Roanoke Valley Governor's School for Science and Technology
Advanced Placement Chemistry
Competency List, 2018-2019

Last updated: August 16, 2018

Course Description:
AP Chemistry is an in-depth laboratory-focused course equivalent to an introductory college course for science majors. The major themes include the phases of matter and the forces that produce them, the study of energy transfer in chemical reactions, how far chemical reactions proceed and how fast they go, and the role of electron transfer in chemical reactions. Students are expected to obtain a qualifying score of 3, 4, or 5 on the AP Chemistry exam at the end of this course.

This course is taught using best practices in gifted education. Each competency is aligned with Hockett's five principles of gifted education (Hockett, J.A. (2009) "Curriculum for Highly Able Learners That Conforms to General Education and Gifted Education Quality Indicators." *Journal of Education for the Gifted***.** Vol. 32, No. 3, p. 394-440):

Principle 1: High-quality curriculum for gifted learners uses a conceptual approach to organize or explore content that is discipline based and integrative.

Principle 2: High-quality curriculum for gifted learners pursues advanced levels of understanding beyond the general education curriculum through abstraction, depth, breadth, and complexity.

Principle 3: High-quality curriculum for gifted learners asks students to use processes and materials that approximate those of an expert, disciplinarian, or practicing professional.

Principle 4: High-quality curriculum for gifted learners emphasizes problems, products, and performances that are true to life, and outcomes that are transformational.

Principle 5: High-quality curriculum for gifted learners is flexible enough to accommodate self-directed learning fueled by student interests, adjustments for pacing, and variety.

Competencies/Objectives

COMPETENCY 1: ***Demonstrate awareness, and proper use, of laboratory safety techniques.***

ENABLING OBJECTIVES

1-1. Differentiate between safe and unsafe procedures, applications, and methods of disposal of chemicals.
1-2. Chose the appropriate safety equipment for specific laboratory situations.
1-3. Decide which safety and emergency procedures to follow in case of particular accidents including fires and hazardous material spills.
1-4. Demonstrate the proper methods for carrying and moving chemicals and equipment.
1-5. Demonstrate the ability to understand and follow the safety codes on chemical containers.

COMPETENCY 2: ***Categorize matter and its properties.***

ENABLING OBJECTIVES

2-1. Describe the general properties of matter and classify according to whether it is an element, a compound or a mixture.
2-2. Distinguish between physical and chemical properties of matter.
2-3. **Determine chemical and physical properties of substances by carrying out physical and chemical changes.**

COMPETENCY 3: ***Review the rules of chemical nomenclature for writing formulas and naming compounds.***

ENABLING OBJECTIVES

3-1. Identify basic differences between atoms, molecules, and ions, and classify compounds as being ionic or molecular.
3-2. Write the names of ionic and binary covalent compounds from their formulas using the older system of prefixes and suffixes and the newer IUPAC system.
3-3. Use the ion-charge method to write formulas for ionic compounds.
3-4. Write the formulas for binary covalent compounds.
3-5. **Experimentally determine the formula for a hydrated ionic compound.**

COMPETENCY 4: ***Utilize the periodic table to determine properties of an element, or a set of elements.***

ENABLING OBJECTIVES

4-1. Describe the events leading to the present arrangement of the periodic table.
4-2. Describe the periodic trends of the general characteristics of metals, nonmetals, and metalloids.
4-3. Describe and explain the trends in atomic radius and ionization energy.

COMPETENCY 5: ***Review the categories of chemical reactions and write balanced equations for reactions.***

ENABLING OBJECTIVES

5-1. Write and balance chemical equations when given reactants and products.
5-2. Classify those equations that come under the heading of synthesis, decomposition, replacement, and ionic reactions.
5-3. Predict the products of chemical reactions when given the reactants.
5-4. Define oxidation and reduction, and identify any species undergoing oxidation or reduction, and identify the oxidizing and reducing agents.
5-5. Use solubility rules to predict the formation of insoluble products, and the activity series to predict the occurrence of replacement reactions.
5-6. Simplify equations by writing net ionic equations.
5-7. Relate complete and incomplete combustion to oxidation.

COMPETENCY 6: ***Review the mole concept as related to calculations involving empirical and molecular formulas and to stoichiometry.***

ENABLING OBJECTIVES

6-1. Convert numbers of atoms and molecules to masses by using the mole, and vice versa.
6-2. State the masses of atoms or molecules in terms of molar masses.
6-3. Calculate, and prepare solutions of known molarity.
6-4. Distinguish between empirical and molecular formulas.
6-5. Calculate the percent composition of a compound from its formula, and from experimental data.
6-6. Calculate empirical and molecular formulas from experimental data.
6-7. Calculate mass relationships based on balanced chemical equations.
6-8. Determine the limiting reactant, and the theoretical yield for chemical reactions.
6-9. **Experimentally determine the composition of an alloy, and compare it to its accepted value.**
6-10. **Experimentally determine the mole ratio for a chemical reaction, and use it to determine the equation for the reaction.**

COMPETENCY 7: ***Predict the thermodynamic favorability of reactions.***

ENABLING OBJECTIVES

7-1. Define and calculate ΔH° and ΔS° for a reaction.
7-2. Use the Gibbs-Helmholtz equation to calculate the free energy change for a reaction.
7-3. **Experimentally determine ΔH°_{soln} and ΔH°_{rxn}**
7-4. Describe how the signs of ΔH°, ΔS°, and ΔG° relate to the thermodynamic favorability of a reaction.

COMPETENCY 8: ***Characterize the electronic structure of the atom.***

ENABLING OBJECTIVES

8-1. State and interpret the postulates of quantum theory.
8-2. Relate energy differences, wavelength, and frequencies of EMR.
8-3. Describe the atomic spectrum of hydrogen in terms of the Bohr model, and calculate energy transitions for the Lyman and Balmer series.
8-4. Describe the wave nature of electrons according to deBroglie, Planck, and Schrodinger.
8-5. Write electron configurations and use Hund's rule to draw orbital notations for electrons in an atom.
8-6. Use PES data to deduce the electronic structure of an atom.
8-7. **Experimentally determine the wavelengths and frequencies of the line spectra of selected elements.**

COMPETENCY 9: ***Relate ionic and covalent bonding to the electronic structure of atoms and the ionic and/or molecular compounds they form.***

ENABLING OBJECTIVES

9-1. Describe the formation of cations and anions, and relate it to ionization energies and electronegativities, and position on the periodic table.
9-2. Relate the ΔH° of ionic compounds to their lattice energies, and relate their lattice energies to Coulomb's Law.
9-3. Write Lewis structures to show the covalent bonding in molecules and polyatomic ions.
9-4. Determine polarity of covalent bonds from electronegativities.
9-5. Compare bond lengths of covalent bonds.
9-6. Use bond energies to calculate ΔH° for the formation of molecular compounds.

COMPETENCY 10: ***Determine the shape of molecules and describe the distribution of the valence electrons according to atomic orbital theory.***

ENABLING OBJECTIVES

10-1. Use the VSEPR model to predict the geometric shape of simple molecules and polyatomic ions.
10-2. Construct models of molecules and polyatomic ions to illustrate their predicted geometric shapes.
10-3. Predict the polarity of molecules by using the VSEPR model for molecules containing polar covalent bonds.
10-4. Describe covalent bonding in terms of atomic orbitals: sp, sp^2, and sp^3 hybrid orbitals, sigma and pi bonds, and expanded octets.

COMPETENCY 11: ***Describe gases in terms of kinetic molecular theory, apply the gas laws and the Ideal Gas Law to problems, and compare real gases to ideal gases.***

ENABLING OBJECTIVES

11-1. Define pressure and relate to kinetic theory.
11-2. Describe the effect of temperature on pressure and volume of gases.
11-3. Apply the mole-volume relationship of gases to gas phase reactions.
11-4. Describe the relationship between pressure and volume of gases (Boyle's Law).
11-5. Combine Boyle's, Charles, and Avogadro's laws of gases into the Ideal gas law.
11-6. Describe the diffusion of gases and relate it to Graham's Law.
11-7. Describe mixtures of gases in terms of Dalton's Law of Partial Pressures.
11-8. Relate the density of gases to molar volume and molar mass.
11-9. Relate the motion of molecules to the Boltzman distribution and temperature.
11-10. Compare the behavior of real gases to ideal gases using the van der Waals equation.
11-11. Experimentally determine the molar mass of a gas.

COMPETENCY 12: ***Describe solids and liquids in terms of kinetic molecular theory.***

ENABLING OBJECTIVES

12-1. Describe and compare the properties of solids and liquids.
12-2. Describe the intermolecular forces of attraction between molecules.
12-3. Compare these forces in terms of permanent and induced dipoles.
12-4. Relate the type of intermolecular forces present to the melting and boiling points of substances.
12-5. Compare the vapor pressure of pure liquids to the vapor pressure of solutions, and explain how the presence of a solute lowers vapor pressure.
12-6. Describe how the surface tension, capillary action, and viscosity of liquids are related to intermolecular forces.
12-7. Interpret phase diagrams.
12-8. **Experimentally relate the solubility of one liquid in another to the type of intermolecular forces in each liquid, and the effect the presence of hydrogen bonding has on this solubility.**

COMPETENCY 13: ***Characterize the properties of chemical systems that reach equilibrium.***

ENABLING OBJECTIVES

13-1. Write the expression for K from the balanced equation for a reaction.
13-2. Calculate K from equilibrium concentrations of all species, or from original concentrations of all species and the equilibrium concentration of one species.
13-3. Predict the direction a chemical system will move to reach equilibrium when the value of K and Q are known.
13-4. Predict the equilibrium concentration of one species when given those of all other species when the value of K is known.
13-5. Predict the equilibrium concentrations of all species when given their original concentrations and when the value of K is known.
13-6. Predict the equilibrium concentration of all species when the value of K is known, and when one of the ions involved is already present in solution.
13-6. Using LeChatelier's Principle, predict the effect of a change in the number of moles, volume, or temperature upon the position of an equilibrium.
13-7. **Experimentally determine K_c for an equilibrium system.**
13-8. Relate the standard free energy change for a reaction to its equilibrium constant.

COMPETENCY 14: ***Describe the properties of acids and bases.***

ENABLING OBJECTIVES

14-1. Relate the acidic and basic properties of aqueous solutions to the dissociation of water.
14-2. Carry out calculations involving pH and pOH.
14-3. Compare strong and weak acids.
14-4. Compare strong and weak bases.
14-5. Predict the acidity or basicity of salt solutions (cations and anions).
14-6. Write the equations for reactions for reactions between strong acids and strong bases, strong acids and weak bases, and weak acids and strong bases.
14-7. **Carry out acid-base titrations and write equations for the reactions.**
14-8. Compare Arrhenius, Bronsted-Lowry, and Lewis theories of acids.

COMPETENCY 15: ***Apply properties of systems at equilibrium to dissociation of acids/bases.***

ENABLING OBJECTIVES

15-1. Write the equilibrium expression for dissociation of weak acids and calculate K_a.
15-2. Calculate the hydrogen ion concentration in solutions of weak acids when given K_a.
15-3. Calculate the hydrogen ion concentration in buffered solutions.
15-4. Write the equilibrium expression for the dissociation of weak bases and calculate K_b.
15-5. Calculate the hydroxide ion concentration in solutions of weak bases when given K_b.
15-6. Relate K_a and K_b to each other and to K_w.
15-7. **Experimentally determine K_a for a weak acid by titration.**

COMPETENCY 16: ***Describe the properties of solutions and carry out calculations related to these properties.***

ENABLING OBJECTIVES

16-1. Compare unsaturated, saturated, and supersaturated solutions to equilibrium conditions.
16-2. Distinguish between electrolytes and non-electrolytes.
16-3. Carry out calculations involving solution concentrations in mole fractions, molality, and/or molarity.
16-4. Describe the factors that affect the solubility of a solute in a particular solvent.
16-5. Describe the colligative properties of solutions.
16-6. Use the K_{sp} value for a solid to determine its molar solubility, and vice versa.
16-7. **Determine K_{sp} for an ionic solid.**

COMPETENCY 17: ***Identify and characterize the factors that affect the kinetics (rate) of a reaction.***

ENABLING OBJECTIVES

17-1. Determine the order of a reaction when given the initial rate as a function of concentration of a reactant.
17-2. Calculate, for a first order reaction, the concentration of a reactant after a given time.
17-3. Calculate, for a first order reaction, the time required for the concentration to drop by a given amount when given the rate constant.
17-4. When given either the half-life or the rate constant for a first order reaction, calculate the other given the original concentration and the rate constant.
17-5. **Experimentally determine the rate constant, order, and activation energy of a reaction.**
17-6. Compare homogeneous with heterogeneous catalysts, and their affects on reaction rates.

COMPETENCY 18: ***Describe oxidation-reduction reactions, and relate them to the principles of electrochemical reactions*****.**

ENABLING OBJECTIVES

18-1. Balance redox reactions by half-reaction method.
18-2. **Experimentally carry out a redox titration.**
18-3. Relate corrosion to oxidation-reduction and how it may be prevented.
18-4. Compare voltaic cells to electrolytic cells.
18-5. Use the Nernst equation to calculate voltages of cells and half-cells.
18-6. Use standard reduction potentials to calculate voltages of cells or electrodes.
18-7. **Experimentally determine the Faraday Constant.**

COMPETENCY 19: ***Describe the basic principles of spectroscopy and correlate the basics of spectroscopy to the operation of specific analytical instruments.***

ENABLING OBJECTIVES

19-1. Describe the characteristics common to all spectroscopy.
19-2. Differentiate between the various kinds of spectroscopy and the types of analysis for which they are best suited.
19-3. **Obtain a spectral curve for a solution by using an UV-Vis spectrophotometer.**
19.4. **Determine the concentration of a solution by using a spectrophotometer and Beer's Law.**

COMPETENCY 20: ***Describe the basic principles of chromatography and apply various chromatographic methods to the analysis of mixtures.***

ENABLING OBJECTIVES

20-1. Describe the characteristics common to all chromatography.
20-2. Differentiate between the various kinds of chromatography and the types of separation/analysis for which they are suited.
20-3**. Use column chromatography to separate colors in inks.**