Enduring Understanding # 1: Scientific inquiry affords all learners opportunities to make observations, pose questions, develop hypotheses, design and conduct investigations, and analyze data to draw conclusions.				
Chemistry Benchmarks				
Students will understand:	**Essential Questions**	**Students will know the/that**	**Students will be able to**	**Notes**
1.1 Scientific thought is not philosophical; rather, it is substantiated by valid, reproducible evidence leading to logical conclusions.	-Do scientists think or solve problems differently than other people?	-Scientific method is an organized approach to scientific inquiry. -Observation is the key inquiry process used by Montana American Indians.	-Generate testable questions, safely design and conduct controlled investigations, make logical inferences based on observations, analyze the strengths and weaknesses of an experimental design, and effectively communicate results.	
	-What types of tools are used in chemistry?	-Basic laboratory techniques associated with chemical analysis. -Names and proper uses of common laboratory equipment.	-Demonstrate basic laboratory techniques. • Use of electronic balance • Lighting a Bunsen burner • Filtering and decanting • Titrating -Select and properly use appropriate tools and technology to gather and analyze data.	Could include electronic balance, barometer, spectrophotometer, pH meter, centrifuge, CBL or interface with probes, internet

	-Why is graphing an important tool in chemistry?	-Graphical analysis of data helps reveal relationships between and among variables. -These relationships often lead to mathematical formulas that can be used to predict properties or behavior within and beyond the data set.	-Use statistical, mathematical, and graphical methods to analyze data. • Identify and graph dependent and independent variables. • Determine a line of best fit. • Demonstrate proper use of significant figures and scientific notation. • Calculate % error and/or % yield	Excel and/or graphing calculators may be introduced to ease in data analysis
	-How can my behaviors as a chemistry student impact myself and the environment? -Where can I find information regarding protocol for chemical use?	-Most states have set guidelines and regulations for proper use, exposure and disposal of chemicals. -Location of laboratory safety equipment.	-Evaluate and apply information found in Material Safety Data Sheets (MSDS) • handling chemicals • hazards • disposal • chemical spill clean-up -Perform experiments following appropriate safety guidelines.	

Enduring Understanding # 2: Exploring systems, order, and organizations in our natural and designed world are integral to understanding the scientific disciplines and their interdependence.

Chemistry Benchmarks

Students will understand:	Essential Questions	Students will know the/that	Students will be able to	Notes
2.1 Atomic structure determines physical properties and chemical reactivity of substances.	-What are the basic building blocks of matter, and how do we know they exist? -How have scientific discoveries and experiments changed our view of the atom? -Is our current model of the atom correct?	-Atomic theory evolves as new evidence surfaces -The atom is made up of protons and neutrons located in a dense nucleus surrounded by a cloud of electrons.	-Discuss contributions that altered the accepted model of the atom • Dalton • Thomson • Discovery of radioactivity • Rutherford gold foil • Bohr	**Introduce quantum mechanics (spdf orbitals)**
	-Why might it be helpful to classify matter? -In what ways can we classify matter?	-We can classify matter as an element, compound, or mixture	-Differentiate among models of atoms, molecules, elements, compounds, and mixtures	
	-How does the location of an element in the periodic table relate to its properties and chemical reactivity? -Why is the arrangement of the table so odd? (Note tall columns, short columns, extra rows at the bottom, etc.)	-The Periodic Table displays the elements in increasing atomic number resulting in periodicity of the physical and chemical properties.	-Use the periodic table to • identify properties of elements • write electron configurations • determine number of valence electrons available for bonding • chemical reactivity • relative sizes of atoms & ions	

Chemistry Benchmarks

Students will understand:	Essential Questions	Students will know the/that	Students will be able to	Notes
	-Why do chemical substances behave differently?	-Chemical, physical, and biological properties of matter result from the ability of atoms to form bonds based on electrostatic forces between electrons and protons, and between atoms and molecules.	-Distinguish between ionic and covalent bonding and resulting properties	
	-What causes a substance to be a solid, liquid or gas at room temperature?	-The strength of intermolecular attractions determines state of matter and interactions with other substances	-Draw Lewis dot diagrams to represent elements and compounds	
	-How does the three dimensional arrangement of atoms in a molecule of a substance affect the properties, reactivity, and stability of the substance?		**-Predict the shape and polarity of molecules based on the VSEPR model.** **-Describe intermolecular attractions:** • **Hydrogen bonding** • **Dipole-dipole** • **London dispersion**	

Chemistry Benchmarks

Students will understand:	Essential Questions	Students will know the/that	Students will be able to	Notes
2.2 Chemical combinations and interactions are defined by definite mathematical proportions.	-Can a chemical formula be deduced from experimental data?	-Compounds contain a definite proportion of elements by mass and can be expressed as empirical and molecular formulas.	-Calculate percent composition. **-Describe the significance of the Laws of Definite and Multiple Proportions.** -Determine empirical and molecular formulas from experimental data.	
	-How do we count atoms knowing that we cannot see them?	-The mole is a unit used to describe 6.02×10^{23} particles and is the basis for all mathematical calculations in chemistry.	-Convert between units of moles and grams, particles, and liters of a substance.	
	-What relationships exist among reactant and product quantities in a chemical reaction?	-Stoichiometry calculations rely on the fixed quantitative proportions of substances involved in chemical reactions.	-Calculate stoichiometric relationships in chemical reactions • mass – mass • Limiting Reactants • **mass-volume** • **volume – volume** • **solution stoichiometry**	
	What relationship exists between the motions of atoms and molecules and	Kinetic-molecular theory Gas laws	-Describe the behavior of gases using the kinetic-molecular theory. -Solve gas law problems	

	the behavior of gases?		• Boyles Law • Charles Law • Gay-Lussac's Law • Ideal Gas Law • Dalton's law of partial pressure • **Graham's Law**	
	-How do chemists define concentrations of solutions? -How does Ice Melt work?	-There are a variety of ways to express concentrations of solutions. -Solutes raise the boiling point and lower the freezing point of a solvent.	Calculate solution concentrations. • molarity • **molality** • **percent (m/v, v/v)** • **ppm, ppb** **-Mole fraction** -Predict changes in freezing and boiling point of a solvent upon addition of a solute. **-Calculate change in fp and bp of a solvent upon addition of a solute.**	

Chemistry Benchmarks

Students will understand:	Essential Questions	Students will know the/that	Students will be able to	Notes
2.3 Mass and energy are conserved in chemical reactions.	Is matter conserved in chemical reactions?	-Conservation of matter is represented in balanced chemical equations.	-Balance chemical and nuclear equations.	
	-Why is it that some chemical changes require energy while others release energy? -When a chemical reaction produces energy, where does the energy come from?	-Energy is stored in chemical bonds. -Energy involved in chemical reactions is the net result of breaking bonds and forming new bonds.	-Investigate **and calculate** energy relationships in physical and chemical changes • Endo & exothermic • Phase Changes • Conservation of energy • **Specific Heat** • **Molar Heat of Fusion** • **Molar Heat of vaporization** • **Enthalpy & Hess's Law** • **Thermodynamic relationships**	
	-How do batteries work and why can't we recharge all batteries?	**-Spontaneous oxidation/reduction reactions can be used to produce electricity, while electricity can be used to cause non spontaneous reactions to occur.**	**-Describe the components of an electrochemical cell.**	
	-How does the sun produce so much energy? -What is the difference between a chemical and nuclear reaction?	-Nuclear processes are those in which the atomic nucleus changes. -These include alpha, beta, and gamma radioactive decay of isotopes, nuclear fission, and fusion.	-Compare and contrast energy produced in chemical vs. nuclear reactions.	

Chemistry Benchmarks

Students will understand:	Essential Questions	Students will know the/that	Students will be able to	Notes
2.4 There is a specific and unique language for chemistry.	-Is there a systematic method to naming compounds?	-Symbols represent elements. -Formulas represent compounds. -Equations represent chemical reactions.	-Write chemical formulas. -Name compounds.	
2.5 When two or more substances interact to form new substances, the elements composing them combine in new ways.	-What determines whether a chemical reaction takes place? -What are causes and effects of acid rain?	-Types of reactions: • synthesis • single replacement • double replacement • decomposition • combustion • nuclear • Redox **(half reactions)** • acid/base	-Identify the type of reaction based on reactants given. -Predict the products of chemical reactions. • Activity series • Solubility table -Characterize acids and bases. • Arrhenius • Bronsted-Lowry • **Lewis** **-Identify conjugate acid/base pairs.**	
	-Why do some reactions happen quickly and others do not?	-Chemical reaction rates depend on factors that influence the frequency of collision of reactant molecules.	-Adjust the rate of a chemical reaction through • Concentration • temperature • surface area • catalyst	
	-Do all reactions go to completion?	-Many reactions are reversible and reach a state of dynamic equilibrium.	-Anticipate the change in a chemical system predicted by LeChatelier's principle. **-Calculate values associated with equilibria systems** **K_{eq}, K_{sp}, K_w, K_a, K_b**	

Enduring Understanding # 3: Both contemporary and historical scientific understandings inform technological, ethical, cultural and life decisions.

Chemistry Benchmarks

Students will understand:	Essential Questions	Students will know the/that	Students will be able to	Notes
3.1 Knowledge of past and present practices leads to informed decisions.	-Is nuclear energy the fuel of the future? -How does nuclear energy compare to traditional and alternative fuel sources?	-Difference between fission and fusion. -Use of isotopes in the diagnosis and treatment of medical issues.	-Compare and contrast nuclear and non-nuclear energy sources. -Calculate half-life -Identify clinical uses of radioactive isotopes.	
	-Why is it important for us to study the history of science?	-Reevaluation of present understandings in the light of new data is essential to keeping scientific knowledge current.	-Review past and present chemical developments and reflect upon their impact on society, including Montana American Indian examples. -Give examples of scientific innovations challenging commonly held perceptions.	

Enduring Understanding # 1: Scientific inquiry affords all learners opportunities to make observations, pose questions, develop hypotheses, design and conduct investigations, and analyze data to draw conclusions.

Organic Chemistry Benchmarks

Students will understand:	Essential Questions	Students will know the/that	Students will be able to	Notes
1.1 Scientific thought is not philosophical; rather, it is substantiated by valid, reproducible evidence leading to logical conclusions.	-Do scientists think or solve problems differently than other people?	-The scientific method is an organized approach to scientific inquiry. -Observation is the key inquiry process used by Montana American Indians.	-Generate testable questions, safely design and conduct controlled investigations, make logical inferences based on observations, analyze the strengths and weaknesses of an experimental design, and effectively communicate results.	
	-What laboratory techniques are unique to organic chemistry?	-Basic laboratory techniques associated with chemical analysis and synthesis. -Names and proper uses of organic glassware.	-Demonstrate methods and applications of standard organic laboratory procedures. • Melting points • Boiling points • Recrystallization • Extraction • Distillation • Chromatography	Could include spectral analysis: nuclear magnetic resonance (NMR), infrared (IR), visible and ultraviolet (UV/Vis), mass spectrometry

	-Why is graphing an important tool in chemistry?	-Graphical analysis of data helps reveal relationships between and among variables. -These relationships often lead to mathematical formulas that can be used to predict properties or behavior within and beyond the data set.	-Use statistical, mathematical, and graphical methods to analyze data. • Identify and graph dependent and independent variables. • Determine a line of best fit. • Calculate % error and/or % yield -Examine time vs. temperature graphs to evaluate the effectiveness of simple vs. fractional distillation.		
	-How can my behaviors as a chemistry student impact myself and the environment? -Where can I find information regarding protocol for chemical use?	-Most states have set guidelines and regulations for proper use, exposure and disposal of chemicals. -Location of laboratory safety equipment.	-Evaluate and apply information found in Material Safety Data Sheets (MSDS) • handling chemicals • hazards • disposal • chemical spill clean-up -Perform experiments following appropriate safety guidelines.		

Enduring Understanding # 2: Exploring systems, order, and organizations in our natural and designed world are integral to understanding the scientific disciplines and their interdependence.

Organic Chemistry Benchmarks

Students will understand:	Essential Questions	Students will know the/that	Students will be able to	Notes
2.1 There is a specific and unique language for chemistry	-Is there a systematic method to naming organic compounds? -In what ways can we classify organic compounds?	-Difference between aliphatic, cyclic and aromatic compounds	-Name and write formulas following the IUPAC system for • Alkanes • Alkenes • Alkynes • Aromatic compounds -Identify organic functional groups.	
	-What properties of carbon make it the key element of life and of most of the 15 million chemical compounds that have been isolated, identified and characterized?	-Carbon is the basic building block of all organic molecules. -The major biological constituents in living matter (proteins, carbohydrates, lipids, nucleic acids, cell membranes, enzymes, and hormones) are organic.	-Draw Lewis dot diagrams showing single, double, and triple bonds. -Identify the hybrid orbitals used to form single, double, and triple bonds. -Describe the difference between a sigma and a pi bond. -Identify cumulated, conjugated, and isolated multiple bonds. -Determine the formal charges of all atoms in a structure. -Discuss resonance structures and the importance of resonance in benzene.	

Organic Chemistry Benchmarks

Students will understand:	Essential Questions	Students will know the/that	Students will be able to	Notes
	-Why are organic compounds so numerous and diverse? -How does the three dimensional arrangement of atoms in a molecule of a substance affect the properties, reactivity, and stability of the substance?	-A given organic chemical formula can represent numerous different compounds due to isomerism. -The structure (shape) of an organic compound plays a key role in determining its function and properties.	-Draw and name configurational (structural) isomers. -Identify cis-trans isomers. -Illustrate conformational isomers using Newman projections, dash & wedges, and sawhorse diagrams. -Differentiate between the chair and boat conformations of cyclohexane. -Identify axial and equatorial positions in cyclohexane. -Describe characteristics of stereoisomer's: -Optical activity -Chirality and chiral centers -Enantiomers -Diastereoisomers -Racemic mixtures and meso compounds.	

2.2 Molecular structure determines physical properties and chemical reactivity of substances.				
2.3 When two or more substances interact to form new substances the elements composing them combine in new ways.	-What are the similarities and differences between organic and inorganic reactions?	-Characteristic organic reactions: • Combustion of hydrocarbons • Substitution of alkanes • Addition reactions for alkenes and alkynes • Polymerization • Nucleophilic substitutions • Elimination reactions • Esterification • Saponification Markovnikov's Rule can be used to predict correct products for addition reactions. Reactions rarely take place in a single step.	-Predict the products of organic chemical reactions. -Discuss the role of carbocation stability as it relates to Markovnikov's Rule. -Diagram reaction mechanisms for organic reactions • Free radical chain reaction • Electrophilic addition to alkenes and alkynes • Electrophilic aromatic substitution • Polymerization -Describe the role of a catalyst in reaction mechanisms. • Pt catalyst for hydrogenation • Acid catalyst for hydration -Identify ortho-para directing and meta-directing groups in electrophilic aromatic substitution.	

Enduring Understanding # 3: Both contemporary and historical scientific understandings inform technological, ethical, cultural and life decisions.

Organic Chemistry Benchmarks

Students will understand:	Essential Questions	Students will know the/that	Students will be able to	Notes
3.1 Knowledge of past and present practices will lead to informed decisions.	-Why is it important for us to study the history of science? -What are the many uses of organic compounds?"	-Reevaluation of present understandings in the light of new data is essential to keeping scientific knowledge current.	-Give examples of scientific innovations challenging commonly held perceptions. -Review past and present chemical developments and reflect upon their impact on society, including Montana American Indian examples.	
3.2 Chemists synthesize new substances and materials.	-How are synthetic and natural compounds similar? How do they differ?	-Chemists use combinations of chemical reactions to create new substances and materials designed to meet societal needs.	-Choose reactants and reagents and describe a reaction that could be used to synthesize a given compound.	

Enduring Understanding # 1: Scientific inquiry affords all learners opportunities to make observations, pose questions, develop hypotheses, design and conduct investigations, and analyze data to draw conclusions.

Advanced Chemistry Benchmarks

Students will understand:	Essential Questions	Students will know the/that	Students will be able to	Notes
1.1 Scientific thought is not philosophical; rather, it is substantiated by valid, reproducible evidence leading to logical conclusions.	-Do scientists think or solve problems differently than other people?	-The scientific method is an organized approach to scientific inquiry. -Observation is the key inquiry process used by Montana American Indians.	-Generate testable questions, safely design and conduct controlled investigations, make logical inferences based on observations, analyze the strengths and weaknesses of an experimental design, and effectively communicate results.	
1.2 Chemistry is an experimental science.	-What types of tools are used in chemistry?	-Basic laboratory techniques associated with chemical analysis. -Names and proper uses of common laboratory equipment.	-Demonstrate basic laboratory techniques. • Use of electronic balance • Lighting a Bunsen burner • Filtering and decanting • Titrating -Select and properly use appropriate tools and technology to gather and analyze data.	Could include electronic balance, barometer, spectrophotometer, pH meter, centrifuge, CBL or interface with probes, internet
1.3 Chemists carry out experiments to discover the quantitative relationships on which the underlying concepts for a model of the physical world can be based.	-Why is graphing an important tool in chemistry?	-Graphical analysis of data helps reveal relationships between and among variables. These relationships often lead to mathematical formulas that can be used to predict properties or behavior within and beyond the data set.	-Use statistical, mathematical, and graphical methods to analyze data. • Identify and graph dependent and independent variables. • Determine a line of best fit. • Demonstrate proper use of significant figures and scientific notation. • Calculate % error and/or % yield	Excel and/or graphing calculators may be introduced to ease in data analysis
	-How can my behaviors as a chemistry student impact myself and the environment? -Where can I find information regarding protocol for chemical use?	-Most states have set guidelines and regulations for proper use, exposure and disposal of chemicals. -Location of laboratory safety equipment.	-Evaluate and apply information found in Material Safety Data Sheets (MSDS) • handling chemicals • hazards • disposal • chemical spill clean-up -Perform experiments following appropriate safety guidelines.	

Enduring Understanding # 2: Exploring systems, order, and organizations in our natural and designed world are integral to understanding the scientific disciplines and their interdependence.

Advanced Chemistry Benchmarks

Students will understand:	Essential Questions	Students will know the/that	Students will be able to	Notes
2.1 The rate at which reactions take place depends upon a number of factors.	-Why do some reactions happen quickly and others do not? -What factors affect the rate of a chemical reaction?	-Chemical reaction rates depend on factors that influence the frequency of collision of reactant molecules.	-Adjust the rate of a chemical reaction by changing concentration, temperature, surface area, or adding a catalyst.	
	-Can reaction rates be described mathematically?	-An equation that describes the rate of a reaction can only be determined by conducting a rate experiment.	-Use experimental data and graphical analysis to determine reaction order, rate constants, and reaction rate laws.	Method of initial rates
	-What does half life tell us about the rate of a reaction?	-Half life is the amount of time required for one half of the original quantity of a reactant to be consumed.	-Determine the half life for a reaction given the order of reaction.	
	-How does activation energy affect the rate of a chemical reaction?	-Reactants must collide in the appropriate orientation and with enough force to overcome activation energy in order for a reaction to occur.	-Calculate activation energy from experimental data using the Arrhenius equation.	
	-Why is it important to study reaction mechanisms?	-Reactions rarely take place in a single step.	-Describe the relationship between the rate-determining step and a mechanism.	

Advanced Chemistry Benchmarks

Students will understand:	Essential Questions	Students will know the/that	Students will be able to	Notes
2.2 The world exists in a state of dynamic equilibrium	-What does it mean to say that a reaction is in equilibrium?	-Many reactions are reversible and reach a state of dynamic equilibrium.	-Define dynamic equilibrium for both physical and chemical systems.	
	-How can we alter a system in equilibrium?	-Changes in concentration, temperature, pressure, or addition of a catalyst will disturb a system at equilibrium.	-Predict shift in equilibrium position according to LeChatelier's principle.	
	-Can chemical equilibria systems be defined mathematically?	Chemical equilibrium can be quantified through a mathematical proportion known as the equilibrium constant expression, K_{eq}.	-Calculate equilibrium constants for gaseous reactions. -Convert between K_p and K_c. -Calculate equilibrium constants for reactions in solution.	
	-What is the pH of 1M hydrochloric acid different than the pH of 1M acetic acid?	-The pH of buffers can be quickly calculated using the Henderson-Hasselbach equation. -Some salts undergo hydrolysis and alter the pH of water.	-Calculate the pH for the following solutions: -Strong acid/base -Weak acid/base -Salt -Buffer -Determine the pH at any point along a titration curve.	
		-Ionic compounds that we consider insoluble actually dissolve to a very small extent.	-Determine the solubility of a slightly soluble compound using its K_{sp} value.	

Advanced Chemistry Benchmarks

Students will understand:	Essential Questions	Students will know the/that	Students will be able to	Notes
2.3 Energy and randomness are the driving forces of change.	-When a chemical reaction produces energy, where does the energy come from?	-There are three fundamental laws of thermodynamics.	-Define state functions.	
		Changes of state are accompanied by and increase or decrease of potential energy.	-Perform an experiment to determine the heat of fusion or vaporization of a compound.	
	-Why is it that some chemical changes require energy while others release energy?	-Energy is stored in chemical bonds. -Energy involved in chemical reactions is the net result of breaking bonds and forming new bonds.	-Write a chemical equation corresponding to the Heat of Formation of a compound. -Use either Hess's Law or Heats of formation to determine the enthalpy change of a reaction	
	-What is entropy?	-The entropy of the universe is always increasing.	-Describe the relationship of entropy to reaction spontaneity.	
	-What is the difference between the terms endo/exothermic and ender/exergonic?	-Overall spontaneity of a chemical change is a balance between enthalpy and entropy changes, and can be altered by a change in temperature.	-Predict the spontaneity of a chemical reaction or phase change using Gibbs free energy.	
		-T-here is a mathematical relationship between change in free energy and both equilibrium constants and electrode potentials.	-Given the change in free energy, determine the equilibrium constant for a reaction or the cell potential for an electrochemical cell.	

Advanced Chemistry Benchmarks

Students will understand:	Essential Questions	Students will know the/that	Students will be able to	Notes
2.4 Many chemical reactions involve a transfer of electrons between reactants.	-Can oxidation take place if there is no oxygen in the reaction?	-Oxidation occurs when a substance loses electrons and reduction involves a gain of electrons.	-Identify the substance oxidized, substance reduced, oxidizing agent, and reducing reagent in a redox reaction. -Assign oxidation numbers to elements in a compound. -Balance redox equations by the half reaction method, including reactions in acidic and basic solutions.	
2.5 Electricity can be produced by forcing these electrons through an outside wire while being transferred.	-How do batteries work and why can't we recharge all batteries?	-Spontaneous oxidation/reduction reactions can be used to produce electricity, while electricity can be used to cause non spontaneous reactions to occur.	-Describe the components of an electrochemical cell. -Write equations for the reaction that occurs at the cathode and the anode. -Compare and contrast voltaic and electrolytic cells. -Describe an electrochemical cell using line notation. -Calculate cell potentials for standard cells. -Use the Nernst equation to predict cell potentials for non-standard cells.	

Enduring Understanding # 3: Both contemporary and historical scientific understandings inform technological, ethical, cultural and life decisions.

Advanced Chemistry Benchmarks

Students will understand:	Essential Questions	Students will know the/that	Students will be able to	Notes
3.1 Knowledge of past and present practices will lead to informed decisions.	-Why is it important for us to study the history of science?	-Reevaluation of present understandings in the light of new data is essential to keeping scientific knowledge current. -Real problems have more than one solution and decisions to accept one over another are made on the basis of weighing all sides of the issue.	-Give examples of scientific innovations challenging commonly held perceptions. -Review past and present chemical developments and reflect upon their impact on society, including Montana American Indian examples.	