.26
Ideal gas law	5.32, 5.34, 5.36, 5.38, 5.42, 5.44
Stoichiometry	5.54, 5.56, 5.60
Partial pressures	5.70, 5.72, 5.74, 5.76
Kinetic-Molecular Theory/Graham's Law	5.88
Additional Problems	5.98, 5.100, 5.110, 5.142

Section 2: Thermochemistry (Chapter 6: pages 230-273; 4 lectures)

2.1. Basic concepts

(Reading: pages 231-232, 234-240)

Forms of energy: kinetic, potential, and other examples
Thermochemistry
Energy units
System and surroundings
Internal energy; changes in internal energy
State functions
First Law of Thermodynamics: mathematical expression

Questions you should be able to answer:
- Be familiar with different forms of energy (radiant energy, thermal energy, chemical energy, potential energy, kinetic energy).
- Be able to identify what a system and its surroundings are for a given study.
- Explain what the internal energy of a system is and the sign of its change for physical and chemical processes.
- Explain what a state function is and provide examples.
- State and explain the First Law of Thermodynamics (energy conservation)
- Be able to use the equation that expresses the First Law of Thermodynamics in calculations that relate the change in internal energy to the heat (q, released or absorbed) and work done (w, on the system or by the system). For this you need to be able to determine the correct signs of q and w.

2.2. Enthalpy of chemical reactions

(Reading: pages 232-234, 240-246)

Enthalpy and Heat of reaction, ΔH^o
Exothermic and endothermic processes
Thermochemical equations
Sign and magnitude of ΔH^o

Questions you should be able to answer:
- Explain what enthalpy is and its variation for a chemical reaction
- Know how to classify a reaction according to the sign of its standard enthalpy change $\Delta H°$ (endothermic or exothermic), and be able to indicate if heat is absorbed or liberated by the reaction.
- Use thermochemical equations and stoichiometry to determine amount of heat lost or gained in a chemical reaction.

2.3. Calorimetry

(Reading: pages 246-252)

Specific heat capacity and heat capacity
Constant-pressure calorimeter
Calorimetry problems
Constant-volume calorimeter

Questions you should be able to answer:
- Explain what specific heat capacities and heat capacities are.
- Solve simple problems that relate heat released or absorbed with (specific) heat capacities and temperature changes.
- Understand how a constant-pressure calorimeter works and what its main components are.
- Determine heats of reactions, specific heat capacities or temperature changes given experimental data collected in a constant-pressure calorimetry experiment.
- Understand what a constant-volume calorimeter is and what can be calculated using it.

2.4. Hess' law: Applications

(Reading: pages 252-258)

Hess' law of heat summation: Applications
Heat of formation, ΔH_f^o
Calculation of ΔH^o using standard heats of formation

Questions you should be able to answer:
- Explain what a standard enthalpy of formation (ΔH_f^o) is and be able to obtain the equation whose ΔH is the ΔH_f^o of a given compound.
- Know that the ΔH_f^o of the most stable form of an element in its standard state is zero by definition.
- Know how to relate algebraic transformations on a chemical reaction to the changes in its $\Delta H°$ (inversion and multiplication by a number).
- Given the $\Delta H°$ of a group of reactions, know how to algebraically manipulate them in order to calculate the $\Delta H°$ of another reaction (application of Hess' law).
- Calculate the $\Delta H°$ of a reaction from the standard enthalpies of formation ($\Delta H°_f$) of the reactants and products involved.

2.5. **Examples of enthalpy changes that refer to specific processes** (self-study)

(Reading: pages 258-260)

Heat of vaporization
Heat of fusion
Heat of combustion
Heat of solution
Heat of dilution

Book Exercises for Practice

Calorimetry	6.32, 6.34, 6.36
Enthalpy	6.26, 6.46
Hess' Law	6.62, 6.64
Enthalpies of Formation	6.54, 6.56, 6.58
Additional Problems	6.78, 6.84, 6.88, 6.98, 6.120

Section 3: Chemical Kinetics (Chapter 13: pages 556-615; 5 lectures)

3.1. The rate of a reaction

(Reading: pages 557-564)

Average rates of reaction
Instantaneous rates of reaction
Relationship between reaction rate and concentration
Reaction rates and stoichiometry

Questions you should be able to answer:
- Know the definition of rate of reaction, average rate and instantaneous rate.
- Calculate average reaction rates.
- Express the rate of a reaction (write the rate expressions) relative to the change in concentration over time of any of the reactants or products involved.

3.2. The rate law

(Reading: pages 565-568)

The rate law
Order of reaction and overall order of reaction
Method of initial rates

Questions you should be able to answer:
- Explain what a rate law is.
- Given a rate law, be able to determine the order of reaction with respect to every reactant, the overall order of reaction and the units of the rate constant.
- Apply the method of initial rates to determine the rate law of a reaction and its rate constant.

3.3. The relation between reactant concentration and time

(Reading: pages 569-581)

Integrated rate laws for first- second- and zero-order reactions
Reaction half-life
Pseudo-first-order reactions

Questions you should be able to answer:
- Understand the procedure to derive an integrated rate law.
- Understand what half-life is and the procedure followed to derive its expression for first- second- and zero-order reactions.
- Given the order of a reaction, identify the corresponding integrated rate law and use it to calculate: (a) the concentration of a reactant after a certain period of time, (b) the time required to achieve a particular reduction of concentration, or (c) the rate constant.
- Given the order of a reaction, identify the corresponding half-life expression and use it in calculations.

- Given the order of a reaction, identify the corresponding integrated rate law and be able to identify the magnitudes that should be plotted, [A] or ln[A] or 1/[A] *versus* time, to experimentally confirm the order of such a reaction. Identify the slope and the intercept of the plot in each case.
- Understand how second-order reactions could become pseudo-first-order reactions under certain reaction conditions.

3.4. Activation energy and temperature dependence of rate constants

(Reading: pages 582-587)

Arrhenius equation (exponential and logarithmic forms)
Arrhenius parameters (E_a, A)
Collision theory

Questions you should be able to answer:

- Given the Arrhenius equation, identify what an Arrhenius plot is and the Arrhenius parameters that can be determined from its slope ($-E_a/R$) and intercept ($\ln A$).
- Given an Arrhenius plot, be able to extract useful information from its slope and intercept.
- Use the Arrhenius equation in calculations: (a) given k at two temperatures, determine E_a and A, (b) Given E_a and A, determine k at a given temperature, *etc*.
- Understand the basis of Collision theory and the factors that determine the effectiveness of collisions from a chemical point of view.
- Explain the meaning of the Arrhenius parameters, E_a and A, within the framework of Collision theory.

3.5. Reaction mechanisms

(Reading: pages 588-593)

Complex reactions
Reaction mechanism
Reaction intermediates
Elementary reactions (steps)
Molecularity of an elementary reaction (unimolecular, bimolecular, termolecular)

Questions you should be able to answer:

- Understand what complex and elementary reactions are.
- Know what a reaction mechanism is.
- Identify reaction intermediates given the elementary steps of a reaction mechanism.
- Be able to identify the molecularity of elementary reactions (steps) and to classify them in unimolecular, bimolecular or termolecular reactions.
- Understand what the rate-determining step (RDS) of a reaction mechanism is.
- Formulate the rate law of a reaction given a suggested reaction mechanism and the identification of the RDS (and vice-versa).

3.6. Catalysis

(Reading: pages 593-601)

Homogeneous catalysis
Heterogeneous catalysis
Enzyme catalysis

Questions you should be able to answer:
- Understand what a catalyst is and how it acts.
- Explain heterogeneous, homogeneous, and enzyme catalysis.

Book Exercises for Practice

Rate of Reaction	13.5, 13.6, 13.8
Rate Law	13.15, 13.17abd, 13.18
Reaction Concentration vs Time	13.25, 13.26a, 13.30
Activation Energy: Temperature Effects	13.47
Reaction Mechanisms	13.49, 13.51, 13.53, 13.55, 13.58 (ignore mechanism III)
Additional Problems	13.69, 13.74a, 13.76, 13.77, 13.78, 13.79ab, 13.85, 13.101ab, 13.102, 13.104, 13.109, 13.110, 13.111ac, 13.115, 13.117, 13.118, 13.134

Section 4: Acid-Base equilibrium (Review, Chapter 15: pages 660-711; 5 lectures)

4.1. Acid-Base concepts

(Reading: pages 661-662, 670-673)

Arrhenius theory
Brønsted-Lowry theory
Conjugate acid-base pairs
Amphiprotic (or amphoteric) substances

Questions you should be able to answer:

- Explain and apply the acid-base definitions according to Arrhenius and Brønsted-Lowry theories.
- Determine conjugate acid-base pairs.
- Be able to identify acids and bases in a chemical reaction
- Understand and be able to identify amphiprotic species

4.2. Acidity of a solution

(Reading: pages 663-673)

Autoionization of water
Calculations of pH, pOH, pK_w, $[H^+]$, $[OH^-]$
Neutral, acid and basic classification of solutions

Questions you should be able to answer:

- Calculate pH, pOH, and the concentrations of H^+ (H_3O^+) and OH^- in any solution, given one of these values.
- Classify a solution according to its pH in neutral, acidic or basic.
- Understand what K_w is and how it can be calculated

4.3. Acid-base strength and equilibrium

(Reading: pages 670-688)

Strong and weak acids and bases: Degree of dissociation and K (pK) values
K_a and K_b expressions for weak acids and bases
Calculation of pK_a and pK_b
Relationship between the K_a and K_b of a conjugate acid-base pair
Using acid-base strength to determine the direction of an equilibrium
Monoprotic, diprotic and polyprotic acids

Questions you should be able to answer:

- Relate the strength of an acid or base (strong/weak), with its degrees of dissociation (fully or partially dissociated) and the magnitude of the K of its reaction with water (K_a or K_b).
- Know the six strong acids: HCl, HBr, HI, HNO_3, $HClO_4$ and H_2SO_4 (first dissociation).
- Be able to calculate the pH or pOH of strong acids and bases in aqueous solution.
- Be able to compare the strength of an acid (base) with that of its conjugate base (acid).
- Obtain the K_a (or K_b) expression for the dissociation of any acid (or base) in water.

- Given K_a and K_b be able to calculate pK_a and pK_b, and vice versa.
- Know the relationship that exists between the K_a of an acid and the K_b of its conjugate base.
- Estimate the K of a particular acid-base reaction (>1 or <1) and predict the direction of acid-base reactions from the K_a (K_b) values of their respective conjugate acid-base pairs
- Be able to identify monoprotic, diprotic, and polyprotic acids.
- Understand what happens to the strength of a weak polyprotic acid as it dissociates in several steps.

4.4. Problems involving weak-acid and weak-base equilibria
(Reading: pages 674-683, 684-688)

Questions you should be able to answer:
- Solve acid-base equilibrium problems.
  (a) Knowing the initial acid or base concentration, and the pH (or pOH), calculate K_a or K_b.
  (b) Given the K_a or K_b, and the initial concentration of the weak acid or base, calculate the concentrations of all the species at equilibrium, and pH/pOH.
- Be able to apply assumptions to simplify an equilibrium problem and calculate the error made when making such assumptions.
- Calculate the pH of a polyprotic acid (self-study)

4.5. Acid-base properties of salt solutions (Hydrolysis)
(Reading: pages 692-697)

Salts that yield neutral, acid and basic aqueous solutions
pH calculations

Questions you should be able to answer:
- Determine the acid-base properties of salt solutions.
- Calculate the pH of different types of salts

4.6. Lewis theory of acids and bases (self-study)
(Reading: pages 699-701)

Book Exercises for Practice

Brønsted Acids and Bases	15.4, 15.6, 15.8
Acid and Base Strength	15.34, 15.36. 15.38
Strong Acids and Bases	15.16, 15.18, 15.22, 15.24
Weak Acids and Bases	15.44, 15.46, 15.54, 15.56
Salts	15.78, 15.80, 15.82
Lewis Acids and Bases	15.94
Additional Exercises	15.102, 15.104, 15.110, 15.130

Section 5: Buffers, Titrations & Solubility Equilibria (Chapter 16: pages 714-767; 6 lectures)

5.1. Buffer solutions: pH calculations

(Reading: pages 715-724)

Common ion effect
Acid-base buffers (pH buffers)
The Henderson-Hasselbalch (H & H) equation
pH calculations (before and after the addition of acid or base to a buffer)
Buffer capacity
Buffer range
Steps to prepare a buffer solution

Questions you should be able to answer:

- Understand and be able to explain the common ion effect
- Understand what a pH buffer is, how it works, and how it is normally prepared.
- Apply the Henderson-Hasselbalch equation to determine the pH of a buffer or its composition.
- Know the assumptions made in its use and its limitations.
- Understand what happens when additions of a strong acid or base are made to a pH buffer system
- Calculate the pH of a buffer system after the addition of small amounts of an acid or a base, using the H&H equation or solving an standard acid-base equilibrium problem (first a complete reaction takes place and then the equilibrium is re-established).
- Understand and apply the terms buffer capacity and pH range of a buffer.
- Compare several buffer solutions with respect to their buffer capacity and be able to determine their buffer range.
- Do the necessary calculations to prepare a given buffer solution.

5.2. Acid-base titrations

(Reading: pages 724-736)

Indicators
Equivalence point. End point
General characteristics of different types of titrations: SA-SB/SB-SA, WA-SB/WB-SA
pH calculations at different points during different types of titrations
Titration curves of polyprotic acids

Questions you should be able to answer:

- Calculate the pH during the course of a strong acid/strong base (SA-SB or SB-SA) titration
- Calculate the pH during the course of a weak acid/strong base (WA-SB) titration
- Calculate the pH during the course of a weak base/strong acid (WB-SA) titration
- Recognize the type of acid-base titration from a titration curve provided (or *vice versa*): SA-SB, SB-SA, WA-SB and WB-SA.
- Understand the terms equivalence point and end point of a titration.
- Choose an appropriate acid-base indicator knowing the pK_a of the indicator and the pH at the equivalence point.
- Explain the main characteristics of the types of the titrations curves studied, including those of polyprotic acids.

5.3. Solubility equilibria

(Reading: pages 736-749)

K_{sp} expressions for insoluble compounds
Predicting the formation of a precipitate from the concentration of its ions
Molar solubility and K_{sp} values
Common-ion effect on solubility
Effect of pH on solubility

Questions you should be able to answer:
- Write the equilibrium equation of an insoluble compound and the expression of its K_{sp}.
- Determine if after mixing certain solutions a precipitate will form or not.
- Compare the solubilities of compounds of similar stoichiometry by using their K_{sp} values.
- Calculate K_{sp} values from solubilities and *vice versa*.
- Determine the effects of adding a common ion or changing the pH on the solubility of a compound.

Book Exercises for Practice

Common Ion Effect	16.6, 16.8
Buffers	16.10, 16.12, 16.18, 16.20
Indicators	16.44, 16.46
Titrations	16.28, 16.30, 16.32, 16.34, 16.36
Solubility	16.54, 16.56, 16.58, 16.60, 16.68, 16.72, 16.74
Additional Exercises	16.98, 16.126

Section 6: Entropy, Free Energy & Electrochemistry (Chapter 17: 770-805; 7 lectures)
(Chapter 4: pages 136-145, Chapter 18: pages 806-853)

6.1. Spontaneous and non-spontaneous processes
(Reading: pages 771-773)

Questions you should be able to answer:
- Understand what spontaneous and non-spontaneous processes are and be able to provide examples.

6.2. Entropy and entropy changes
(Reading: pages 773-777, 781-782)

Entropy (S)
Predicting the sign of ΔS for physical and chemical processes
Third Law of Thermodynamics
Standard molar entropies
Calculating ΔS^o for chemical reactions using standard molar entropies

Questions you should be able to answer:
- Understand the meaning of entropy (disorder or randomness of the system) and some of its characteristics: state function, extensive (depends on mass), absolute.
- Understand how entropy changes with changes in the state of matter (from solid to liquids and gases), temperature, volume, and changes in the number of independent particles in the system.
- Estimate the sign of ΔS for concrete physical and chemical process.
- State the Third Law of thermodynamics (S is zero at 0 K) and understand its implications when calculating ΔS for any process at a given temperature.
- Calculate the standard entropy change (ΔS^o) of a reaction or physical process from the standard molar entropies of the reactants and products.

6.3. The Gibbs free energy
(Reading: pages 777-781, 782-796)

Second Law of Thermodynamics
The Gibbs free energy (G)
Predicting spontaneity at constant T,p conditions
The standard Gibbs free energy change (ΔG^o)
Calculating ΔG^o from ΔH^o and ΔS^o
Calculating ΔG^o from standard Gibbs free energies of formation
Relationship between ΔG and ΔG^o: $\Delta G = \Delta G^o + RT\ln Q$
Interpreting the sign of ΔG and ΔG^o for a system
Effect of temperature on spontaneity
Coupled reactions: Biochemical coupling

Questions you should be able to answer:
- State the Second Law of thermodynamics.

- Use ΔG for a process as criteria for spontaneity and equilibrium when working at constant temperature and pressure ($\Delta H°$ and $\Delta S°$ for a reaction, separately, do not provide this information).
- Interpret the sign of ΔG for a given reaction mixture, and the sign of its $\Delta G°$. Understand their difference and be able to use them in calculations.
- Given the values of $\Delta H°$ and $\Delta S°$ for a reaction (or enough data to estimate them), calculate its standard Gibbs free energy change ($\Delta G°$).
- From $\Delta G = \Delta G° + RT\ln Q$, derive the equation that relates $\Delta G°$ with K.
- Calculate the $\Delta G°$ of a reaction from the standard Gibbs free energies of formation ($\Delta G°_f$) of the reactants and products. Know that the standard Gibbs free energy of formation of the most stable form of an element in its standard state is zero by definition.
- Calculate equilibrium constants from $\Delta G°$ values, and *vice versa*.
- Given a reaction mixture, calculate the reaction quotient (Q) and ΔG to determine if the system is at equilibrium or if the forward or reverse reaction is spontaneous at a given temperature (either $\Delta G°$ or K should be known).
- Given the values of $\Delta H°$ and $\Delta S°$ for a reaction, determine if it is thermodynamically spontaneous (favourable) or not, after calculating $\Delta G°$. If it is not thermodynamically favourable, calculate the temperature at which it will be.
- Knowing that $\Delta G°$ is a state function be able to combine reactions as necessary for calculations.

6.4. Thermodynamics of redox reactions

(Reading: Chapter 4: pages 136-145; Chapter 18, pages 807-826)

Electrochemistry and electrochemical processes
Standard reduction potentials
Galvanic cells and cell potential (emf)
Standard cell potential ($E°_{cell}$)
Free energy and electrical work
The Nernst equation

Questions you should be able to answer:
- Recognize redox reactions as electron transfer processes
- Calculate the standard emf of a cell, E°, from the standard reduction potentials of the half-cell reactions
- Rank oxidizing and reducing agents on the basis of standard reduction potentials
- From $\Delta G = \Delta G° + RT\ln Q$, derive the Nernst equation and be able to use it in calculations to assess the effect of concentrations on the cell potential.

Book Exercises for Practice

Entropy and Free Energy:

Entropy	17.5, 17.12, 17.14, 17.46, 17.61
Free Energy and Equilibrium	17.18, 17.19, 17.20, 17.24, 17.28

Electrochemistry (depending on actual topics covered in the course):

Half-Reactions, etc	4.44
Oxidation Numbers	4.46, 4.48, 4.50
Activity Series	4.52, 4.54
Additional Exercises	4.124
Redox Reactions	18.1, 18.2
Galvanic Cells	18.6
Standard Reduction Potentials	18.11-18.20
Thermodynamics of Redox Reactions	18.23-18.25
Nernst Equation (Concentration effects)	18.31, 18.34, 18.36
Corrosion	18.42, 18.43
Additional Problems	18.67, 18.73, 18.75, 18.76, 18.78, 18.79, 18.83, 18.95ab, 18.103, 18.114, 18.116, 18.125, 18.128, 18.136

Equations you are expected to know or derive:

Section 1

$pV = nRT$

$n(x) = \frac{m(x)}{M(x)}$

$c(x) = \frac{n(x)}{V}$

$P_{Total} = P_A + P_B + \ldots\ldots P$

$d(x) = \frac{m(x)}{V}$

$N(x) = n(x)\ N_A$

$\chi(x) = \frac{n(x)}{n_{Total}}$

$p(x) = \chi(x)\ P_T$

$u_{rms} = \sqrt{\frac{3RT}{M(x)}}$

Section 2

$q = m\ s\ \Delta T = C\ \Delta T$

$\Delta H° = \Sigma m\Delta H°_f$ (products) - $\Sigma n\Delta H°_f$ (reactants)
Where m and n are the stoichiomentric coefficients of products and reactants, respectively.
(equation provided but must know how to use it)

Section 4

$pH = -\log [H^+]$

$[H^+] = 10^{-pH}$

$pOH = -\log [OH^-]$

$[OH^-] = 10^{-pOH}$

$K_w = [H^+]\ [OH^-]$

$pK_w = pH + pOH = 14.00$ (at 25°C)

$K_w = K_a\ K_b$

$pK_w = pK_a + pK_b$

Section 6

For any reaction:

$\Delta S° = \Sigma mS°$ (products) - $\Sigma nS°$ (reactants)

$\Delta G° = \Sigma m\Delta G°_f$ (products) - $\Sigma n\Delta G°_f$ (reactants)

Where m and n are the stoichiomentric coefficients of products and reactants, respectively.
(equations provided but must know how to use them)

$\Delta S_{univ} = \Delta S_{sys} + \Delta S_{surr}$

$\Delta G° = -\ RT\ln K$