Washoe County School District
Curriculum & Instruction

High School Chemistry

Standards with Evidence Statements

Essential DCIs are highlighted

Washoe County School District
Every Child, By Name And Face, To Graduation

June 2022

SEMESTER 1

Standard	Topics
HS-PS1-1	<u>Atomic Theory</u> • Atomic numbers • Mass numbers • Isotopes • Atomic weight • Subatomic particles • Ions <u>Periodic Trends</u> • Atomic size (radius) • Electronegativity trends (conceptually) • Reactivity • Valence electrons
HS-PS1-2	• Covalent Bonding • Ionic Bonding • Predict outcomes of simple chemical reactions
HS-PS1-3	• Lewis symbols • Octet rule • Ionic Compounds and Bonding • Molecular Compounds and Covalent Bonding • Bond Polarity and Electronegativity (qualitative only) • Intermolecular Forces (trends, not vocabulary)
HS-PS1-8	• Nuclear processes • Energy related to nuclear processes

NOTE: These topics are tentative as the S2 final exam has not yet been developed.

SEMESTER 2

Standard	Topics
HS-PS1-4	• Bond Enthalpies ○ Energy in bonds—conceptually • Exothermic Reactions • Endothermic Reactions
HS-PS1-5	• Factors that affect reaction rates (temperature, concentration) • Kinetic Molecular Theory of Gases
HS-PS1-6	• Chemical equilibrium • Le Chatelier's Principle (conceptually; push-pull)
HS-PS1-7	• Conservation of Mass ○ Balancing equations • Moles, molar mass, and number of particles (interconversion) • Stoichiometry • Limiting Reactants, percent yield

HS-PS3-1	• States of matter and phase changes (with respect to energy) Note: Quantify
	• Kinetic Molecular Theory
	• Thermochemistry
	  ○ Endothermic, Exothermic
	  ○ First law of thermodynamics, internal energy

HS-PS3-4	• States of Matter
	  ○ Energy associated with phase changes
	• Kinetic Molecular Theory of Gases
	• Thermal Chemistry
	  ○ Endothermic
	  ○ Exothermic

Periodic Table of the Elements

Atomic Number — 3
Symbol — Li
Name — Lithium
Atomic Weight — 6.941

↔ Groups
↕ Periods

1 **H** Hydrogen 1.0795																	2 **He** Helium 4.00260
3 **Li** Lithium 6.941	4 **Be** Beryllium 9.01218											5 **B** Boron 10.812	6 **C** Carbon 12.0108	7 **N** Nitrogen 14.0067	8 **O** Oxygen 15.9994	9 **F** Fluorine 18.9984	10 **Ne** Neon 20.1798
11 **Na** Sodium 22.9898	12 **Mg** Magnesium 24.3051											13 **Al** Aluminum 26.9815	14 **Si** Silicon 28.0855	15 **P** Phosphorus 30.9738	16 **S** Sulfur 32.066	17 **Cl** Chlorine 35.453	18 **Ar** Argon 39.984
19 **K** Potassium 39.0983	20 **Ca** Calcium 40.078	21 **Sc** Scandium 44.9559	22 **Ti** Titanium 47.867	23 **V** Vanadium 50.9415	24 **Cr** Chromium 51.9961	25 **Mn** Manganese 54.9380	26 **Fe** Iron 55.845	27 **Co** Cobalt 58.9332	28 **Ni** Nickel 58.6934	29 **Cu** Copper 63.546	30 **Zn** Zinc 65.38	31 **Ga** Gallium 69.723	32 **Ge** Germanium 72.64	33 **As** Arsenic 74.9216	34 **Se** Selenium 78.96	35 **Br** Bromine 79.904	36 **Kr** Krypton 83.798
37 **Rb** Rubidium 85.4678	38 **Sr** Strontium 87.62	39 **Y** Yttrium 88.9059	40 **Zr** Zirconium 91.224	41 **Nb** Niobium 92.9064	42 **Mo** Molybdenum 95.96	43 **Tc** Technetium (98)	44 **Ru** Ruthenium 101.07	45 **Rh** Rhodium 102.906	46 **Pd** Palladium 106.42	47 **Ag** Silver 107.868	48 **Cd** Cadmium 112.412	49 **In** Indium 114.818	50 **Sn** Tin 118.711	51 **Sb** Antimony 121.760	52 **Te** Tellerium 127.60	53 **I** Iodine 126.904	54 **Xe** Xenon 131.294
55 **Cs** Cesium 132.905	56 **Ba** Barium 137.327	57-71 **La-** **Lu**	72 **Hf** Hafnium 178.49	73 **Ta** Tantalum 180.948	74 **W** Tungsten 183.84	75 **Re** Rhenium 186.207	76 **Os** Osmium 190.23	77 **Ir** Iridium 192.217	78 **Pt** Platinum 195.085	79 **Au** Gold 196.967	80 **Hg** Mercury 200.59	81 **Tl** Thallium 204.383	82 **Pb** Lead 207.2	83 **Bi** Bismuth 208.980	84 **Po** Polonium (209)	85 **At** Astatine (210)	86 **Rn** Radon (222)
87 **Fr** Francium (223)	88 **Ra** Radium (226)	89-103 **Ac-** **Lr**	104 **Rf** Rutherfordium (267)	105 **Db** Dubnium (268)	106 **Sg** Seaborgium (271)	107 **Bh** Bohrium (272)	108 **Hs** Hassium (270)	109 **Mt** Meitnerium (276)	110 **Ds** Darmstadtium (281)	111 **Rg** Roentgenium (280)	112 **Cn** Copernicium (285)	113 **Nh** Nihonium (286)	114 **Fl** Flerovium (289)	115 **Mc** Moscovium (289)	116 **Lv** Livermorium (293)	117 **Ts** Tennessine (294)	118 **Og** Oganesson (294)

57 **La** Lanthanum 138.905	58 **Ce** Cerium 140.116	59 **Pr** Praseodymium 140.908	60 **Nd** Neodymium 144.242	61 **Pm** Promethium (145)	62 **Sm** Samarium 150.36	63 **Eu** Europium 151.964	64 **Gd** Gadolinium 157.25	65 **Tb** Terbium 158.925	66 **Dy** Dysprosium 162.500	67 **Ho** Holmium 164.930	68 **Er** Erbium 167.259	69 **Tm** Thulium 168.934	70 **Yb** Ytterbium 173.054	71 **Lu** Lutetium 174.967
89 **Ac** Actinium (227)	90 **Th** Thorium 232.038	91 **Pa** Protactinium 231.036	92 **U** Uranium 238.029	93 **Np** Neptunium (237)	94 **Pu** Plutonium (244)	95 **Am** Americium (243)	96 **Cm** Curium (247)	97 **Bk** Berkelium (247)	98 **Cf** Californium (251)	99 **Es** Einsteinium (252)	100 **Fm** Fermium (257)	101 **Md** Mendelevium (258)	102 **No** Nobelium (259)	103 **Lr** Lawrencium (262)

HS-PS1-1	SEMESTER 1

Students who demonstrate understanding can:

HS-PS1-1. **Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.** [Clarification Statement: Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, and reactions with oxygen.] [*Assessment Boundary: Assessment is limited to main group elements. Assessment does not include quantitative understanding of ionization energy beyond relative trends.*]

The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). • E3 Use a model to predict the relationships between systems or between components of a system.	**PS1.A: Structure and Properties of Matter** • E1 Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. • E2 The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states.	**Patterns** • E1 Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

WCSD Assessed Topics

- Atomic Theory
  - Atomic numbers
  - Mass numbers
  - Isotopes
  - Atomic weight
  - Subatomic particles
  - Ions
- Periodic Trends
  - Atomic size (radius)
  - Electronegativity trends (conceptually)
  - Reactivity
  - Valence electrons

Observable features of the student performance by the end of the course:			
1	Components of the model		
	a	From the given model, students identify and describe* the components of the model that are relevant for their predictions, including:	
		i.	Elements and their arrangement in the periodic table;
		ii.	A positively-charged nucleus composed of both protons and neutrons, surrounded by negatively-charged electrons;
		iii.	Electrons in the outermost energy level of atoms (i.e., valence electrons); and
		iv.	The number of protons in each element.
2	Relationships		
	a	Students identify and describe* the following relationships between components in the given model, including:	
		i.	The arrangement of the main groups of the periodic table reflects the patterns of outermost electrons.
		ii.	Elements in the periodic table are arranged by the numbers of protons in atoms.
3	Connections		
	a	Students use the periodic table to predict the patterns of behavior of the elements based on the attraction and repulsion between electrically charged particles and the patterns of outermost electrons that determine the typical reactivity of an atom.	
	b	Students predict the following patterns of properties:	
		i.	The number and types of bonds formed (i.e. ionic, covalent, metallic) by an element and between elements;
		ii.	The number and charges in stable ions that form from atoms in a group of the periodic table; the periodic table, based on attractions of outermost (valence) electrons to the nucleus; and
		iv.	The relative sizes of atoms both across a row and down a group in the periodic table.

HS-PS1-2	SEMESTER 1

Students who demonstrate understanding can:

HS-PS1-2. **Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.** [Clarification Statement: Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.] [*Assessment Boundary: Assessment is limited to chemical reactions involving main group elements and combustion reactions.*]

The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • E2 Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, and peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.	**PS1.A: Structure and Properties of Matter** • E2 The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. **PS1.B: Chemical Reactions** • E3 The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.	**Patterns** • E1 Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

WCSD Assessed Topics

- Covalent Bonding
- Ionic Bonding
- Predict outcomes of simple chemical reactions

Observable features of the student performance by the end of the course:		
1	Articulating the explanation of phenomena	
	a	Students construct an explanation of the outcome of the given reaction, including:
		i. The idea that the total number of atoms of each element in the reactant and products is the same;
		ii. The numbers and types of bonds (i.e., ionic, covalent) that each atom forms, as determined by the outermost (valence) electron states and the electronegativity;
		iii. The outermost (valence) electron state of the atoms that make up both the reactants and the products of the reaction is based on their position in the periodic table; and
		iv. A discussion of how the patterns of attraction allow the prediction of the type of reaction that occurs (e.g., formation of ionic compounds, combustion of hydrocarbons).
2	Evidence	
	a	Students identify and describe* the evidence to construct the explanation, including:
		i. Identification of the products and reactants, including their chemical formulas and the arrangement of their outermost (valence) electrons;
		ii. Identification that the number and types of atoms are the same both before and after a reaction;
		iii. Identification of the numbers and types of bonds (i.e., ionic, covalent) in both the reactants and the products;
		iv. The patterns of reactivity (e.g., the high reactivity of alkali metals) at the macroscopic level as determined by using the periodic table; and
		v. The outermost (valence) electron configuration and the relative electronegativity of the atoms that make up both the reactants and the products of the reaction based on their position in the periodic table.
3	Reasoning	
	a	Students describe* their reasoning that connects the evidence, along with the assumption that theories and laws that describe their natural world operate today as they did in the past and will continue to do so in the future, to construct an explanation for how the patterns of outermost electrons and the electronegativity of elements can be used to predict the number and types of bonds each element forms.
	b	In the explanation, students describe* the causal relationship between the observable macroscopic patterns of reactivity of elements in the periodic table and the patterns of outermost electrons for each atom and its relative electronegativity.
4	Revising the explanation	
	a	Given new evidence or context, students construct a revised or expanded explanation about the outcome of a chemical reaction and justify the revision.

HS-PS1-3 SEMESTER 1

Students who demonstrate understanding can:

HS-PS1-3. **Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.** [Clarification Statement: Emphasis is on understanding the strengths of forces between particles, not on naming specific intermolecular forces (such as dipole-dipole). Examples of particles could include ions, atoms, molecules, and networked materials (such as graphite). Examples of bulk properties of substances could include the melting point and boiling point, vapor pressure, and surface tension.] [*Assessment Boundary: Assessment does not include Raoult's law calculations of vapor pressure.*]

The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. • Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. E2	**PS1.A: Structure and Properties of Matter** • The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. E3	**Patterns** • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. E1

WCSD Assessed Topics

- Lewis symbols
- Octet rule
- Ionic Compounds and Bonding
- Molecular Compounds and Covalent Bonding
- Bond Polarity and Electronegativity (qualitative only)
- Intermolecular forces (trends, not vocabulary)

Observable features of the student performance by the end of the course:			
1	Identifying the phenomenon to be investigated		
	a	Students describe* the phenomenon under investigation, which includes the following idea: the relationship between the measurable properties (e.g., melting point, boiling point, vapor pressure, surface tension) of a substance and the strength of the electrical forces between the particles of the substance.	
2	Identifying the evidence to answer this question		
	a	Students develop an investigation plan and describe* the data that will be collected and the evidence to be derived from the data, including bulk properties of a substance (e.g., melting point and boiling point, volatility, surface tension) that would allow inferences to be made about the strength of electrical forces between particles.	
	b	Students describe* why the data about bulk properties would provide information about strength of the electrical forces between the particles of the chosen substances, including the following descriptions*:	
		i.	The spacing of the particles of the chosen substances can change as a result of the experimental procedure even if the identity of the particles does not change (e.g., when water is boiled the molecules are still present but further apart).
		ii.	Thermal (kinetic) energy has an effect on the ability of the electrical attraction between particles to keep the particles close together. Thus, as more energy is added to the system, the forces of attraction between the particles can no longer keep the particles close together.
		iii.	The patterns of interactions between particles at the molecular scale are reflected in the patterns of behavior at the macroscopic scale.
		iv.	Together, patterns observed at multiple scales can provide evidence of the causal relationships between the strength of the electrical forces between particles and the structure of substances at the bulk scale.
	Planning for the investigation		
	a	In the investigation plan, students include:	
		i.	A rationale for the choice of substances to compare and a description* of the composition of those substances at the atomic molecular scale.
		ii.	A description* of how the data will be collected, the number of trials, and the experimental set up and equipment required.
	b	Students describe* how the data will be collected, the number of trials, the experimental set up, and the equipment required.	
4	Collecting the data		
	a	Students collect and record data — quantitative and/or qualitative — on the bulk properties of substances.	
5	Refining the design		
	a	Students evaluate their investigation, including evaluation of:	
		i.	Assessing the accuracy and precision of the data collected, as well as the limitations of the investigation; and
		ii.	The ability of the data to provide the evidence required.
	b	If necessary, students refine the plan to produce more accurate, precise, and useful data.	

HS-PS1-8	SEMESTER 1

Students who demonstrate understanding can:

HS-PS1-8. **Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.** [Clarification Statement: Emphasis is on simple qualitative models, such as pictures or diagrams, and on the scale of energy released in nuclear processes relative to other kinds of transformations.] [*Assessment Boundary: Assessment does not include quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decays.*]

The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. • E3 Develop a model based on evidence to illustrate the relationships between systems or between components of a system.	**PS1.C: Nuclear Processes** • E1 Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process.	**Energy and Matter** • E5 In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

WCSD Assessed Topics

- Nuclear processes
- Energy related to nuclear processes

Observable features of the student performance by the end of the course:			
1	Components of the model		
	a	Students develop models in which they identify and describe* the relevant components of the models, including:	
		i.	Identification of an element by the number of protons;
		ii.	The number of protons and neutrons in the nucleus before and after the decay;
		iii.	The identity of the emitted particles (i.e., alpha, beta — both electrons and positrons, and gamma); and
		iv.	The scale of energy changes associated with nuclear processes, relative to the scale of energy changes associated with chemical processes.
2	Relationships		
	a	Students develop five distinct models to illustrate the relationships between components underlying the nuclear processes of 1) fission, 2) fusion and 3) three distinct types of radioactive decay.	
	b	Students include the following features, based on evidence, in all five models:	
		i.	The total number of neutrons plus protons is the same both before and after the nuclear process, although the total number of protons and the total number of neutrons may be different before and after.
		ii.	The scale of energy changes in a nuclear process is much larger (hundreds of thousands or even millions of times larger) than the scale of energy changes in a chemical process.
3	Connections		
	a	Students develop a fusion model that illustrates a process in which two nuclei merge to form a single, larger nucleus with a larger number of protons than were in either of the two original nuclei.	
	b	Students develop a fission model that illustrates a process in which a nucleus splits into two or more fragments that each have a smaller number of protons than were in the original nucleus.	
	c	In both the fission and fusion models, students illustrate that these processes may release energy and may require initial energy for the reaction to take place.	
	d	Students develop radioactive decay models that illustrate the differences in type of energy (e.g., kinetic energy, electromagnetic radiation) and type of particle (e.g., alpha particle, beta particle) released during alpha, beta, and gamma radioactive decay, and any change from one element to another that can occur due to the process.	
	e	Students develop radioactive decay models that describe* that alpha particle emission is a type of fission reaction, and that beta and gamma emission are not.	

Semester 2

NOTE: The Semester 2 Final Exam has not yet been developed so the "WCSD Assessed Topics" are tentative at this time.

HS-PS1-4 SEMESTER 2

Students who demonstrate understanding can:

HS-PS1-4. **Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.** [Clarification Statement: Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.] [*Assessment Boundary: Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.*]

The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. • Develop a model based on evidence to illustrate the relationships between systems or between components of a system. E3	**PS1.A: Structure and Properties of Matter** • A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. E4 **PS1.B: Chemical Reactions** • Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. E1	**Energy and Matter** • Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. E2

NOTE: The Semester 2 Final Exam has not yet been developed so the "WCSD Assessed Topics" are tentative at this time.

WCSD Assessed Topics

- Bond Enthalpies
  - Energy in bonds--<u>conceptually</u>
- Exothermic Reactions
- Endothermic Reactions

NOTE: Qualitative in this standard; more quantitative in HS-PS3-4

Observable features of the student performance by the end of the course:			
1	Components of the model		
	a	Students use evidence to develop a model in which they identify and describe* the relevant components, including:	
		i.	The chemical reaction, the system, and the surroundings under study;
		ii.	The bonds that are broken during the course of the reaction;
		iii.	The bonds that are formed during the course of the reaction;
		iv.	The energy transfer between the systems and their components or the system and surroundings;
		v.	The transformation of potential energy from the chemical system interactions to kinetic energy in the surroundings (or vice versa) by molecular collisions; and
		vi.	The relative potential energies of the reactants and the products.
2	Relationships		
	a	In the model, students include and describe* the relationships between components, including:	
		i.	The net change of energy within the system is the result of bonds that are broken and formed during the reaction (Note: This does not include calculating the total bond energy changes.);
		ii.	The energy transfer between system and surroundings by molecular collisions;
		iii.	The total energy change of the chemical reaction system is matched by an equal but opposite change of energy in the surroundings (Note: This does not include calculating the total bond energy changes.); and
		iv.	The release or absorption of energy depends on whether the relative potential energies of the reactants and products decrease or increase.
3	Connections		
	a	Students use the developed model to illustrate:	
		i.	The energy change within the system is accounted for by the change in the bond energies of the reactants and products. (Note: This does not include calculating the total bond energy changes.)
		ii.	Breaking bonds requires an input of energy from the system or surroundings, and forming bonds releases energy to the system and the surroundings.
		iii.	The energy transfer between systems and surroundings is the difference in energy between the bond energies of the reactants and the products.
		iv.	The overall energy of the system and surroundings is unchanged (conserved) during the reaction.
		v.	Energy transfer occurs during molecular collisions.
		vi.	The relative total potential energies of the reactants and products can be accounted for by the changes in bond energy.

HS-PS1-5	SEMESTER 2

Students who demonstrate understanding can:

HS-PS1-5. **Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.** [Clarification Statement: Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules.] [*Assessment Boundary: Assessment is limited to simple reactions in which there are only two reactants; evidence from temperature, concentration, and rate data; and qualitative relationships between rate and temperature.*]

The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • E3 Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.	**PS1.B: Chemical Reactions** • E1 Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.	**Patterns** • E1 Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

NOTE: The Semester 2 Final Exam has not yet been developed so the "WCSD Assessed Topics" are tentative at this time.

WCSD Topic Alignment:	
• Factors that affect reaction rates (temperature, concentration)	• Kinetic Molecular Theory of Gases

Observable features of the student performance by the end of the course:		
1	Articulating the explanation of phenomena	
	a	Students construct an explanation that includes the idea that as the kinetic energy of colliding particles increases and the number of collisions increases, the reaction rate increases.
2	Evidence	
	a	Students identify and describe* evidence to construct the explanation, including:
		i. Evidence (e.g., from a table of data) of a pattern that increases in concentration (e.g., a change in one concentration while the other concentration is held constant) increase the reaction rate, and vice versa; and
		ii. Evidence of a pattern that increases in temperature usually increase the reaction rate, and vice versa.
3	Reasoning	
	a	Students use and describe* the following chain of reasoning that integrates evidence, facts, and scientific principles to construct the explanation:
		i. Molecules that collide can break bonds and form new bonds, producing new molecules.
		ii. The probability of bonds breaking in the collision depends on the kinetic energy of the collision being sufficient to break the bond, since bond breaking requires energy.
		iii. Since temperature is a measure of average kinetic energy, a higher temperature means that molecular collisions will, on average, be more likely to break bonds and form new bonds.
		iv. At a fixed concentration, molecules that are moving faster also collide more frequently, so molecules with higher kinetic energy are likely to collide more often.
		v. A high concentration means that there are more molecules in a given volume and thus more particle collisions per unit of time at the same temperature.

HS-PS1-6	SEMESTER 2

Students who demonstrate understanding can:

HS-PS1-6. **Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.*** [Clarification Statement: Emphasis is on the application of Le Chatelier's Principle and on refining designs of chemical reaction systems, including descriptions of the connection between changes made at the macroscopic level and what happens at the molecular level. Examples of designs could include different ways to increase product formation including adding reactants or removing products.] [*Assessment Boundary: Assessment is limited to specifying the change in only one variable at a time. Assessment does not include calculating equilibrium constants and concentrations.*]

The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • E5 Refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.	**PS1.B: Chemical Reactions** • E2 In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present. **ETS1.C: Optimizing the Design Solution** • Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. *(secondary)*	**Stability and Change** • E1 Much of science deals with constructing explanations of how things change and how they remain stable.

NOTE: The Semester 2 Final Exam has not yet been developed so the "WCSD Assessed Topics" are tentative at this time.

WCSD Topic Alignment:

- Chemical equilibrium
  - Predicting direction of reaction
- Le Chatelier's Principle (conceptually; push-pull)

Observable features of the student performance by the end of the course:		
1	Using scientific knowledge to generate the design solution	
	a	Students identify and describe* potential changes in a component of the given chemical reaction system that will increase the amounts of particular species at equilibrium. Students use evidence to describe* the relative quantities of a product before and after changes to a given chemical reaction system (e.g., concentration increases, decreases, or stays the same), and will explicitly use Le Chatelier's principle, including:
		i. How, at a molecular level, a stress involving a change to one component of an equilibrium system affects other components;
		ii. That changing the concentration of one of the components of the equilibrium system will change the rate of the reaction (forward or backward) in which it is a reactant, until the forward and backward rates are again equal; and
		iii. A description* of a system at equilibrium that includes the idea that both the forward and backward reactions are occurring at the same rate, resulting in a system that appears stable at the macroscopic level.
2	Describing criteria and constraints, including quantification when appropriate	
	a	Students describe* the prioritized criteria and constraints, and quantify each when appropriate. Examples of constraints to be considered are cost, energy required to produce a product, hazardous nature and chemical properties of reactants and products, and availability of resources.
3	Evaluating potential solutions	
	a	Students systematically evaluate the proposed refinements to the design of the given chemical system. The potential refinements are evaluated by comparing the redesign to the list of criteria (i.e., increased product) and constraints (e.g. energy required, availability of resources).
4	Refining and/or optimizing the design solution	
	a	Students refine the given designed system by making tradeoffs that would optimize the designed system to increase the amount of product, and describe* the reasoning behind design decisions.

HS-PS1-7	SEMESTER 2

Students who demonstrate understanding can:

HS-PS1-7. **Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.** [Clarification Statement: Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Emphasis is on assessing students' use of mathematical thinking and not on memorization and rote application of problem-solving techniques.] [*Assessment Boundary: Assessment does not include complex chemical reactions.*]

The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematical and Computational Thinking Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • E3 Use mathematical representations of phenomena to support claims.	**PS1.B: Chemical Reactions** • E3 The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.	**Energy and Matter** • E1 The total amount of energy and matter in closed systems is conserved. - ***Connections to Nature of Science*** **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** • Science assumes the universe is a vast single system in which basic laws are consistent.

NOTE: The Semester 2 Final Exam has not yet been developed so the "WCSD Assessed Topics" are tentative at this time.

WCSD Assessed Topics	
• Conservation of Mass (balancing equations)	• Moles, molar mass, and number of particles (interconversion) • Stoichiometry • Limiting Reactants, percent yield

Observable features of the student performance by the end of the course:			
1	Representation		
	a	Students identify and describe* the relevant components in the mathematical representations:	
		i.	Quantities of reactants and products of a chemical reaction in terms of atoms, moles, and mass;
		ii.	Molar mass of all components of the reaction;
		iii.	Use of balanced chemical equation(s); and
		iv.	Identification of the claim that atoms, and therefore mass, are conserved during a chemical reaction.
	b	The mathematical representations may include numerical calculations, graphs, or other pictorial depictions of quantitative information.	
	c	Students identify the claim to be supported: that atoms, and therefore mass, are conserved during a chemical reaction.	
2	Mathematical modeling		
	a	Students use the mole to convert between the atomic and macroscopic scale in the analysis.	
	b	Given a chemical reaction, students use the mathematical representations to	
		i.	Predict the relative number of atoms in the reactants versus the products at the atomic molecular scale; and
		ii.	Calculate the mass of any component of a reaction, given any other component.
3	Analysis		
	a	Students describe* how the mathematical representations (e.g., stoichiometric calculations to show that the number of atoms or number of moles is unchanged after a chemical reaction where a specific mass of reactant is converted to product) support the claim that atoms, and therefore mass, are conserved during a chemical reaction.	
	b	Students describe* how the mass of a substance can be used to determine the number of atoms, molecules, or ions using moles and mole relationships (e.g., macroscopic to atomic molecular scale conversion using the number of moles and Avogadro's number).	

HS-PS3-1 SEMESTER 2

Students who demonstrate understanding can:

HS-PS3-1. Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known. [Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.] [*Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.*]

The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

Science and Engineering Practices

Using Mathematics and Computational Thinking

Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis; a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms; and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- E2 Create a computational model or simulation of a phenomenon, designed device, process, or system.

Disciplinary Core Ideas

PS3.A: Definitions of Energy

- E1 Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.

PS3.B: Conservation of Energy and Energy Transfer

- E1 Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.
- E2 Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- E3 Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.
- E4 The availability of energy limits what can occur in any system.

Crosscutting Concepts

Systems and System Models

- E4 Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems

- Science assumes the universe is a vast single system in which basic laws are consistent.

WCSD Assessed Topics

NOTE: These are tentative until S2 final exam is developed.

- States of matter and phase changes (with respect to energy) Note: Quantify
- Kinetic Molecular Theory
- Thermochemistry
  - Endothermic, Exothermic
- First law of thermodynamics, internal energy

Observable features of the student performance by the end of the course:			
1	Representation		
	a	Students identify and describe* the components to be computationally modeled, including:	
		i.	The boundaries of the system and that the reference level for potential energy = 0 (the potential energy of the initial or final state does not have to be zero);
		ii.	The initial energies of the system's components (e.g., energy in fields, thermal energy, kinetic energy, energy stored in springs — all expressed as a total amount of Joules in each component), including a quantification in an algebraic description to calculate the total initial energy of the system;
		iii.	The energy flows in or out of the system, including a quantification in an algebraic description with flow into the system defined as positive; and
		iv.	The final energies of the system components, including a quantification in an algebraic description to calculate the total final energy of the system.
2	Computational Modeling		
	a	Students use the algebraic descriptions of the initial and final energy state of the system, along with the energy flows to create a computational model (e.g., simple computer program, spreadsheet, simulation software package application) that is based on the principle of the conservation of energy.	
	b	Students use the computational model to calculate changes in the energy of one component of the system when changes in the energy of the other components and the energy flows are known.	
3	Analysis		
	a	Students use the computational model to predict the maximum possible change in the energy of one component of the system for a given set of energy flows.	
	b	Students identify and describe* the limitations of the computational model, based on the assumptions that were made in creating the algebraic descriptions of energy changes and flows in the system.	

HS-PS3-4	SEMESTER 2

Students who demonstrate understanding can:

HS-PS3-4. **Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).** [Clarification Statement: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.] [*Assessment Boundary: Assessment is limited to investigations based on materials and tools provided to students.*]

The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. • E2 Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.	**PS3.B: Conservation of Energy and Energy Transfer** • E2 Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. • E5 Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). **PS3.D: Energy in Chemical Processes** • E1 Although energy cannot be destroyed, it can be converted to less useful forms — for example, to thermal energy in the surrounding environment.	**Systems and System Models** • E2 When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

NOTE: The Semester 2 Final Exam has not yet been developed so the “WCSD Assessed Topics” are tentative at this time.

• **WCSD Assessed Topics**	
• States of Matter—energy associated with phase changes • Kinetic Molecular Theory of Gases	• Thermal Chemistry ○ Endothermic ○ Exothermic

Observable features of the student performance by the end of the course:		
1	Identifying the phenomenon to be investigated	
	a	Students describe* the purpose of the investigation, which includes the following idea, that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).
2	Identifying the evidence to answer this question	
	a	Students develop an investigation plan and describe* the data that will be collected and the evidence to be derived from the data, including:
		i. The measurement of the reduction of temperature of the hot object and the increase in temperature of the cold object to show that the thermal energy lost by the hot object is equal to the thermal energy gained by the cold object and that the distribution of thermal energy is more uniform after the interaction of the hot and cold components; and
		ii. The heat capacity of the components in the system (obtained from scientific literature).
3	Planning for the investigation	
	a	In the investigation plan, students describe*:
		i. How a nearly closed system will be constructed, including the boundaries and initial conditions of the system;
		ii. The data that will be collected, including masses of components and initial and final temperatures; and
		iii. The experimental procedure, including how the data will be collected, the number of trials, the experimental set up, and equipment required.
4	Collecting the data	
	a	Students collect and record data that can be used to calculate the change in thermal energy of each of the two components of the system.
5	Refining the design	
	a	Students evaluate their investigation, including:
		i. The accuracy and precision of the data collected, as well as the limitations of the investigation; and
		ii. The ability of the data to provide the evidence required.
	b	If necessary, students refine the plan to produce more accurate, precise, and useful data that address the experimental question.
	c	Students identify potential causes of the apparent loss of energy from a closed system (which should be zero in an ideal system) and adjust the design of the experiment accordingly.