General Chemistry 168: Spring 2015

Instructors:

Lecture: Pamela Mills
   Email: Pamela.Mills@lehman.cuny.edu
   Office Hours: Tu, 12-4pm (or by appointment)

Recitations: Emily Bell
   Email: Emily.bell42@myhunter.cuny.edu

Goal of the course: This is the second semester of a 2-semester general chemistry sequence that begins to prepare you for a science-based career. CHE 168 is a demanding course and while its primary objective is to introduce you to the fundamental principles that underlie the chemical sciences, to achieve success in this course you will need to organize large quantities of information in coherent ways so that you are able to recall and apply your knowledge. Organization of your time will be essential! And the mathematics is more demanding than in CHE 166!

This semester general chemistry is experimenting with a flipped classroom model. In this model you will watch videos and complete online homework at home and then come to class to complete workshop assignments (during your recitation section) and participate in peer-learning activities using an iClicker (during lecture every Thursday). Professor McGregor and I will hold extensive office hours on Tuesdays to answer any questions you might have. At first students have trouble getting themselves organized but then figure out how to make this work.

You should plan to spend at least 10-15 hours per week watching videos, doing your online homework, engaging with your classmates and learning the material. We are here to support you in your learning.

We will also be working with General Chemistry 2 at Hunter College and their students will be sharing the website with you. This course approach was started at Hunter and may have more of a Hunter feel until we get going. This course is designed to follow the 1st semester course at Hunter. I know there is about 90% overlap. Please feel free to ask any questions you have about the material – I know that you didn’t cover exactly the same topics as Hunter last semester. We’ll figure that out as we go.

Text: For the purposes of this course this semester you don’t have to buy anything. We will be using online homework from Sapling but you can register for Sapling for free (just this once!). Continue to use the General Chemistry textbook you purchased for CHE 166. We will not be working through a textbook in a chapter-by-chapter fashion; rather we will cover 18 chemistry topics and use the textbook as a reference. In the past about 90% of the students said they didn’t use the textbook.

Web Site: As part of this course we will be using a new platform called GenChem. The GenChem platform will be ready for account registration on January 20, 2015. You should log on to GenChem as soon as you can and register your account so that you can become familiar with the look and feel of the web interface.

To claim your GenChem account:

1. Log on to http://genchemcuny104.org on or after January 26th.
2. Click Register and complete the registration process by entering your blackboard ID number, a working email address and a password that you create. It is very important that you use the same email address to claim your GenChem account and register both your iClicker and your Sapling homework account. This email address must be one that you check regularly as we will use it to communicate with you via the GenChem platform.
**To find your Lehman College Blackboard ID number:**

1. Log on to [https://cunyportal.cuny.edu/cpr/authenticate/portal_login.jsp](https://cunyportal.cuny.edu/cpr/authenticate/portal_login.jsp)
2. Log into your account and Click on the Blackboard Tab in the "Applications/Resources" panel.
3. Click on the “Personal Information” tab on the top left side of the screen in the “Tools” panel.
4. Click on the “Edit personal Information” tab.
5. Here you will find your username followed by a 20-digit number. This 20-digit number is your Lehman College blackboard number.

The GenChem platform will be used in lieu of CUNY Blackboard and has been designed specifically for our course. This is where you will find **ALL** course documents including the Learning Goal Analysis (LGA), videos, links to online Sapling homework and workshop assignments. PDF documents of the videos for each topic will be made available on the Monday morning after the topic deadline and extra exam practice materials will be made available 7 days before each exam.

**Email:** Please make sure that you use the same email address to claim your GenChem account and register both your iClicker and your Sapling homework account. This should be an email address that you check frequently as we will be using email through the GenChem platform to communicate with the class. If you do not check your email regularly it is possible that you will miss important information - which is likely to have a negative impact your grade.

**Grading policy:** Every component of this course earns you points towards your final grade, but to earn your points you must complete each component by its due date. Please see the GenChem platform and Pacing Guide for more information on due dates.

To earn full credit in this course you must accumulate 1400 points. 400 points come from your TOPIC grade and 1000 points come from your EXAM grades. The points you earn will be normalized to 100 and then assigned a letter grade according to the Lehman College grading system.

<table>
<thead>
<tr>
<th>TOPIC</th>
<th>LGA</th>
<th>Videos</th>
<th>Workshop</th>
<th>i-Clicker</th>
<th>Homework</th>
<th>TOPIC TOTAL</th>
<th>In-Class Exams</th>
<th>Final Exam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topic 1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topic 2</td>
<td>1</td>
<td>1</td>
<td>10</td>
<td>0</td>
<td>5</td>
<td>17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topic 3</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>11</td>
<td>5</td>
<td>18</td>
<td></td>
<td>Exam 1</td>
</tr>
<tr>
<td>Topic 4</td>
<td>1</td>
<td>1</td>
<td>10</td>
<td>0</td>
<td>5</td>
<td>17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topic 5</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>11</td>
<td>5</td>
<td>18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topic 6</td>
<td>2</td>
<td>2</td>
<td>10</td>
<td>11</td>
<td>10</td>
<td>35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topic 7</td>
<td>2</td>
<td>2</td>
<td>10</td>
<td>11</td>
<td>10</td>
<td>35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topic 8</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topic 9</td>
<td>2</td>
<td>2</td>
<td>10</td>
<td>11</td>
<td>10</td>
<td>35</td>
<td></td>
<td>Exam 2</td>
</tr>
<tr>
<td>Topic 10</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>10</td>
<td>10</td>
<td>14</td>
<td></td>
<td>400 pts</td>
</tr>
<tr>
<td>Topic 11</td>
<td>2</td>
<td>2</td>
<td>10</td>
<td>11</td>
<td>10</td>
<td>35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topic 12</td>
<td>2</td>
<td>2</td>
<td>10</td>
<td>11</td>
<td>10</td>
<td>35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topic 13</td>
<td>2</td>
<td>2</td>
<td>10</td>
<td>11</td>
<td>10</td>
<td>35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topic 14</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topic 15</td>
<td>2</td>
<td>2</td>
<td>10</td>
<td>11</td>
<td>10</td>
<td>35</td>
<td></td>
<td>Exam 3</td>
</tr>
<tr>
<td>Topic 16</td>
<td>2</td>
<td>2</td>
<td>10</td>
<td>11</td>
<td>10</td>
<td>35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topic 17</td>
<td>2</td>
<td>2</td>
<td>10</td>
<td>11</td>
<td>10</td>
<td>35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topic 18</td>
<td>2</td>
<td>2</td>
<td>10</td>
<td>11</td>
<td>10</td>
<td>35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTALS</td>
<td>31</td>
<td>31</td>
<td>110</td>
<td>121</td>
<td>145</td>
<td>438</td>
<td>600</td>
<td>400</td>
</tr>
</tbody>
</table>

**Total Topic Grade Required = 400 out of a total of 438 possible points**

**Total Exam Grade = 1000**

**Total number of points to be earned in the course: 400 + 1000 = 1400**
1. The points for an LGA is an all or nothing score. 1 or 2 points (as indicated) are earned for completion of an assignment and zero points are earned for an incomplete assignment.
2. The points for each workshop, iClicker and homework assignment are scaled to the totals indicated.
3. The total score for each topic is computed by summing the topic components. There are 435 total TOPIC points, but only the first 400 points count. Think of the extra 35 points as extra points that you can accumulate and use if you miss an assignment. **You cannot earn more than 400 TOPIC points.** These extra points cannot be applied to your exam score.
4. If you miss an in-class exam the final exam will count for 600 points instead of 400 points. There are NO make-up exams.

**Exams:** There will be three equally weighted in-class exams (200 points each for a total of 600 points) given during the course of the semester. There will also be a **Comprehensive Final Exam** (400 points, ACS test) given during finals week. If your final exam grade is higher than your lowest in-class exam grade your final grade will count for 600 points and your lowest in-class exam grade will be dropped.

For your exams you will be required to bring a pencil and a calculator to class. All other materials (e.g. periodic table and/or other necessary information such as a formula sheet) will be provided for you. **Exams must be taken during the designated class period. NO MAKE-UP EXAMS will be given.** If you miss one in-class exam you will earn a grade of zero for that exam. This grade will then be dropped as your lowest in-class exam grade and your final exam grade will automatically be counted for 600 points. If you miss more than one in-class exam you will receive a grade of ZERO for the second missed exam.

**Detailed Course Outline:** Please see the GenChem platform and course Pacing Guide for a detailed course schedule that includes all your assignments and exam dates. In addition to the pacing guide we have created a video table of contents to help you organize your time effectively.

---

**Exam schedule (Sorry for the negative tone here - everyone do well!)**

- **EXAM 1: Thursday, March 5th.**
  This exam is a Chem 104 placement exam. If you fail this exam you should consider withdrawing from the course. The last day to withdraw from the course is Thursday April 16th. The 2nd exam results may not be available in time to make this decision.

- **EXAM 2: Thursday, April 16th**
  This exam is more difficult than exam 1. If you failed exam 1 and you also fail this exam you should begin considering the credit/no credit option as it is now too late to withdraw from the course.

- **EXAM 3: Thursday, May 14th**
  This is your last and most difficult in-class exam. In general, student grades drop by 10% from exam 2 to exam 3 so make sure you put in enough time to prepare for this exam.

- **Final Exam:** **Tentatively scheduled for Thursday, May 21st, 1:30-3:30 pm.**
  You will not have much time to review for the Final, so study in advance. The final is the ACS test.

---

**Required Learning Goal Analysis (LGA):** Before you begin a new topic you will be required to complete a Learning Goal Analysis in the GenChem platform. This analysis asks you to read each learning goal for that topic and assess how comfortable you feel with the content presented. There is no wrong answer to an LGA question. The goal is to help you begin accurately self-assessing your own content understanding.
and focus your attention on the learning goals to drive your learning. These learning goals serve as both an outline for the course and a tool to help you prepare for your exams.

**Required Recitation Workshops:** In addition to completing the videos and LGA assignments, you are responsible for submitting a weekly recitation assignment called a workshop. Workshops are to be completed in groups of 3 or 4 students and must be submitted to your recitation instructor. You may submit your workshop in person during your assigned recitation period or electronically (using the GenChem website) no later than 5:00pm every Sunday.

There are 12 required workshop assignments this semester. Each workshop is worth 10 points. You must attend the recitation section that you registered for every week in order to earn these points. If you miss a workshop you do not earn the points for that workshop. Remember that there are 35 extra points built into your topic grade so if you miss a workshop you can use 10 of these extra points to make up the loss. Please see the Workshop Grading Policy on GenChem for more information.

During exam weeks recitation sections will be classed as “OPEN SECTION”. This means that there will be no workshop due that week and recitation attendance is optional. During “OPEN SECTION” recitation you may attend ANY workshop to ask questions or get individual help from one of the TA’s as you prepare for your upcoming exam.

If there is no class on a day that you would regularly have attended a workshop, you may attend any other workshop session for that week to get help with the material. Please see the Recitation Schedule on GenChem for information about available recitation sections.

**Required iClicker:** As part of this course we will be making use of a personal response device called an iClicker. You will use the iClicker to respond to in-class questions during lecture every Friday. This will serve a dual purpose: 1) Your responses will provide me with real-time feedback about student understanding of course content and 2) Your participation will help you practice the material and grow as a chemistry student.

There will be 10 required iClicker sessions, each worth a total of 11 points. You earn 1 point for attending a session and then 1 point for every question that you answer correctly during the session. Some sessions will have only 10 questions and some will have more than 10 questions. The maximum number of points you can earn per session is 11 so only 10 correct responses will be counted for each session. If your iClicker malfunctions or when you forget it at home you will not earn the points for that session. Please do NOT ask for points if you fail to have a functioning iClicker. Once again, remember that there are 35 extra points built into your topic grade so if you do not earn the points for an iClicker session you can use 11 of these extra points to make up the loss.

iClickers will be borrowed from Lehman College Once you have your iClicker you will need to register it. **To register your iClicker:**

2. Complete the registration questions. **Note:** You must register using your full first and last name and your Lehman College Blackboard ID number. Your blackboard number will be used to link your iClicker responses to our online student roster.

**Required Homework:** This semester we will be using an on-line homework system called Sapling. While links to your homework will be provided in the GenChem platform, you will need an access code through the Sapling Website and register for our course in order to access and complete your Sapling assignments. **Sapling will be available on January 21**. **To register for Sapling:**
1. Log on to [https://www.saplinglearning.com/](https://www.saplinglearning.com/)
2. Click on the orange “create account” tab and follow the online instructions to create a user profile (choose a username and password) Please make sure that you use the same email address to claim your GenChem account and register for your Sapling homework account.
3. Select **CUNY, Lehman College** as your school.
4. Select **CUNY Lehman - Chem 168 Spring 15 – McGregor/Mills** as your course.
5. Follow the online instructions to purchase an Access Code.

This semester for CHEM 168, the Sapling homework platform will be provided to you for free courtesy of Sapling and McMillan.

---

**Academic Dishonesty:** Lehman College regards acts of academic dishonesty (e.g., plagiarism, cheating on examinations, obtaining unfair advantage, and falsification of records and official documents) as serious offenses against the values of intellectual honesty. The college is committed to enforcing the CUNY Policy on Academic Integrity and will pursue cases of academic dishonesty according to the Lehman College Academic Integrity Procedures, see:

[http://www.lehman.edu/undergraduate-bulletin/academicintegrity.htm](http://www.lehman.edu/undergraduate-bulletin/academicintegrity.htm)

Students who are caught cheating on an exam in this course will automatically obtain a grade of ZERO for that exam and will be reported for Academic Dishonesty. This grade of ZERO cannot be used as your lowest exam score to be dropped in the course.

---
General Chemistry 2: Learning Goals

**Topic 1: Equilibrium**

1. Use molarity formula to determine moles, volume, and concentration.
2. Use the dilution formula to compute molarity and volume after dilution.
3. Write molecular and net ionic equations for any reaction when appropriate.
4. Be able to write sentences or use drawings to illustrate the difference between static and dynamic equilibrium as applied to chemical systems. (Be able to include the words macroscopic and microscopic in the definitions).
5. Graph concentration vs time for all species in a stoichiometric equation.
6. Use an equilibrium graph (concentration vs time) to identify the equilibrium region, to identify the stoichiometric coefficients, and to identify the reactants and products.
7. Write a general equilibrium expression in terms of activity from the stoichiometric equation using the law of mass action.
8. Identify the appropriate units for each species in the stoichiometric equation (molarity, atm).
9. Write expressions for $K$ for reactions that include aqueous species, gaseous species, and solids.
10. Calculate a value of $K$ from the known equilibrium concentrations or partial pressures.
11. Use $PV=nRT$ to find any variables and relate partial pressure to moles.
12. Use the value of $K$ for a given stoichiometry equation to obtain $K$ for the same stoichiometric relationship but written forward or backward and written with a different set of stoichiometric coefficients.
13. Write expressions for $K$ for reactions that include aqueous species, gaseous species, and solids.

**Topic 2: Predicting Chemical Change**

1. Describe the equilibrium state of a chemical system using $K$ if the system is at equilibrium or $Q$ if the system is not at equilibrium.
2. Obtain the value of $Q$ from the concentrations or pressures of the species present if the system is not at equilibrium.
3. Predict the direction of the shift of a reaction towards equilibrium by comparing $Q$ to $K$.
4. Use LeChatelier's principle to predict the shift of system that had its equilibrium perturbed. How does a reaction respond to a) an increase in mole number of one species, b) a decrease in mole number of one species, c) an increase or decrease in temperature, d) an increase or decrease in total pressure, e) an increase or decrease of reaction volume.
5. Determine under what circumstances the actual value of $K$ changes? Predict changes in $K$ for all of the above perturbations. (In many cases $K$ does not change – which cases?)
6. Recognize a noble gas and recognize an catalyst and realize that noble gases and catalysts do not perturb the equilibrium position.
### Topic 3: Acids and Bases

1. identify Arrhenius acid/base reactions
2. identify Bronsted acid/base reactions
3. identify the conjugate acids and bases in Bronsted reactions
4. define amphoteric and recognize that water is amphoteric
5. determine relative acid strength from $K_a$ values
6. memorize and identify strong acids and bases
7. write equilibrium reactions and associate the appropriate equilibrium constant to the reaction (for acid, $K_a$, base $K_b$ reactions)
8. use the pH scale to identify acidic or basic solutions
9. determine hydronium ion concentration from pH and pH from hydronium ion concentration
10. use the ICE table to solve for equilibrium concentrations for reactions with 1:1 stoichiometry
11. make appropriate approximations and use the 5% rule
12. solve the quadratic equation to obtain the equilibrium position

### Topic 4: pH Calculations

1. compute pH from hydrogen ion concentration
2. compute pOH from hydroxide ion concentration
3. compute relevant concentrations from pH or pOH
4. find pH from pOH or pOH from pH based upon the $K_w$ at 298 (1x10$^{-14}$) or other temperatures when a value for $K_w$ is known
5. identify strong acids and bases and calculate pH (and pOH) of strong acid or base solutions
6. use ICE to compute pH and pOH of weak acid and base solutions.
7. use ICE to compute concentrations of all species in weak acid and base solutions.
8. recognize a salt (ionic compound) from a chemical formula
9. identify the pH active species of salt solutions
10. identify an aqueous salt solution as acidic, basic, or neutral
11. obtain $K_b$ from $K_a$ or $K_s$ from $K_b$ using $K_w$
12. determine $pK_a$ from $K_a$ and $pK_b$ and $K_b$ (or vice versa) and relate $pK_a$ or $pK_b$ values to the strength of the acid or base compound
13. calculate the pH of salt solutions

### Topic 5: Polyprotic Acids and Bases

1. identify a polyprotic acid from its chemical formula and state how many acidic protons are in that compound
2. identify a polyprotic base from its chemical formula and identify the basic sites on the compound
3. link $pK_{a1}$, $pK_{a2}$, $pK_{a3}$ etc values to the appreciate species and equilibrium reaction
4. obtain $K_{b1}$ and $K_{b2}$ values from the appropriate $pK_a$ values.
5. Calculate pH and concentration of all species present in the solution for a polyprotic acid.
6. Calculate pH and concentration of all species present in the solution for a polyprotic base.
7. Calculate the pH for an amphoteric species.
**Topic 6: Buffers**

1. predict products of acid-base reactions
2. predict pH of solutions obtained when strong acids are mixed with strong bases in different stoichiometric ratios
3. predict pH of solutions obtained when mixing a strong acid with a weak base or strong base with a strong acid in different stoichiometric ratios
4. recognize that buffers contain weak acids and their conjugates or weak bases and their conjugates
5. identify a solution as a buffer solution from the species present in the solution and their relative concentrations
6. calculate the pH of a buffer solution using the Henderson-Haselbach equation.
7. identify the major species of aqueous solutions and identify which solutions are buffer solutions
8. calculate the pH of the buffer solution
9. use a table of Ka and Kb values and select from the table appropriate species to construct a buffer for a desired pH
10. select the best buffer for a particular situation based upon desired pH and buffering capacity
11. describe how to prepare a buffer of given concentration and pH from strong acid and weak base (or strong base and weak acid)
12. calculate the number of moles of acid and base in a buffer based on the buffer concentration and pH
13. know difference between buffer range (pH range) and buffer capacity (moles)
14. determine buffer capacity toward added acid or base
15. use all the buffer properties to predict concentrations of all species in a buffer solution

**Topic 7: Titration Curves**

1. read a titration curve and identify the major species at each point on the curve
2. identify key features of the curve including the end point, midpoint, buffering region
3. compute titrant volume required to reach the endpoint and compute pH of endpoint
4. determine the concentration of buffer species and pH at any point on the curve
5. recognize the characteristic s shape curve for strong-strong titrations and distinguish the curve from strong-weak titrations
6. recognize the buffer zone and determine the buffer range from the titration curve
7. find the pKa on a titration curve and guess the likely species based on the pKa using the table of Ka values
8. determine the buffer capacity from the titration curve for any pH in the buffer range
9. recognize a polyprotic titration curve and identify the major species in solution at any point on the curve
10. obtain major species at any pH from speciation graph
11. identify polyprotic buffer solutions from the curve and the pKa values
**Topic 8: Heat and Work**

1. Articulate the difference between heat and work – work is a force acting over a distance and heat is dissipative energy.
2. Identify the system and surroundings for various scenarios.
3. Determine if energy is leaving or entering the system and the appropriate signs for these processes.
4. Identify the sign of delta H for exo or endo reactions and articulate the movement of energy in these systems.
5. Use tables of bond energies to compute delta H of reaction.
6. State the first law and explain how it is a statement of energy conservation (recognize that negative heat and work represent a loss of energy and positive heat and work represent a gain in energy).
7. Calculate the amount of work does to or by a gaseous system.
8. Recognize the appropriate signs for heat and work of any system (including gaseous systems).
9. Compute the heat of a reaction using calorimetry at constant pressure or constant volume.
10. Compute the specific heat capacity or molar heat capacity from calorimetry.
11. Calculate latent for any phase transition given $\Delta H$ values.
12. Compute the overall heat for a system undergoing changes in both temperature and phases as read from a heating curve.

**Topic 9: Enthalpy**

1. Enumerate the standard conditions in thermodynamics and in gases (STP) – clearly the indicate the differences.
2. Recognize the relationship between energy and enthalpy.
3. Use $\Delta H^o$ data and Hess’s law to compute heats of reaction or formation.
4. Relate Hess’s law to the properties of a state function.
5. Use Hess’s law to combine the values of $\Delta H^o$ for multiple reactions to find the value of $\Delta H^o$ for a new reaction.
6. Compute the $\Delta H^o$ for a reaction or $\Delta H^o_f$ from tabulated formation data and/or heats of reaction.

**Topic 10: Entropy**

1. Define spontaneity from a scientific or chemical perspective and contrast that with the more colloquial definition.
2. Identify the system of greater entropy and predict entropy changes of a system.
3. Be able to relate $\Delta S$ and $\Delta H$ of the system to $\Delta S$ of the universe.
4. Know that $\Delta S$ is related to $\Delta H$ only for the surroundings or only when the system is at equilibrium.
5. State the 2nd law of thermodynamics and recognize that the second law is not a conservation principle.
6. Rationalize the temperature dependence of entropy.
7. Identify all standard state conditions.
8. Relate the existence of an absolute entropy to the third law of thermodynamics.
**Topic 11: Probability**

1. interpret entropy as a measure of disorder and recognize that entropy is a consequence of systems with large numbers of particles
2. compute the number of microstates available based on combinatorial analysis for a given total energy
3. compute the most probable state and equate that with the highest entropy state
4. state the 3rd law of thermodynamics and recognize that the zero point for entropy is not arbitrary
5. compute $\Delta S^\circ$ and $\Delta H^\circ$ from thermodynamic tables.

**Topic 12: Free Energy**

1. predict spontaneity of chemical reactions from thermodynamic data using free energy
2. compute $\Delta G^\circ$, $\Delta S^\circ$, and $\Delta H^\circ$ for chemical reactions from thermodynamic tables.
3. relate $\Delta G$ for non-standard states to the standard state $\Delta G^\circ$
4. compute $\Delta G$ using $\Delta G^\circ$ and the reaction quotient $Q$ for any chemical reaction.
5. Use $\Delta G^\circ=\Delta H^\circ-T\Delta S^\circ$ to compute $\Delta G$ and predict spontaneity.
6. relate free energy changes to the equilibrium constant ($K$). Calculate $K$ from $\Delta G^\circ$ and $\Delta G^\circ$ from $K$
7. understand that equilibrium constants that were important in previous topics, such as $K_w$, $K_a$ or $K_b$, and $K_{sp}$, can also be calculated from free energy values at 298K.
8. recognize that free energy represent the energy available to do work

**Topic 13: Applications of Free Energy**

1. understand that equilibrium constants that were important in previous topics, such as $K_w$, $K_a$ or $K_b$, and $K_{sp}$, can also be calculated from free energy values at temperatures other than 298K
2. be able to estimate both normal boiling (or melting) points and boiling (or melting) points at atmospheric pressures other than 1 atm.
3. obtain equilibrium data (vapor pressure, boiling point) from thermodynamic data
4. calculate free energy changes for transport of a species from one concentration to another for both aqueous solutions and gases
5. compute thermodynamic parameters from the temperature dependence of the equilibrium constant, and conversely be able to predict the temperature dependence of $K$ from thermodynamic parameters, including changes in vapor pressure with temperature
6. compare and/or rationalize bonding effects ($\Delta H$) with disorder ($\Delta S$) in solubility reactions
Topic 14: Redox Reactions
1. determine the oxidation states of atoms in molecules
2. identify oxidized species and reduced species
3. count the number of electrons transferred from the oxidized species to the reduced species.
4. identify half reactions and balance redox reactions
5. compute the standard cell potentials for redox reactions
6. use the relationships between the cell potential and work to relate potentials to free energy change in redox reactions
7. predict spontaneity for redox reactions.
8. identify oxidizing and reducing agents
9. predict best oxidizing and reducing agents based on standard cell potentials

Topic 15: Batteries
1. draw diagrams for a galvanic cell identifying the cathode, anode, direction of electron flow, and ion flow within the salt bridge
2. sketch an "atomic" or "ionic" level diagram showing where the oxidation and reduction actually occurs
3. compute the standard cell potentials for galvanic cells and predict the spontaneous direction of galvanic cells
4. use and interpret line notation to describe a galvanic cell
5. use the Nernst equation to explore the temperature and concentration effects on galvanic cell potential
6. be able to compute cell potentials using thermodynamic data
7. draw an electrolytic cell and predict products of electrolysis
8. use q=it to compute current or time needed to plate metals

Topic 16: Chemical Kinetics
1. understand a concentration vs time plot and use this graph to identify concentrations of species at any point in time and/or instantaneous reaction rates at any point in time
2. understand the notation for reaction rates, the units for reaction rates, and be able to relate reaction rates expressed in terms of any reactant or product
3. identify the order of a reaction from a rate law and be able to compute the rate constant from the rate law and appropriate data
4. compute the rate law using the method of initial rates
5. compute the rate law for first order reactions from graphs of concentration vs time
6. obtain the value of the rate constant from appropriate graphs for first order kinetics or from a half-life for the reaction
7. use first order kinetics to obtain half lives of radioactive decay, or to obtain the rate constant from the half-life
8. use the integrated first order rate equation to calculate concentration as a function of time
9. date materials using carbon-14 or uranium-238 (understand concept and perform calculations)
10. determine the half lives of reactions having 1st order kinetics from appropriate graphs or from the rate constant

**Topic 17: Reaction Mechanisms and Arrhenius Theory**

1. write rate laws corresponding to elementary reactions and simple reaction mechanisms
2. determine if a reaction mechanism is consistent with a given experimental rate law
3. use the Arrhenius equation for calculations of rate constant changes with temperature or activation energy
4. graph and interpret the Arrhenius equation
5. state the different between hetero- and homogeneous catalysts and know how a catalyst impacts the activation energy and its diagram
6. interpret and sketch reaction coordinate diagrams given appropriate information

**Topic 18: Radiochemistry**

1. read and interpret the island of stability graph.
2. identify the types of nuclear decay and write nuclear decay equations (alpha, beta, gamma and electron capture)
3. Review first order kinetics to obtain half lives of radioactive decay, or to obtain the rate constant from the half-life (dating materials using carbon-14 or uranium-238)
4. use the relationship between mass and energy to compute nuclear binding energies
5. identify the fusion and fission processes and compute the exothermicity of fusion or fission reactions
6. understand and be able to define the terms ‘chain reaction’ and ‘critical mass’

**Topic OTHER: Extension to Organic Chemistry**

1. relate structure of oxy-acids to strengths of the acids
2. identify Lewis acids and bases and Lewis acid-base reactions