QualityCore®

Instructional Units Plan
Chemistry

This set of plans presents the topics and selected ACT Course Standards for ACT's rigorous Chemistry course. The topics and standards are arranged in twenty units by suggested instructional sequence. Unit 1 is a Model Instructional Unit developed by ACT that illustrates exemplary practice and shows how the Course Standards are best connected to classroom instruction. Teachers can use the *Guidelines for Developing an Instructional Unit* to develop additional instructional units based on the topics listed in this document.

Unit No.	Unit Topic
1	Introduction to Chemistry: What Matters?
2	Measurement and Analysis of Matter
3	Language of Chemistry: Part I
4	Language of Chemistry: Part II
5	Chemical Equations
6	Stoichiometry
7	Gases and Gas Stoichiometry
8	Thermal Chemistry
9	Atomic Structure
10	Periodicity
11	Bonding I
12	Bonding II
13	Qualitative Aspects of Solutions
14	Quantitative Aspects of Solutions
15	Chemical Equilibrium
16	Chemical Kinetics
17	Qualitative Aspects of Acids and Bases
18	Quantitative Aspects of Acids and Bases
19	Oxidation-Reduction Reactions and Electrochemistry
20	Nuclear Chemistry

Unit 1
Introduction to Chemistry: What Matters?

ACT Course Standards

Unit 1 Introduction to Chemistry: What Matters?	
I.A.1. Scientific Inquiry	a. Identify and clarify research questions and design experiments
	b. Design experiments so that variables are controlled and appropriate numbers of trials are used
	c. Collect, organize, and analyze data accurately and use techniques and equipment appropriately
	d. Interpret results and draw conclusions, revising hypotheses as necessary and/or formulating additional questions or explanations
	e. Write and speak effectively to present and explain scientific results, using appropriate terminology and graphics
	f. Safely use laboratory equipment and techniques when conducting scientific investigations
I.A.2. Mathematics and Measurement in Science	b. Use appropriate SI units for length, mass, time, temperature, quantity of matter, area, volume, and density; describe the relationships among SI unit prefixes (e.g., centi-, milli-, kilo-); recognize commonly used non-SI units
	g. Use graphical, mathematical, and/or statistical models to express patterns and relationships inferred from sets of scientific data
II.A.2. Elements, Atomic Mass, and Nomenclature	b. Compare the characteristics of elements, compounds, and mixtures
II.B.1. Phases of Matter, Phase Changes, and Physical Changes	a Compare the definition of matter and energy and the laws of conservation of matter and energy
	b. Describe how matter is classified by state of matter and by composition
	c. Describe the phase and energy changes associated with boiling/condensing, melting/freezing, sublimation, and crystallization (deposition)
	d. Explain the difference between chemical and physical changes and demonstrate how these changes can be used to separate mixtures and compounds into their components
	e. Define chemical and physical properties and compare them by providing examples
IV.A.1. Structure of Liquids and Solids	b. Describe and perform common separation techniques (e.g., filtration, distillation, chromatography)

Unit 2
Measurement and Analysis of Matter

ACT Course Standards

Unit 2 Measurement and Analysis of Matter		
I.A.1.	Scientific Inquiry	a. Identify and clarify research questions and design experiments
		b. Design experiments so that variables are controlled and appropriate numbers of trials are used
		c. Collect, organize, and analyze data accurately and use techniques and equipment appropriately
		d. Interpret results and draw conclusions, revising hypotheses as necessary and/or formulating additional questions or explanations
		e. Write and speak effectively to present and explain scientific results, using appropriate terminology and graphics
		f. Safely use laboratory equipment and techniques when conducting scientific investigations
		g. Routinely make predictions and estimations
I.A.2.	Mathematics and Measurement in Science	a. Distinguish between precision and accuracy with respect to experimental data
		b. Use appropriate SI units for length, mass, time, temperature, quantity of matter, area, volume, and density; describe the relationships among SI unit prefixes (e.g., centi-, milli-, kilo-); recognize commonly used non-SI units
		c. Use the correct number of significant figures in reporting measurements and the results of calculations
		d. Use appropriate statistical methods to represent the results of investigations
		e. Express numbers in scientific notation when appropriate
		f. Solve for unknown quantities by manipulating variables
		g. Use graphical, mathematical, and/or statistical models to express patterns and relationships inferred from sets of scientific data
I.A.3.	Science in Practice	b. Explain why experimental replication and peer review are essential to eliminate as much error and bias as possible in scientific claims
II.A.1.	Mass, Volume, and Density	a. Explain why mass is used as a quantity of matter and differentiate between mass and weight
		b. Explain density qualitatively and solve density problems by applying an understanding of the concept of density

Unit 3
Language of Chemistry: Part I

ACT Course Standards

Unit 3 Language of Chemistry: Part I		
I.A.1.	Scientific Inquiry	c. Collect, organize, and analyze data accurately and use techniques and equipment appropriately
		d. Interpret results and draw conclusions, revising hypotheses as necessary and/or formulating additional questions or explanations
		e. Write and speak effectively to present and explain scientific results, using appropriate terminology and graphics
		f. Safely use laboratory equipment and techniques when conducting scientific investigations
		g. Routinely make predictions and estimations
I.A.2.	Mathematics and Measurement in Science	a. Distinguish between precision and accuracy with respect to experimental data
		b. Use appropriate SI units for length, mass, time, temperature, quantity of matter, area, volume, and density; describe the relationships among SI unit prefixes (e.g., centi-, milli-, kilo-); recognize commonly used non-SI units
		c. Use the correct number of significant figures in reporting measurements and the results of calculations
		d. Use appropriate statistical methods to represent the results of investigations
		g. Use graphical, mathematical, and/or statistical models to express patterns and relationships inferred from sets of scientific data
I.A.3.	Science in Practice	a. Explain and apply criteria that scientists use to evaluate the validity of scientific claims and theories
		b. Explain why experimental replication and peer review are essential to eliminate as much error and bias as possible in scientific claims
		c. Explain the criteria that explanations must meet to be considered scientific (e.g., be consistent with experimental/observational evidence about nature, be open to critique and modification, use ethical reporting methods and procedures)
		e. Use a variety of appropriate sources (e.g., Internet, scientific journals) to retrieve relevant information; cite references properly
II.A.2.	Elements, Atomic Mass, and Nomenclature	a. Use the IUPAC symbols of the most commonly referenced elements
		b. Compare the characteristics of elements, compounds, and mixtures
		c. Compare characteristics of isotopes of the same element
III.A.1.	Empirical Formulas, Molecular Formulas, and Percentage Composition	a. Distinguish between chemical symbols, empirical formulas, molecular formulas, and structural formulas
		b. Interpret the information conveyed by chemical formulas for numbers of atoms of each element represented
		c. Use the names, formulas, and charges of commonly referenced polyatomic ions
		d. Provide the interconversion of molecular formulas, structural formulas, and names, including common binary and ternary acids
		e. Calculate the percent composition of a substance, given its formula or masses of each component element in a sample
		g. Determine percent composition experimentally and derive empirical formulas from the data (e.g., for hydrates)
IV.B.2.	Periodic Table and Periodicity	c. Use the periodic table to determine the atomic number; atomic mass; mass number; and number of protons, electrons, and neutrons in isotopes of elements
		d. Calculate the weighted average atomic mass of an element from isotopic abundance, given the atomic mass of each contributor

Unit 4
Language of Chemistry: Part II

ACT Course Standards

Unit 4 Language of Chemistry: Part II		
I.A.1.	Scientific Inquiry	c. Collect, organize, and analyze data accurately and use techniques and equipment appropriately
		d. Interpret results and draw conclusions, revising hypotheses as necessary and/or formulating additional questions or explanations
		e. Write and speak effectively to present and explain scientific results, using appropriate terminology and graphics
		f. Safely use laboratory equipment and techniques when conducting scientific investigations
I.A.2.	Mathematics and Measurement in Science	a. Distinguish between precision and accuracy with respect to experimental data
		b. Use appropriate SI units for length, mass, time, temperature, quantity of matter, area, volume, and density; describe the relationships among SI unit prefixes (e.g., centi-, milli-, kilo-); recognize commonly used non-SI units
		c. Use the correct number of significant figures in reporting measurements and the results of calculations
		e. Express numbers in scientific notation when appropriate
		f. Solve for unknown quantities by manipulating variables
I.A.3.	Science in Practice	d. Explain why all scientific knowledge is subject to change as new evidence becomes available to the scientific community
II.B.2.	The Nature of Gases	f. Describe Avogadro's hypothesis and use it to solve stoichiometric problems
III.A.1.	Empirical Formulas, Molecular Formulas, and Percentage Composition	e. Calculate the percent composition of a substance, given its formula or masses of each component element in a sample
		f. Determine the empirical formulas and molecular formulas of compounds, given percent composition data or mass composition data
		g. Determine percent composition experimentally and derive empirical formulas from the data (e.g., for hydrates)
III.A.2.	Mole Concept, Molar Mass, Gram Formula Mass, and Molecular Mass	a. Explain the meaning of mole and Avogadro's number
		b. Interconvert between mass, moles, and number of particles
		c. Distinguish between formula mass, empirical mass, molecular mass, gram molecular mass, and gram formula mass

Unit 5
Chemical Equations

ACT Course Standards

Unit 5 Chemical Equations		
I.A.1.	Scientific Inquiry	c. Collect, organize, and analyze data accurately and use techniques and equipment appropriately
		d. Interpret results and draw conclusions, revising hypotheses as necessary and/or formulating additional questions or explanations
		e. Write and speak effectively to present and explain scientific results, using appropriate terminology and graphics
		f. Safely use laboratory equipment and techniques when conducting scientific investigations
		g. Routinely make predictions and estimations
I.A.3.	Science in Practice	e. Use a variety of appropriate sources (e.g., Internet, scientific journals) to retrieve relevant information; cite references properly
III.A.3.	Chemical Equations and Stoichiometry	a. Explain how conservation laws form the basis for balancing chemical reactions and know what quantities are conserved in physical, chemical, and nuclear changes
		b. Write and balance chemical equations, given the names of reactants and products
		c. Describe what is represented, on a molecular and molar level, by chemical equations
		d. Use the appropriate symbols for state (i.e., solid, liquid, gaseous, aqueous) and reaction direction when writing chemical equations
		e. Classify chemical reactions as being synthesis, decomposition, single replacement, or double replacement reactions
		f. Predict the products of synthesis, combustion, and decomposition reactions and write balanced equations for these reactions

Unit 6
Stoichiometry

ACT Course Standards

Unit 6 Stoichiometry		
I.A.1.	Scientific Inquiry	c. Collect, organize, and analyze data accurately and use techniques and equipment appropriately
		d. Interpret results and draw conclusions, revising hypotheses as necessary and/or formulating additional questions or explanations
		e. Write and speak effectively to present and explain scientific results, using appropriate terminology and graphics
		f. Safely use laboratory equipment and techniques when conducting scientific investigations
I.A.2.	Mathematics and Measurement in Science	a. Distinguish between precision and accuracy with respect to experimental data
		b. Use appropriate SI units for length, mass, time, temperature, quantity of matter, area, volume, and density; describe the relationships among SI unit prefixes (e.g., centi-, milli-, kilo-); recognize commonly used non-SI units
		c. Use the correct number of significant figures in reporting measurements and the results of calculations
		d. Use appropriate statistical methods to represent the results of investigations
		e. Express numbers in scientific notation when appropriate
		f. Solve for unknown quantities by manipulating variables
		g. Use graphical, mathematical, and/or statistical models to express patterns and relationships inferred from sets of scientific data
I.A.3.	Science in Practice	e. Use a variety of appropriate sources (e.g., Internet, scientific journals) to retrieve relevant information; cite references properly
II.B.2.	The Nature of Gases	f. Describe Avogadro's hypothesis and use it to solve stoichiometric problems
III.A.3.	Chemical Equations and Stoichiometry	i. Use chemical equations to perform basic mole-mole, mass-mass, and mass-mole computations for chemical reactions
		j. Identify limiting reagents and use this information when solving reaction stoichiometry problems
		k. Compute theoretical yield, actual (experimental) yield, and percent yield
		l. Calculate percent error and analyze experimental errors that affect percent error

Unit 7
Gases and Gas Stoichiometry

ACT Course Standards

Unit 7 Gases and Gas Stoichiometry	
I.A.1. Scientific Inquiry	c. Collect, organize, and analyze data accurately and use techniques and equipment appropriately
	d. Interpret results and draw conclusions, revising hypotheses as necessary and/or formulating additional questions or explanations
	e. Write and speak effectively to present and explain scientific results, using appropriate terminology and graphics
	f. Safely use laboratory equipment and techniques when conducting scientific investigations
	g. Routinely make predictions and estimations
I.A.2. Mathematics and Measurement in Science	a. Distinguish between precision and accuracy with respect to experimental data
	b. Use appropriate SI units for length, mass, time, temperature, quantity of matter, area, volume, and density; describe the relationships among SI unit prefixes (e.g., centi-, milli-, kilo-); recognize commonly used non-SI units
	c. Use the correct number of significant figures in reporting measurements and the results of calculations
	d. Use appropriate statistical methods to represent the results of investigations
	e. Express numbers in scientific notation when appropriate
	f. Solve for unknown quantities by manipulating variables
	g. Use graphical, mathematical, and/or statistical models to express patterns and relationships inferred from sets of scientific data
I.A.3. Science in Practice	d. Explain why all scientific knowledge is subject to change as new evidence becomes available to the scientific community
	e. Use a variety of appropriate sources (e.g., Internet, scientific journals) to retrieve relevant information; cite references properly
	g. Compare the scientific definitions of fact, law, and theory, and give examples of each in chemistry
II.B.1. Phases of Matter, Phase Changes, and Physical Changes	a. Compare the definition of matter and energy and the laws of conservation of matter and energy
	b. Describe how matter is classified by state of matter and by composition
	c. Describe the phase and energy changes associated with boiling/condensing, melting/freezing, sublimation, and crystallization (deposition)
	d. Explain the difference between chemical and physical changes and demonstrate how these changes can be used to separate mixtures and compounds into their components
	e. Define chemical and physical properties and compare them by providing examples
II.B.2. The Nature of Gases	a. Define gas pressure and the various pressure units (e.g., torr, kilopascals, mm Hg, atmospheres)
	b. Describe the use and operation of mercury barometers and manometers to find atmospheric pressure or relative gas pressures
	c. Define the gas laws given by Boyle, Charles, Gay-Lussac, and Dalton and solve problems based on these laws
	e. Explain the basis for gaseous diffusion and effusion
	f. Describe Avogadro's hypothesis and use it to solve stoichiometric problems

Unit 7 Gases and Gas Stoichiometry (continued)		
II.B.3.	Ideal Gas Law	a. Explain the difference between an ideal and real gas, the assumptions made about an ideal gas, and what conditions favor ideal behavior for a real gas
		b. Apply the mathematical relationships that exist among the volume, temperature, pressure, and number of particles in an ideal gas
		c. Compute gas density when given molar mass, temperature, and pressure
		d. Apply the ideal gas law to determine the molar mass of a volatile compound
		e. Solve gas stoichiometry problems at standard and nonstandard conditions
IV.A.1.	Structure of Liquids and Solids	a. Describe differences between solids, liquids, and gases at the atomic and molecular levels
IV.A.2.	Kinetic Molecular Theory of Gases	a. Use the kinetic molecular theory to explain the states and properties (i.e., microscopic and macroscopic) of matter and phase changes
		b. Explain the basis and importance of the absolute temperature scale and convert between the Kelvin and Celsius scales
		c. Use the kinetic-molecular theory as a basis for explaining gas pressure, Avogadro's hypothesis, and Boyle's/Charles's laws

Unit 8
Thermal Chemistry

ACT Course Standards

Unit 8 Thermal Chemistry		
I.A.1.	Scientific Inquiry	c. Collect, organize, and analyze data accurately and use techniques and equipment appropriately
		d. Interpret results and draw conclusions, revising hypotheses as necessary and/or formulating additional questions or explanations
		e. Write and speak effectively to present and explain scientific results, using appropriate terminology and graphics
		f. Safely use laboratory equipment and techniques when conducting scientific investigations
		g. Routinely make predictions and estimations
I.A.2.	Mathematics and Measurement in Science	a. Distinguish between precision and accuracy with respect to experimental data
		b. Use appropriate SI units for length, mass, time, temperature, quantity of matter, area, volume, and density; describe the relationships among SI unit prefixes (e.g., centi-, milli-, kilo-); recognize commonly used non-SI units
		c. Use the correct number of significant figures in reporting measurements and the results of calculations
		d. Use appropriate statistical methods to represent the results of investigations
		e. Express numbers in scientific notation when appropriate
		f. Solve for unknown quantities by manipulating variables
		g. Use graphical, mathematical, and/or statistical models to express patterns and relationships inferred from sets of scientific data
I.A.3.	Science in Practice	e. Use a variety of appropriate sources (e.g., Internet, scientific journals) to retrieve relevant information; cite references properly
		f. Identify and analyze the advantages and disadvantages of widespread use of and reliance on technology
V.B.3.	Chemical Processes and Heat; Calorimetry	a. Explain the law of conservation of energy in chemical reactions
		b. Describe the concept of heat, and explain the difference between heat energy and temperature
		c. Explain physical and chemical changes as endothermic or exothermic energy changes
		d. Solve heat capacity and heat transfer problems involving specific heat, heat of fusion, and heat of vaporization
		e. Calculate the heat of reaction for a given chemical reaction when given calorimetric data
V.B.4.	Enthalpy and Entropy	a. Define enthalpy and explain how changes in enthalpy determine whether a reaction is endothermic or exothermic
		b. Compute ΔH_{rxn} from $\Delta H_f°$ values and explain why the $\Delta H_f°$ values for elements are zero
		c. Explain and apply, mathematically, the relationship between $\Delta H_{rxn}°$ (forward) and $\Delta H_{rxn}°$ (reverse)

Unit 9
Atomic Structure

ACT Course Standards

Unit 9 Atomic Structure		
I.A.1.	Scientific Inquiry	c. Collect, organize, and analyze data accurately and use techniques and equipment appropriately
		d. Interpret results and draw conclusions, revising hypotheses as necessary and/or formulating additional questions or explanations
		e. Write and speak effectively to present and explain scientific results, using appropriate terminology and graphics
		f. Safely use laboratory equipment and techniques when conducting scientific investigations
I.A.3.	Science in Practice	a. Explain and apply criteria that scientists use to evaluate the validity of scientific claims and theories
		c. Explain the criteria that explanations must meet to be considered scientific (e.g., be consistent with experimental/observational evidence about nature, be open to critique and modification, use ethical reporting methods and procedures)
		d. Explain why all scientific knowledge is subject to change as new evidence becomes available to the scientific community
		e. Use a variety of appropriate sources (e.g., Internet, scientific journals) to retrieve relevant information; cite references properly
		g. Compare the scientific definitions of fact, law, and theory, and give examples of each in chemistry
IV.B.1.	Atomic Theory (Dalton), Atomic Structure, and Quantum Theory	a. Describe the importance of models for the study of atomic structure
		b. Describe the crucial contributions of scientists and the critical experiments that led to the development of the modern atomic model
		c. Describe characteristics of a wave, such as wavelength, frequency, energy, and speed
		d. Describe the role of probability in orbital theory
		e. Describe atomic orbitals (s, p, d, f) and their basic shapes
		f. Apply Hund's rule and the Aufbau process to specify the electron configurations of the elements

Unit 10
Periodicity

ACT Course Standards

Unit 10 Periodicity		
I.A.1.	Scientific Inquiry	c. Collect, organize, and analyze data accurately and use techniques and equipment appropriately
		d. Interpret results and draw conclusions, revising hypotheses as necessary and/or formulating additional questions or explanations
		e. Write and speak effectively to present and explain scientific results, using appropriate terminology and graphics
		f. Safely use laboratory equipment and techniques when conducting scientific investigations
		g. Routinely make predictions and estimations
I.A.2.	Mathematics and Measurement in Science	g. Use graphical, mathematical, and/or statistical models to express patterns and relationships inferred from sets of scientific data
I.A.3.	Science in Practice	d. Explain why all scientific knowledge is subject to change as new evidence becomes available to the scientific community
		g. Compare the scientific definitions of fact, law, and theory, and give examples of each in chemistry
IV.B.2.	Periodic Table and Periodicity	a. Describe the historical development of the modern periodic table, including work by Mendeleev and then Moseley
		b. Describe and explain the organization of elements into periods and groups in the periodic table
		e. Identify regions (e.g., groups, families, series) of the periodic table and describe the chemical characteristics of each
		f. Compare the periodic properties of the elements (e.g., metal/nonmetal/metalloid behavior, electrical/heat conductivity, electronegativity and electron affinity, ionization energy, atomic/covalent/ionic radius) and how they relate to position in the periodic table
		g. Use the periodic table to predict and explain the valence electron configurations of the elements, to identify members of configuration families, and to predict the common valences of the elements

Unit 11
Bonding I

ACT Course Standards

Unit 11 Bonding I	
I.A.1. Scientific Inquiry	d. Interpret results and draw conclusions, revising hypotheses as necessary and/or formulating additional questions or explanations
	e. Write and speak effectively to present and explain scientific results, using appropriate terminology and graphics
	g. Routinely make predictions and estimations
I.A.3. Science in Practice	d. Explain why all scientific knowledge is subject to change as new evidence becomes available to the scientific community
	g. Compare the scientific definitions of fact, law, and theory, and give examples of each in chemistry
IV.B.3. Intermolecular Forces and Types of Bonds	a. Describe the characteristics of ionic and covalent bonding
	b. Explain ionic stability, recognize typical ionic configurations, and predict ionic configurations for elements (e.g., electron configurations, Lewis dot models)
	c. Describe the nature of the chemical bond with respect to valence electrons in bonding atoms
	d. Explain how ionic and covalent compounds differ
	e. Describe the unique features of bonding in carbon compounds
IV.B.4. Orbital Theory Applied to Bonding	a. Use Lewis dot diagrams to represent bonding in ionic and covalent compounds
	b. Draw Lewis structures for molecules and polyatomic ions, including those that must be represented by a set of resonance structures
	c. Use VSEPR theory to explain geometries of molecules and polyatomic ions
	d. Describe how orbital hybridization models relate to molecular geometry
	e. Describe the molecular orbital models for double bonds, triple bonds, and delocalized pi electrons

Unit 12
Bonding II

ACT Course Standards

Unit 12 Bonding II	
I.A.1. Scientific Inquiry	d. Interpret results and draw conclusions, revising hypotheses as necessary and/or formulating additional questions or explanations
	e. Write and speak effectively to present and explain scientific results, using appropriate terminology and graphics
	g. Routinely make predictions and estimations
I.A.3. Science in Practice	d. Explain why all scientific knowledge is subject to change as new evidence becomes available to the scientific community
	g. Compare the scientific definitions of fact, law, and theory, and give examples of each in chemistry
II.B.2. The Nature of Gases	d. Predict boiling point changes based on changes in atmospheric pressure
IV.B.3. Intermolecular Forces and Types of Bonds	a. Describe the characteristics of ionic and covalent bonding
	f. Compare the different types of intermolecular forces (e.g., van der Waals, dispersion)
	g. Explain and provide examples for dipole moments, bond polarity, and hydrogen bonding
	h. Describe the unique physical and chemical properties of water resulting from hydrogen bonding
	i. Explain the relationship between evaporation, vapor pressure, molecular kinetic energy, and boiling point for a single pure substance
	j. Explain the relationship between intermolecular forces, boiling points, and vapor pressure when comparing differences in the properties of pure substances
	k. Classify solids as ionic, molecular, metallic, or network
IV.B.4. Orbital Theory Applied to Bonding	f. Describe the relationship between molecular polarity and bond polarity

Unit 13
Qualitative Aspects of Solutions

ACT Course Standards

Unit 13 Qualitative Aspects of Solutions			
I.A.1.	Scientific Inquiry	c.	Collect, organize, and analyze data accurately and use techniques and equipment appropriately
		d.	Interpret results and draw conclusions, revising hypotheses as necessary and/or formulating additional questions or explanations
		e.	Write and speak effectively to present and explain scientific results, using appropriate terminology and graphics
		f.	Safely use laboratory equipment and techniques when conducting scientific investigations
		g.	Routinely make predictions and estimations
I.A.2.	Mathematics and Measurement in Science	b.	Use appropriate SI units for length, mass, time, temperature, quantity of matter, area, volume, and density; describe the relationships among SI unit prefixes (e.g., centi-, milli-, kilo-); recognize commonly used non-SI units
		c.	Use the correct number of significant figures in reporting measurements and the results of calculations
		d.	Use appropriate statistical methods to represent the results of investigations
		f.	Solve for unknown quantities by manipulating variables
		g.	Use graphical, mathematical, and/or statistical models to express patterns and relationships inferred from sets of scientific data
I.A.3.	Science in Practice	e.	Use a variety of appropriate sources (e.g., Internet, scientific journals) to retrieve relevant information; cite references properly
III.A.3.	Chemical Equations and Stoichiometry	h.	Predict the products of double replacement reactions, using solubility charts to identify precipitates, and write balanced equations for these reactions
		m.	Write ionic equations, identifying spectator ions and the net ionic equation
V.A.1.	Types of Solutions, Concentration, and Solubility	a.	Define solution, solute, and solvent
		b.	Compare properties of suspensions, colloids, and true solutions
		c.	Define the terms *saturated*, *unsaturated*, *supersaturated*, *dilute*, and *concentrated* as they pertain to solutions
		d.	Give examples of solid, liquid, or gas medium solutions
		i.	Describe the relationship between temperature or pressure and the solubility of gases in liquids
		j.	Describe the relationship between solvent character and solute character and explain miscibility
		k.	Apply the general rules of solubility to aqueous salt solutions
		l.	Describe the factors affecting the solubility of a solute in a given solvent and its rate of solution

Unit 14
Quantitative Aspects of Solutions

ACT Course Standards

Unit 14 Quantitative Aspects of Solutions	
I.A.1. Scientific Inquiry	a. Identify and clarify research questions and design experiments
	b. Design experiments so that variables are controlled and appropriate numbers of trials are used
	c. Collect, organize, and analyze data accurately and use techniques and equipment appropriately
	d. Interpret results and draw conclusions, revising hypotheses as necessary and/or formulating additional questions or explanations
	e. Write and speak effectively to present and explain scientific results, using appropriate terminology and graphics
	f. Safely use laboratory equipment and techniques when conducting scientific investigations
	g. Routinely make predictions and estimations
I.A.2. Mathematics and Measurement in Science	a. Distinguish between precision and accuracy with respect to experimental data
	b. Use appropriate SI units for length, mass, time, temperature, quantity of matter, area, volume, and density; describe the relationships among SI unit prefixes (e.g., centi-, milli-, kilo-); recognize commonly used non-SI units
	c. Use the correct number of significant figures in reporting measurements and the results of calculations
	d. Use appropriate statistical methods to represent the results of investigations
	e. Express numbers in scientific notation when appropriate
	f. Solve for unknown quantities by manipulating variables
	g. Use graphical, mathematical, and/or statistical models to express patterns and relationships inferred from sets of scientific data
I.A.3. Science in Practice	e. Use a variety of appropriate sources (e.g., Internet, scientific journals) to retrieve relevant information; cite references properly
V.A.1. Types of Solutions, Concentration, and Solubility	e. Define and calculate the molarity of a solution
	f. Define and calculate the percent composition of a solution
	g. Describe the preparation and properties of solutions
	h. Solve stoichiometry calculations based on reactions involving aqueous solutions
V.A.2. Colligative Properties	a. Describe qualitatively the effect of adding solute on freezing point, boiling point, and vapor pressure of a solvent
	b. Define molality and mole fraction
	c. Calculate changes in the boiling point and freezing point when nonvolatile, nonelectrolyte solutes are added to solvents

Unit 15
Chemical Equilibrium

ACT Course Standards

Unit 15 Chemical Equilibrium	
I.A.1. Scientific Inquiry	b. Design experiments so that variables are controlled and appropriate numbers of trials are used
	c. Collect, organize, and analyze data accurately and use techniques and equipment appropriately
	d. Interpret results and draw conclusions, revising hypotheses as necessary and/or formulating additional questions or explanations
	e. Write and speak effectively to present and explain scientific results, using appropriate terminology and graphics
	f. Safely use laboratory equipment and techniques when conducting scientific investigations
	g. Routinely make predictions and estimations
I.A.2. Mathematics and Measurement in Science	b. Use appropriate SI units for length, mass, time, temperature, quantity of matter, area, volume, and density; describe the relationships among SI unit prefixes (e.g., centi-, milli-, kilo-); recognize commonly used non-SI units
	c. Use the correct number of significant figures in reporting measurements and the results of calculations
	e. Express numbers in scientific notation when appropriate
	f. Solve for unknown quantities by manipulating variables
	g. Use graphical, mathematical, and/or statistical models to express patterns and relationships inferred from sets of scientific data
I.A.3. Science in Practice	e. Use a variety of appropriate sources (e.g., Internet, scientific journals) to retrieve relevant information; cite references properly
V.B.1. Chemical Equilibrium and Factors Affecting Reaction Rates; Le Châtelier's Principle	a. Explain the collision theory of reactions
	b. Analyze factors (e.g., temperature, nature of reactants) affecting reaction rates in relation to the kinetic theory
	e. Describe the conditions that define equilibrium systems on a dynamic molecular level and on a static macroscopic scale
	f. Apply Le Châtelier's principle to explain a variety of changes in physical and chemical equilibria
	g. Define K_{sp} and manipulate K_{sp} to predict solubility
	h. Explain the law of concentration (mass) action and write equilibrium law expressions for chemical equilibria
	i. Determine solubility product constants from solubilities (and vice versa) for a given solubility equilibrium system
V.B.4. Enthalpy and Entropy	d. Define entropy and explain the role of entropy in chemical and physical changes, and explain the changes that favor increases in entropy

Unit 16
Chemical Kinetics

ACT Course Standards

Unit 16 Chemical Kinetics		
I.A.1.	Scientific Inquiry	a. Identify and clarify research questions and design experiments
		b. Design experiments so that variables are controlled and appropriate numbers of trials are used
		c. Collect, organize, and analyze data accurately and use techniques and equipment appropriately
		d. Interpret results and draw conclusions, revising hypotheses as necessary and/or formulating additional questions or explanations
		e. Write and speak effectively to present and explain scientific results, using appropriate terminology and graphics
		f. Safely use laboratory equipment and techniques when conducting scientific investigations
		g. Routinely make predictions and estimations
I.A.2.	Mathematics and Measurement in Science	b. Use appropriate SI units for length, mass, time, temperature, quantity of matter, area, volume, and density; describe the relationships among SI unit prefixes (e.g., centi-, milli-, kilo-); recognize commonly used non-SI units
		c. Use the correct number of significant figures in reporting measurements and the results of calculations
		g. Use graphical, mathematical, and/or statistical models to express patterns and relationships inferred from sets of scientific data
V.B.1.	Chemical Equilibrium and Factors Affecting Reaction Rates; Le Châtelier's Principle	c. Relate reaction mechanism, rate-determining step, activated complex, heat of reaction, and activation energy to reaction kinetics
		d. Interpret potential energy diagrams for chemical reactions
V.B.2.	Mechanism, Rate-Determining Step, Activation Energy, and Catalysts	a. Relate the rate of a chemical reaction to the appearance of products and the disappearance of reactants
		b. Describe the meaning of reaction mechanism and rate-determining step
		c. Relate collision theory to the factors that affect the rate of reaction
		d. Describe the meaning of activation energy and activated complex
		e. Interpret and label a plot of energy versus reaction coordinate
		f. Explain the effects of catalysts on reaction rates (e.g., mechanism, activation energy/activated complex)

Unit 17
Qualitative Aspects of Acids and Bases

ACT Course Standards

Unit 17 Qualitative Aspects of Acids and Bases	
I.A.1. Scientific Inquiry	c. Collect, organize, and analyze data accurately and use techniques and equipment appropriately
	d. Interpret results and draw conclusions, revising hypotheses as necessary and/or formulating additional questions or explanations
	e. Write and speak effectively to present and explain scientific results, using appropriate terminology and graphics
	f. Safely use laboratory equipment and techniques when conducting scientific investigations
I.A.3. Science in Practice	d. Explain why all scientific knowledge is subject to change as new evidence becomes available to the scientific community
	g. Compare the scientific definitions of fact, law, and theory, and give examples of each in chemistry
V.C.1. Acid/Base Theories	a. Describe the nature and interactions of acids and bases
	b. Describe the hydronium ion and the concept of amphoterism
	c. Describe Arrhenius and Brønsted-Lowry acids and bases; identify conjugate acids and bases in reactions
	d. Relate solvent interaction to the formation of acidic and basic solutions
	f. Describe characteristics of strong and weak acids and bases, and identify common examples of both
V.C.2. Acid/Base Constants and pH; Titration; Buffers	a. Write and balance a simple equation for a neutralization reaction

Unit 18
Quantitative Aspects of Acids and Bases

ACT Course Standards

Unit 18 Quantitative Aspects of Acids and Bases		
I.A.1.	Scientific Inquiry	c. Collect, organize, and analyze data accurately and use techniques and equipment appropriately
		d. Interpret results and draw conclusions, revising hypotheses as necessary and/or formulating additional questions or explanations
		e. Write and speak effectively to present and explain scientific results, using appropriate terminology and graphics
		f. Safely use laboratory equipment and techniques when conducting scientific investigations
		g. Routinely make predictions and estimations
I.A.2.	Mathematics and Measurement in Science	a. Distinguish between precision and accuracy with respect to experimental data
		b. Use appropriate SI units for length, mass, time, temperature, quantity of matter, area, volume, and density; describe the relationships among SI unit prefixes (e.g., centi-, milli-, kilo-); recognize commonly used non-SI units
		c. Use the correct number of significant figures in reporting measurements and the results of calculations
		d. Use appropriate statistical methods to represent the results of investigations
		e. Express numbers in scientific notation when appropriate
		f. Solve for unknown quantities by manipulating variables
		g. Use graphical, mathematical, and/or statistical models to express patterns and relationships inferred from sets of scientific data
I.A.3.	Science in Practice	a. Explain and apply criteria that scientists use to evaluate the validity of scientific claims and theories
		e. Use a variety of appropriate sources (e.g., Internet, scientific journals) to retrieve relevant information; cite references properly
		f. Identify and analyze the advantages and disadvantages of widespread use of and reliance on technology
V.C.1.	Acid/Base Theories	e. Define the water constant, K_w, and the pH scale
V.C.2.	Acid/Base Constants and pH; Titration; Buffers	b. Calculate hydrogen ion concentration, hydroxide ion concentration, pH, and pOH for acidic or basic solutions
		c. Explain how the acid-base indicators work
		d. Define percent ionization, K_a, and K_b and explain how they relate to acid/base strength
		e. Conduct a titration experiment in order to determine the concentration of an acid or base solution
		f. Qualitatively understand the behavior of a buffer and explain why buffer solutions maintain pH upon dilution

Unit 19
Oxidation-Reduction Reactions and Electrochemistry

ACT Course Standards

Unit 19 Oxidation-Reduction Reactions and Electrochemistry		
I.A.1.	Scientific Inquiry	c. Collect, organize, and analyze data accurately and use techniques and equipment appropriately
		d. Interpret results and draw conclusions, revising hypotheses as necessary and/or formulating additional questions or explanations
		e. Write and speak effectively to present and explain scientific results, using appropriate terminology and graphics
		f. Safely use laboratory equipment and techniques when conducting scientific investigations
		g. Routinely make predictions and estimations
I.A.2.	Mathematics and Measurement in Science	b. Use appropriate SI units for length, mass, time, temperature, quantity of matter, area, volume, and density; describe the relationships among SI unit prefixes (e.g., centi-, milli-, kilo-); recognize commonly used non-SI units
		c. Use the correct number of significant figures in reporting measurements and the results of calculations
I.A.3.	Science in Practice	e. Use a variety of appropriate sources (e.g., Internet, scientific journals) to retrieve relevant information; cite references properly
		f. Identify and analyze the advantages and disadvantages of widespread use of and reliance on technology
III.A.3	Chemical Equations and Stoichiometry	g. Predict products of single replacement reactions, using the activity series, and write balanced equations for these reactions
V.D.	REDOX Reactions and Electro-chemistry	a. Define REDOX reaction, oxidation, reduction, oxidizing agent, and reducing agent
		b. Assign oxidation numbers (states) to reaction species; identify the species oxidized and reduced, and the oxidizing agent and reducing agent, in a REDOX reaction
		c. Balance REDOX equations by the ion-electron and half-reaction methods
		d. Diagram and explain the operation of a voltaic cell
		e. Determine the net voltage obtained when standard half-cells are paired to form a voltaic cell, and use this voltage to predict reaction spontaneity

Unit 20
Nuclear Chemistry

ACT Course Standards

Unit 20 Nuclear Chemistry		
I.A.1.	Scientific Inquiry	c. Collect, organize, and analyze data accurately and use techniques and equipment appropriately
		d. Interpret results and draw conclusions, revising hypotheses as necessary and/or formulating additional questions or explanations
		e. Write and speak effectively to present and explain scientific results, using appropriate terminology and graphics
		f. Safely use laboratory equipment and techniques when conducting scientific investigations
		g. Routinely make predictions and estimations
I.A.2.	Mathematics and Measurement in Science	g. Use graphical, mathematical, and/or statistical models to express patterns and relationships inferred from sets of scientific data
I.A.3.	Science in Practice	c. Explain the criteria that explanations must meet to be considered scientific (e.g., be consistent with experimental/observational evidence about nature, be open to critique and modification, use ethical reporting methods and procedures)
		e. Use a variety of appropriate sources (e.g., Internet, scientific journals) to retrieve relevant information; cite references properly
		f. Identify and analyze the advantages and disadvantages of widespread use of and reliance on technology
II.A.2.	Elements, Atomic Mass, and Nomenclature	c. Compare characteristics of isotopes of the same element
V.E.	Nuclear Chemistry	a. Describe alpha, beta, and gamma decay, half-life, and fission and fusion
		b. Write appropriate equations for nuclear decay reactions, using particle balance; describe how the nucleus changes during these reactions and compare the resulting radiation with regard to penetrating ability