Roanoke Valley Governor's School for Science and Technology
RVGS Chemistry
Competency List, 2022-2023

(Last updated: June 2022)

RVGS Chemistry explores the fundamental laws, theories, and mathematical concepts of chemistry. The major themes include the study of matter, its composition, structure, and properties, the changes they undergo, and the flow of energy that accompanies those changes. There is an emphasis on the use of technology for data collection and analysis. Virginia chemistry standards of learning are covered during the course.

This course is taught using best practices in gifted education. Each competency is aligned with Hockett's five principles of gifted education:

Gifted Education Principles:
(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)

1. High-quality curriculum for gifted learners uses a conceptual approach to organize or explore content that is discipline based and integrative.
2. High-quality curriculum for gifted learners pursues advanced levels of understanding beyond the general education curriculum through abstraction, depth, breadth, and complexity.
3. High-quality curriculum for gifted learners asks students to use processes and materials that approximate those of an expert, disciplinarian, or practicing professional.
4. High-quality curriculum for gifted learners emphasizes problems, products, and performances that are true to life, and outcomes that are transformational.
5. High-quality curriculum for gifted learners is flexible enough to accommodate self-directed learning fueled by student interests, adjustments for pacing, and variety.

(For the following competencies, **ES** indicates that the objective exceeds the SOL standards.)

COMPETENCY 1

Demonstrate awareness and proper use of laboratory safety techniques.

Enabling Objectives:

1. Differentiate between safe and unsafe procedures, applications, and methods of disposal of chemicals.	1b
2. Choose the appropriate safety equipment for specific laboratory situations.	1b
3. Decide which safety and emergency procedures to follow in case of particular accidents including fires and hazardous material spills.	1c
4. Demonstrate proper methods for carrying and moving chemicals and equipment.	1b
5. Demonstrate the ability to understand the NFPA Chemical Warning Labels on chemical containers.	1b **(ES)**

COMPETENCY 2

Apply System Internationale (SI) units as used in chemistry.

Enabling Objectives:

1. Identify the base units of the SI system and describe the standards for each.	1g
2. Describe the concept of a derived quantity and its units, and identify the dimension (combination of base units) for any derived quantity, initially including area, volume and density.	1g
3. Use dimensional analysis for calculations.	1g
4. Explain and give examples of the system of subdivision used in the SI system, including the use of prefixes to represent powers of ten.	1g
5. Use conversion factors to convert quantities from one metric unit to another, and also between metric and English units.	1g **(ES)**

COMPETENCY 3

Integrate computer use into the laboratory environment.

Enabling Objectives:

1. Acquire and record experimental data from computer interfaced hardware and software.	1h
2. Conduct statistical analysis of data using relevant spreadsheet and graphing programs.	1h
3. Insert graphs, spreadsheets, photos, and other images into a document.	1g **(ES)**
4. Insert a table to organize information in a document.	1h **(ES)**
5. Add labels and arrows to an image.	1h **(ES)**
6. Create graphs that have a title, units, and legend where needed.	1h **(ES)**
7. Use software and appropriate data to create a scatter plot with a linear curve fit.	1g

COMPETENCY 4

Apply appropriate experimental and measurement skills and techniques to laboratory experiences, and organize laboratory data using proper report and notebook format.

Enabling Objectives:

1. Select appropriate systems of measurement, using proper units, metric prefixes and number of significant digits.	1g
2. Report the degree of uncertainty of a measurement, and carry out mathematical operations with measurements containing stated uncertainties.	1f
3. Determine the significant digits in a recorded measurement, and carry out mathematical operations using these measurements with answers rounded off to the correct number of significant digits.	1g
4. Determine the limit (decimal place) to which a measurement can be made for any measuring instrument.	1g
5. Differentiate between precision and accuracy and calculate each.	1f
6. Make linear and volume measurements and determine masses of materials using various pieces of equipment.	1a, 1h
7. Maintain a current, organized, and accurate laboratory notebook.	1e
8. Write a laboratory report that includes the following sections: title, introduction, procedure, data/observations, results, and conclusion.	1e **(ES)**

COMPETENCY 5

Categorize matter and its properties.

Enabling Objectives:

1. Describe the general properties of matter.	2h
2. Identify common elements by chemical symbols.	(ES)
3. Classify matter according to whether it is an element, a compound, or a mixture.	2h
4. Experimentally determine density for a variety of substances.	2h
5. Distinguish between physical and chemical properties of matter.	2h
6. Carry out physical and chemical changes to determine chemical and physical properties of substances.	2h
7. Use physical methods to separate the components of a mixture.	2h **(ES)**
8. Describe the discoveries leading to the modern day arrangement of the periodic table.	2i
9. Observe periodic trends of the general characteristics of metals, nonmetals, and metalloids.	2f

COMPETENCY 6

Investigate the development of modern atomic theory.

Enabling Objectives:

1. Describe the postulates of the modern atomic theory.	2i
2. Relate the Laws of Conservation of Mass, Definite Composition, and Multiple Proportions to atomic theory.	2i (ES)
3. Locate and describe the main components of the atom.	2c
4. Define isotope, and relate atomic number, mass number, and the total number of subatomic particles to each other, and interpret and write isotope symbols.	2b
5. Calculate average atomic mass from isotope abundances.	2a, 2b
6. Define Avogadro's number and its relationship to atomic mass.	2a
7. Balance nuclear reactions, and describe the three main types of nuclear radiation.	2b (ES)
8. For radioactive decay, given three of the following four parameters, calculate the fourth: the half-life, the number of half-lives, the beginning mass, and the final mass.	2b

COMPETENCY 7

Characterize the electronic structure of the atom, and how it produces the periodic properties of the atoms.

Enabling Objectives:

1. State and interpret the postulates of quantum theory.	2i
2. Relate energy differences, wavelength, and frequencies of EMR.	(ES)
3. Describe the atomic spectrum of hydrogen in terms of the Bohr model.	2i
4. Use the principle quantum number to determine the corresponding energy level and the number of sublevels.	2g
5. Write electron configurations and electron dot notations for elements.	2g
6. Use Hund's rule to draw orbital diagrams for electrons in an atom.	2g
7. Relate valence electrons with chemical properties, and then to how the periodic table is organized.	2d, 2f
8. Describe the trends in atomic radius, ionization energy, and electronegativity, and the electronic properties that produce those trends.	2f
9. Explain the difference between groups and periods in the periodic table.	2d

COMPETENCY 8

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

Enabling Objectives:

1. Identify basic differences between atoms, molecules, and ions and classify compounds as being ionic or molecular.	3d
2. Describe the formation of cations and anions, and relate it to electronegativity and position on the periodic table.	3d
3. Write Lewis structures and structural formulas to show the covalent bonding in molecules and polyatomic ions, and draw their resonance structures when applicable.	3c (ES)
4. Determine the polarity of covalent bonds from electronegativities.	3d
5. Explain the theory of atomic bonding in solids including covalent and metallic bonding.	3d (ES)
6. Distinguish between electrolytes and nonelectrolytes using experimental data.	4d
7. Use the VSEPR model to predict the geometric shape of simple molecules and polyatomic ions.	3d
8. Construct models of molecules and polyatomic ions to illustrate their predicted geometric shapes.	3d (ES)
9. Predict the polarity of molecules by using the VSEPR model for molecules containing polar covalent bonds.	3d

COMPETENCY 9

Apply rules of chemical nomenclature to writing formulas and naming compounds.

Enabling Objectives:

1. Write the names of ionic and binary covalent compounds from their formulas using the older system of prefixes and suffixes, along with the newer IUPAC system.	3a
2. Use the ion-charge method to write formulas for ionic compounds.	3c
3. Write formulas for binary covalent compounds.	3c
4. Write formulas for common acids.	3c, 4d

COMPETENCY 10

Apply the mole concept to calculations involving masses and/or numbers of atoms, molecules, or formula units.

Enabling Objectives:

1. State the masses of atoms or molecules (including the seven diatomic elements) in terms of molar masses.	2a
2. Convert numbers of atoms and molecules to masses and vice versa by using the mole concept.	4a
3. Calculate and prepare solutions of known molarity.	4c
4. Distinguish between empirical and molecular formulas.	4b
5. Experimentally determine the anhydrous molar mass of a hydrated compound.	(ES)
6. Calculate the percent composition of a compound from its formula, and from experimental data.	4b
7. Calculate empirical and molecular formulas from experimental data.	(ES)

COMPETENCY 11

Categorize and write balanced equations for chemical reactions.

Enabling Objectives:

1. Write and balance chemical equations when given reactants and products.	3b
2. Classify those equations that come under the heading of synthesis, decomposition, single and double replacement, and combustion reactions.	3e **(ES)**
3. Predict the products of chemical reactions when given the reactants.	3b **(ES)**
4. Define oxidation and reduction, identify the oxidation number of the atoms and/or ions in a chemical reaction, and identify any species undergoing oxidation or reduction in a chemical reaction.	2g **(ES)**
5. Use a solubility table to predict the formation of insoluble products, and the activity series to predict the occurrence of single replacement reactions.	3b, 3c **(ES)**
6. Carry out examples of each kind of reaction, and write balanced equations for each.	3b

COMPETENCY 12

Apply stoichiometry experimentally and in calculations.

Enabling Objectives:

1. Calculate mass relationships based on balanced chemical equations.	4b
2. Determine the percent yield of a reaction using experimental data.	4b
3. Determine the limiting reactant and the theoretical yield for chemical reactions, along with how much of the non-limiting reactant is left over.	4b
4. Experimentally determine the mole ratio for a chemical reaction, and use it to determine the equation for the reaction.	4b
5. Carry out calculations involving solution concentrations expressed in molarity.	4c

COMPETENCY 13

Relate the concepts of energy, enthalpy, and entropy to chemical reactions.

Enabling Objectives:

1. Classify the various forms of energy.	(ES)
2. Distinguish between heat and temperature.	(ES)
3. Distinguish between exothermic and endothermic reactions.	3e
4. Summarize the changes in energy that take place during a chemical reaction. and be able to draw potential energy diagrams for both exothermic and endothermic reactions.	3e **(ES)**
5. Experimentally determine the specific heat capacity for several substances, and relate these quantities to the structures of the substances.	(ES)
6. Calculate $\Delta H°$ for a reaction using heats of formation.	4b **(ES)**
7. Experimentally measure heat flow using a calorimeter, and use the measurements to write a thermochemical equation for the reaction.	4b **(ES)**
8. Define and calculate $\Delta H°$ and $\Delta S°$ for a reaction, and relate the signs to the thermodynamic favorability of the reaction.	(ES)

COMPETENCY 14

Relate the concepts of kinetics and equilibrium to chemical reactions.

Enabling Objectives:

1. Describe the effects of temperature, concentration, and the surface area to volume ratio on the rate of a chemical reaction.	3f
2. Determine the rate of a reaction from experimental data.	3f (ES)
3. Describe the effect of a catalyst on the rate of a reaction, and recognize that enzymes are biological catalysts.	3f
4. Using a potential energy diagram, show how a catalyst speeds up a reaction.	3f (ES)
5. Write the expression for K_c from the balanced chemical equation.	3f (ES)
6. Calculate K_c from equilibrium concentrations of all species, or from original concentrations of all species and the equilibrium concentration of one species.	3f (ES)
7. Using LeChâtelier's Principle, predict the effect of a change in the number of moles, volume, or temperature upon the position of a system at equilibrium.	3f
8. Relate the acidic and basic properties of aqueous solutions to the dissociation of water.	4d
9. Perform calculations involving pH and pOH.	4d
10. Compare strong and weak acids and bases.	4d
11. Write equations for reactions between acids and bases.	4d
12. Carry out acid-base titrations and write equations for the reactions.	4d
13. Compare the Arrhenius and Bronsted-Lowry theories of acids.	4d

COMPETENCY 15

Describe gases in terms of the kinetic theory of gases and apply the gas laws and the Ideal Gas Equation to problems.

Enabling Objectives:

1. State the tenets of kinetic-molecular theory.	5a (ES)
2. Explain how the pressure a gas exerts is created.	5a
3. Describe the interrelated effects of the pressure, temperature, volume, and amount of a gas, and how they are expressed in both the Combined Gas Law and the Ideal Gas Law.	5a (ES)
4. Use the Ideal Gas Law to calculate the amount, pressure, temperature, or volume of a gas.	5a (ES)
5. Describe mixtures of gases in terms of Dalton's Law of Partial Pressures.	5b (ES)
6. Relate the density of gases to molar volume and molar mass.	4a (ES)
7. Describe how the Ideal Gas Law fails to accurately predict the properties of real gases at high pressures and/or low temperatures.	5a (ES)
8. Carry out experiments dealing with Boyle's Law, the Ideal Gas Law, and Dalton's Law of Partial Pressures.	5b (ES)

COMPETENCY 16

Describe the intermolecular forces that produce condensed states of matter, affect the solubility of solutes in a solvent, and how those solutes produce colligative properties.

Enabling Objectives:

1. Identify the three types of intermolecular forces (IMFs) and explain how they differ from intramolecular forces.	5d
2. Relate the vapor pressures and phases of two or more substances at a given temperature to the IMFs present in each one.	5g
3. Rank the boiling point of various substances based on their IMFs.	5g
4. Describe the dissolution process, and write dissociation equations for ionic compounds.	3b
5. On a heating curve, indicate the regions where the substance is being heated, and where IMFs are being overcome.	5d
6. Identify the three types of colligative properties (freezing point depression, boiling point elevation, and vapor pressure lowering), and how the number of solute particles affects them.	5g
7. Determine the van't Hoff factor (i) for a compound based on its formula.	5g (ES)
8. Identify the solid, liquid, and gas regions and the triple point of a phase diagram, and use the diagram to determine the freezing point and the boiling point of a substance.	5d

COMPETENCY 17

Carbon atoms can create unique, long-chain compounds.

Enabling Objectives:

1. Identify the unique properties of carbon that allow the existence of multi-carbon compounds.	6a
2. Describe how the carbon-carbon bonds (alkanes, alkenes, and alkynes) affect the shape and reactivity of organic molecules.	6a
3. Know the prefixes for straight-chain carbon organic up to 10 carbon atoms long.	6a (ES)
4. Given their names, draw structural formulas of specific organic molecules (including alcohols, aldehydes, amines, and carboxylic acids), and vice versa.	6a (ES)
5. Recognize that proteins and nucleic acids are important natural organic polymers.	6b
6. Recognize that plastics formed from petrochemicals are synthetic organic polymers.	6b
7. Identify the uses of organic compounds in pharmaceuticals and genetics, plastics, and food.	6b