A Correlation of

Pearson
Chemistry
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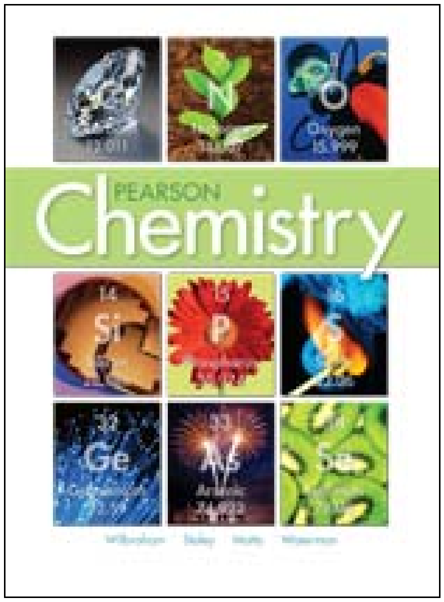

To the

Next Generation Science Standards

Physical Science Standards

DRAFT, MAY 2012

Grades 9-12

Dear Educator,

As we embark upon a new and exciting science journey, Pearson is committed to offering its complete support as classrooms transition to the new Next Generation Science Standards (NGSS). Ready-to-use solutions for today and a forward-thinking plan for tomorrow connect teacher education and development, curriculum content and instruction, assessment, and information and school design and improvement. We'll be here every step of the way to provide the easiest possible transition to the NGSS with a coherent, phased approach to implementation.

Pearson has long-standing relationships with contributors and authors who have been involved with the development and review of the Next Generation Science Frameworks and subsequent Next Generation Science Standards. As such, the spirit and pedagogical approach of the NGSS initiative is embedded in all of our programs, such as ***Pearson Chemistry.***

The planning and development of ***Pearson Chemistry*** was informed by the same foundational research as the NGSS Framework. Specifically, our development teams used Project 2061, the National Science Education Standards (1996) developed by the National Research Council, as well as the Science Anchors Project 2009 developed by the National Science Teachers Association to inform the development of this program. As a result, students make connections throughout the program to concepts that cross disciplines, practice science and engineering skills, and build on their foundational knowledge of key science ideas.

Pearson Chemistry combines proven and tested content with cutting-edge digital support and hands-on learning opportunities. This program provides you with everything you need to engage and motivate your students, as well as the tools to support the varied types of learners in your classroom.

Pearson Chemistry is built on a learning model that connects curriculum, instruction, and assessment to the "Big Ideas" of chemistry that develops deep understanding.

Pearson Chemistry provides all of the problem-solving and math support that students need to be successful in the course, with ample opportunity for practice both in the Student Edition and in the program's digital resources.

Pearson Chemistry helps you meet the unique learning styles of each student in your classroom with a variety of resources. A variety of assessment opportunities helps you monitor student progress ensure student success on high-stakes tests.

Pearsonchem.com provides cutting-edge digital content that engages students and teachers – anytime, anywhere, with numerous practice opportunities and visual support, including interactive art and animations. Online tutors step students through chemistry and math problems, expanding learning beyond the classroom.

The following document demonstrates how ***Pearson Chemistry*** **©2012**, supports the first draft of the Next Generation Science Standards (NGSS) for Grades 9-12. Correlation references are to the Student Edition and Teacher Edition.

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PHYSICAL SCIENCE

HS.PS-SPM.a. Structure and Properties of Matter

Students who demonstrate understanding can:

a. Construct models showing that stable forms of matter are those with minimum magnetic and electrical field energy. **[Clarification Statement: Examples of stable forms of matter can include noble gas atoms, simple molecules, and simple ionic substances.] [*Assessment Boundary: Only for common substances-for example, water, carbon dioxide, common hydrocarbons, sodium chloride.*]**

PEARSON CHEMISTRY: The citations below indicate areas in ***Pearson Chemistry*** where this idea is introduced.

Students **learn** about electron configurations and energy levels on SE/TE pages 134-137. They **learn** about ground state and energy levels on SE/TE pages 144-145. Students **examine** a chart showing the electron configurations of the noble gas elements on SE/TE page 170. Students **examine** Table 7.1 and **identify** the number of total number of electrons and the number of valence electrons of representative elements on SE/TE page 195. Students are then ready to **model** the formation of cations using equations on TE only page 197 (Explore). Students **apply** their knowledge about the octet rule and **predict** how many electrons atoms of representative non-metal elements need to share to achieve the noble gas configuration on TE only page 227 (Explain). Students **practice** different ways to **represent** molecules on TE only page 227 (Explore –Class Activity) and **distinguish** between covalent and ionic bonding by **drawing** electron dot structures on TE only page 229 (Explore –Class Activity). On TE only page 236 (Extend, Connect to Physics), students **investigate** the relationship between potential energy and bond length. In Quick Lab: Strengths of Covalent Bonds on SE/TE page 238, students **model** the dissociation energy of single, double, and triple covalent bonds.

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

Developing and Using Models	**PS1.A: Structure and Properties of Matter**	**Cause and Effect**
Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world. • Construct, revise, and use models to predict and explain relationships between systems and their components. **Related Content: SE/TE:** 194, Valence Electrons 202, Figure 7.7: Formation of Sodium Chloride 237, Resonance 238, Quick Lab: Strengths of Covalent Bonds **Related Content: TE Only:** 195, Explore – Teacher Demo 227, Explore -Class Activity 229, Explore -Class Activity 236, Extend, Connect to Physics	• Stable forms of matter are those in which the electric and magnetic field energy is minimized. A stable molecule has less energy, by an amount known as the binding energy, than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. **Related Content: SE/TE:** 134-137, Electron Configurations 144-145, An Explanation of Atomic Spectra 170, Electron Configurations in Groups 201-202, Formation of Ionic Compounds 202, Figure 7.7: Formation of Sodium Chloride 203, Chem Tutor: Sample Problem 7.1 226, The Octet Rule in Covalent Bonding 229, Chem Tutor: Sample Problem 8.1 236, Bond Dissociation Energies 238, Quick Lab: Strengths of Covalent Bonds	Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Systems can be designed to cause a desired effect. Changes in systems may have various causes that may not have equal effects. • [Clarification Statement for a: Stability is caused by minimization of energy.] **Related Content: SE/TE:** 194-195, Valence Electrons 236, Bond Dissociation Energies **Related Content: TE Only:** 236, Explain 236, Extend, Connect to Physics

	Related Content: TE Only: 202, Explain: Formation of Ionic Compounds 228, Explain (All) 236, Explain 236, Extend, Connect to Physics	

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HS.PS-SPM.b. Structure and Properties of Matter		
Students who demonstrate understanding can: **b. Construct various types of models showing that energy is needed to take molecules apart and that energy is released when the atoms come together to form new molecules. [*Assessment Boundary: Only for common substances- for example, water, carbon dioxide, common hydrocarbons, sodium chloride.*]** **PEARSON CHEMISTRY:** The citations below indicate areas in ***Pearson Chemistry*** where this idea is introduced. Energy needed to take molecules apart is explored in the section Bond Dissociation Energies on SE/TE pages 236-237. Students **obtain information** about chemical bonding in Chapter 7, Ionic and Metallic Bonding, SE/TE pages 192-219 and Chapter 8, Covalent Bonding, SE/TE pages 220-261. They **learn** about Chemical Reactions in Chapter 11, Chemical Reactions, SE/TE pages 344-381; heat in chemical reactions - Chapter 17, Thermochemistry, SE/TE pages 554-578; and collision theory – Chapter 18, Reaction Rates and Equilibrium, SE/TE pages 596-597.		
The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:		
Developing and Using Models Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world. • Use multiple types of models to represent and explain phenomena and move flexibly between model types based on merits and limitations. **Related Content: SE/TE:** 596, Figure 18.4: Collision Theory 597, Figure 18.5: Interpret Graphs	**PS1.A: Structure and Properties of Matter** • Stable forms of matter are those in which the electric and magnetic field energy is minimized. A stable molecule has less energy, by an amount known as the binding energy, than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. **Related Content: SE/TE:** 236-237, Bond Dissociation Energies 238, Quick Lab: Strengths of Covalent Bonds 565-568, Thermochemical Equations 578-579, Hess's Law 580-582, Standard Heats of Formation 596-597, Collision Theory **Related Content: TE Only:** 236, Explain 236, Check for Understanding 236, Extend, Connect to Physics	**Cause and Effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Systems can be designed to cause a desired effect. Changes in systems may have various causes that may not have equal effects. **Related Content: SE/TE:** 597, Interpret Graphs/Fig 18.5

HS.PS-SPM.c. Structure and Properties of Matter

Students who demonstrate understanding can:

c. Develop explanations about how the patterns of electrons in the outer level of atoms, as represented in the periodic table, reflect and can predict properties of elements. **[Clarification Statement: An example of a pattern that predicts element properties is the first column of the periodic table: These elements all have one electron in the outer most energy level and as such are all highly reactive metals.] [*Assessment Boundary: Only for main group elements (not transition metals or elements beyond the third row).*]**

PEARSON CHEMISTRY: Students **learn** about the patterns of electron in atoms in Chapter 5, Lesson 2, Electron Arrangement in atoms, SE/TE pages 134-137. Students are introduced to how elements are organized by increasing atomic number in the periodic table, to the periodic law, and to the broader classification of metals, nonmetals and metalloids in Chapter 6, Lesson 1, SE/TE pages 160-166. The classification of elements into groups based on their electron configuration, and the information that can be obtained from the period table in order to predict the properties of an element are presented in Chapter 6, Lesson 2, SE/TE pages 167-173.

Students **write** the electron configuration of elements using the periodic table and **determine** elements from their electron configuration using the periodic table in Chem Tutor #9, 10 on SE/TE page 173. Students **answer** questions about electron configurations and elements in Lesson Check 6.2 #12 and 15 on SE/TE page 173. In the Performance Task on TE page 185, students **design** and **discuss** a periodic table that contains an eighth period based on their knowledge of how a modern period table is constructed and their understanding of electron.

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

Constructing Explanations and Designing Solutions	PS1.A: Structure and Properties of Matter	Cause and Effect
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 knowledge, principles, and theories. • Construct and revise explanations and arguments based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories) and peer review. **TE Only:** 171, Explain –Use Visuals 185, Performance Tasks	• Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. **SE/TE:** 134-137, Electron Configurations 135, Figure 5.2, Aufbau Diagram 136, Chem Tutor: Sample Problem 5.1, Writing Electron Configurations • 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. **SE/TE:** 162, Today's Periodic Table 168-169, Figure 6.9: Periodic Table 170, Electron Configurations in groups 171, Figure 6.11: Representative Elements 172, Figure 6.13: Electron Configuration 173, Chem Tutor	Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Systems can be designed to cause a desired effect. Changes in systems may have various causes that may not have equal effects. • [Clarification Statement for c: The likelihood of interactions between elements is caused by the number of electrons in their valence shell, and thus the arrangement of the periodic table.]

	173, Lesson Check 6.2, #12, 15, 16 **TE Only:** 185, Performance Tasks	

HS.PS-SPM.d. Structure and Properties of Matter		
Students who demonstrate understanding can: **d. Construct arguments for which type of atomic and molecular representation best explains a given property of matter. [Clarification Statement: Types of atomic and molecular representations can include computer-based, simulations, physical, ball and stick, and symbolic. Properties of matter can include reactivity, and polar vs. non-polar.] [*Assessment Boundary: Not theoretical models.*]** **PEARSON CHEMISTRY:** The citations below indicate areas in ***Pearson Chemistry*** where this idea is introduced. Five models of an ammonia—Molecular formula, Structural formula, Space-filling molecular model, Perspective drawing, and Ball-and-stick molecular drawing—are shown in Figure 8.3, representations of an Ammonia Molecule, on SE/TE page 223. The use of electron dot structures to represent covalent bonding, along with its merits and drawbacks is covered in Chapter 8 Lesson 2 on SE/TE pages 226–238. The molecular orbital, VSEPR and hybrid orbital theories, used to explain the shape of molecules, are presented in Chapter 8 Lesson 3 on SE/TE pages 240–246. Advanced students **make** a poster or **create** models of the various ways the bonding of a hydrogen molecule can be represented in Differentiated Instruction: Advanced Students on TE page 223. In the Class Activity on TE page 242, students **make** stick and ball models to investigate the shape of molecules. Students **use** different models to answer questions in Lesson Check 8.1 #1, 4, 6 on SE/TE page 225, Lesson Check 8.2 #16, 18, 20 on SE/TE page 238, and Lesson Check 8.3 #21-28 on SE/TE page 246.		
The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:		
Engaging in Argument from Evidence Engaging in argument from evidence in 9–12 builds from K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world. Arguments may also come from current scientific or historical episodes in science. • Evaluate the merits of competing arguments, design solutions and/or models. • Evaluate the claims, evidence, and reasoning of currently accepted explanations or solutions as a basis for the merits of the arguments.	**PS1.A: Structure and Properties of Matter** • Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. **SE / TE:** 105-109, Structure of the Nuclear Atom 109, Lesson Check 4.2 -10, 13, 14, 15 128-132, Revising the Atomic Model **TE Only:** 129, Explore –Teacher Demo 131, Explore –Teacher Demo **PS2.B: Types of Interactions** • Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. **SE / TE:** 242-243, VSEPR Theory 242, Figure 8.16: Three-Dimensional Molecules 243, Figure 8.17: Planar and Linear Molecules	**Systems and System Models** Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. 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. **SE / TE:** 223, Figure 8.3: Representations of an Ammonia Molecule 224, Figure 8.4: Molecular Formulas and Structures 242-243, VSEPR Theory 242, Figure 8.16: Three-Dimensional Molecules 243, Figure 8.17: Planar and Linear Molecules 243, Figure 8.18: Molecular Shapes 244-245 Hybrid Orbitals 244, Figure 8.19: Methane Molecule 245, Figure 8.20 Ethene molecule **TE Only:** 223, Differentiated Instruction: Advanced Students

	243, Figure 8.18: Molecular Shapes 244-245 Hybrid Orbitals 244, Figure 8.19: Methane Molecule 245, Figure 8.20 Ethene molecule **TE Only:** 242, Class Activity 243, Explain 244-45, Explain: Hybrid Orbitals	224, Explore –Teacher Demo 242, Class Activity 243, Explain 244-45, Explain: Hybrid Orbitals

HS.PS-SPM.e. Structure and Properties of Matter		
Students who demonstrate understanding can: **e. Analyze and interpret data obtained from measuring the bulk properties of various substances to explain the relative strength of the interactions among particles in the substance. [Clarification Statement: Bulk properties of substances can include melting point and boiling point.] [*Assessment Boundary: Comparisons between ionic and molecular species or network and molecular species are included, but those that require understanding of different intermolecular forces are not included. Only the following types of particles are included in data and explanations: atoms, ions, and molecules.*]** **PEARSON CHEMISTRY:** The effects of the strength of interactions among particles in ionic compounds is covered in Chapter 7, Lesson 3 on SE/TE pages 201-212. Students **learn** the effects of the strength of interactions among particles in molecular compounds in Chapter 8 on SE/TE pages 250-252. In Attractions Between Molecules on SE/TE pages 250-251, the attractive forces between molecules that accounts for what state of matter a molecular compound takes is discussed. On SE/TE page 252, Intermolecular Attractions and Molecular Properties, the effects of molecular structure on melting and boiling points, are described. In the same section, network solids and the effect of the strength of bonds on the melting point in network solids is explored. Students **compare** the electrical conductivity of different ionic compounds in solution and **relate** it to molecular structure in Quick Lab, Solutions Containing Ions, on SE/TE page 207. Students **compare** the malleability of copper metal and a copper compound in the Teacher Demo on TE page 210. In the Teacher Demo on TE page 252, students **observe** differences in surface tension and viscosity of four liquids and **analyze** and **interpret** the data in terms of molecular structure.		
The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:		
Analyzing and Interpreting Data Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. • Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution. **SE / TE:** 207, Quick Lab 427, Interpret Data –Table 13.1 **TE Only:** 210, Teacher Demo 252, Teacher Demo 765, Teacher Demo	**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. **SE / TE:** 204-206, Properties of Ionic Compounds 207, Quick Lab 250-251, Attractions Between Molecules 252, Intermolecular Attractions and Molecular Properties 252, Figure 8.28: Diamond 253, Table 8.5: Characteristics of Ionic and Molecular Compounds **TE Only:** 210, Teacher Demo 250, Teacher Demo 251, Explain – Draw a Diagram 252, Teacher Demo	**Structure and Function** Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. • [Clarification Statement for e: The relative strength of interactions among particles causes different bulk properties.] **SE / TE:** 204-206, Properties of Ionic Compounds 207, Quick Lab 250-251, Attractions Between Molecules 252, Intermolecular Attractions and Molecular Properties 252, Figure 8.28: Diamond 253, Table 8.5: Characteristics of Ionic and Molecular Compounds **TE Only:** 210, Teacher Demo 250, Teacher Demo

	PS2.B: Types of Interactions • Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. **SE / TE:** 195-197, Formation of Cations 198-199, Formation of Anions 201-203, Formation of Ionic Compounds 202, Figure 7.7: Formation of Sodium Chloride 209, Metallic Bonds and Metallic Properties 240-241, Molecular Orbitals 242-243, VSEPR Theory 244-246, Hybrid Orbitals 247-250, Bond Polarity 250-251, Attractions Between Molecules 252, Intermolecular Attractions 252, Figure 8.28: Diamond **TE Only:** 202, Explain - Critical Thinking 205, Check for Understanding 210, Check for Understanding 224, Teacher Demo 224-225, Explain - Critical Thinking 242, Class Activity 243, Explain – VSEPR Theory 248, Explain – Bond Polarity 250, Explain – Describing Polar Covalent Bonds 250, Teacher Demo 251, Explain – Attractions Between Molecules 252, Teacher Demo	252, Teacher Demo

HS.PS-CR.a. Chemical Reactions		
Students who demonstrate understanding can: **a. Analyze and interpret data to support claims that energy of molecular collisions and the concentration of the reacting particles affect the rate at which a reaction occurs.** [***Assessment Boundary: Limited to simple (zero or first order in each reactant) reactions. The exact relationship between rate and temperature is not required.***] **PEARSON CHEMISTRY:** The citations below indicate areas in ***Pearson Chemistry*** where this idea is introduced. Reaction rates are described in terms of collision theory on SE/TE pages 596-598. Students **obtain information** about the effect of concentration on a reaction rate on SE/TE page 599. Students **interpret** graphs illustrating reaction energy on SE/TE page 597. They **perform** a laboratory demonstration in which reaction rates are increased by adding energy and a catalyst on SE/TE page 600.		
The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:		
Analyzing and Interpreting Data Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. • Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution. • Consider limitations (e.g., measurement error, sample selection) when analyzing and interpreting data.	**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 total binding energy (i.e., the sum of all bond energies in the set of molecules) that are matched by changes in kinetic energy. **SE/TE:** 596-598, Collision Theory 596, Figure 18.4: Collision Theory 597, Figure 18.5: Interpret Graphs 598, Factors Affecting Reaction Rates – Concentration 598, Figure 18.6: Effect of Concentration on Reaction Rate 600, Quick Lab: Does Steel Burn? **TE Only:** 596, Explain –Use Visuals 596, Explain –Misconception Alert 596, Explain –An Analogy 598, Explain –Critical Thinking 597, Check for Understanding 600, Quick Lab: Does Steel Burn	**Cause and Effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Systems can be designed to cause a desired effect. Changes in systems may have various causes that may not have equal effects. **SE/TE:** 596-598, Collision Theory 596, Figure 18.4: Collision Theory 597, Figure 18.5: Interpret Graphs 598, Factors Affecting Reaction Rates – Concentration 599, Figure 18.7: Effect of Particle Size on Reaction Rate 600, Quick Lab: Does Steel Burn? **TE Only:** 598, Explain –Critical Thinking

HS.PS-CR.b. Chemical Reactions
Students who demonstrate understanding can: **b. Develop and use models to explain that atoms (and therefore mass) are conserved during a chemical reaction.** **[Clarification Statement: Models can include computer models, ball and stick models, and drawings.] [*Assessment Boundary: Stoichiometric calculations are not required.*]** **PEARSON CHEMISTRY:** Conservation of mass is presented on SE/TE page 50. Students **learn** the concept of a skeleton reaction on SE/TE page 346 and with a sample problem having specific directions for the process on SE/TE page 349. Conservation of mass is modeled using the space-filling molecular model on SE/TE pages 350-351. A summary of the five types of chemical reactions with equations demonstrating conservation of atoms and mass is presented on SE/TE pages 366-367. Students **write** the steps to **write** and **balance** chemical equations in Lesson Check 11.1, #8-11 on SE/TE page 354. In Sample Problem 11.4, #12-14 on SE/TE page 359, Sample Problem 11.5, #15 on ST/TE 361, Sample Problem 11.6, #16-17 on SE/TE page 363, and Sample Problem 11.7 on SE/TE page 365, students **balance** more equations. Students **write** the steps to **write** and **balance** chemical equations in Lesson Check 11.2-#21, and 23 on SE/TE page 367. In Chapter Assessment #52-58 on SE/TE page 377, students **balance** more equations.

The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:		
Developing and Using Models Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world. • Use multiple types of models to represent and explain phenomena and move flexibly between model types based on merits and limitations. **SE / TE:** 349-351, Balancing Chemical Equations • Construct, revise, and use models to predict and explain relationships between systems and their components. **SE / TE:** 349-351, Balancing Chemical Equations	**PS1.B: Chemical Reactions** • 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. **SE / TE:** 50, Conservation of Mass 349-351, Balancing Chemical Equations 352, Sample Problem 11.2 353, Sample Problem 11.3 356-358, Classifying Reactions 359, Sample Problem 11.4 361, Sample Problem 11.5 365, Sample Problem 11.6 **TE Only:** 349, Explain: Sample Practice Problem 349, Explain: Balancing Chemical Equations 351, Misconception Alert 351, Check for Understanding 352, Explain: Balancing Chemical Equations 352, Explore –Teacher Demo 359, Misconception Alert 361, Explain: Sample Practice Problem 365, Explore: Sample Practice Problem	**Cause and Effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Systems can be designed to cause a desired effect. Changes in systems may have various causes that may not have equal effects.

HS.PS-CR.c. Chemical Reactions

Students who demonstrate understanding can:

c. Analyze and interpret data to make claims that reaction conditions can be used to optimize the output of a chemical process. [*Assessment Boundary: Limited to simple reactions. Reaction conditions are limited to temperature, pressure, and concentrations of all substances in the system.*]

PEARSON CHEMISTRY: The citations below indicate areas in ***Pearson Chemistry*** where this idea is introduced.

The concepts of reversible reactions and equilibrium are presented in Chapter 18, Lesson 3 on SE/TE page 609-611. Students **learn** about factors affecting equilibrium on SE/TE pages 614-619. In the Chemistry & You feature on SE/TE page 614, the Make a Connection feature on TE page 614, and Ammonia on SE/TE page R22, the optimization of ammonia production by manipulating pressure and temperature is discussed. Students **learn** about equilibrium between acids and bases in a solution and buffers on SE/TE pages 676-680. An example of altering conditions to maintain an optimum output is given in Swimming Pool Chemistry on SE/TE page R30

Students **interpret** graphs depicting the concentrations of reactants and products as a reaction reaches equilibrium on SE/TE page 610. Students **interpret** a model of the effect of changing pressure on a reaction in Figure 18.16: Effect of Pressure on Equilibrium on SE/TE page 614. Students **predict** the changes in chemical processes after conditions are changed in Sample Problem 18.2 #17 and 18 on SE/TE page 615. Students **interpret** a graph depicting acid-base titrations on SE/TE page 677. Students **write** equations describing how buffers work in acid and base solutions in Sample Problem 19.9 on SE/TE page 680.

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

Analyzing and Interpreting Data	PS1.B: Chemical Reactions	Cause and Effect
Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. • Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution. **SE/TE:** 610, Interpret Graphs –Figure 18.13 614, Figure 18.16: Effect of Pressure on Equilibrium **TE Only:** 610, Explain –Reversible Reactions 616, Explain –Interpret a Diagram • Consider limitations (e.g., measurement error, sample selection) when analyzing and interpreting data.	• 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. **SE/TE:** 609-611, Reversible Reactions 609, Figure 18.12: Opposite Reactions 610, Figure 18.13: Interpret Graphs 611, Figure 18.14: Equilibrium Positions 612-615, Factors Affecting Equilibrium: Le Châteli's Principle 613, Figure 18.15: Effect of Concentration on Equilibrium 614, Figure 18.16: Effect of Pressure on Equilibrium 614, Chemistry & You 616, Figure 18.17: Favoring Reactants or Products 617-619, Sample Problems 660, Measuring pH 676-678, Salt Hydrolysis 678-680, Buffers R22, Ammonia	Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Systems can be designed to cause a desired effect. Changes in systems may have various causes that may not have equal effects. **SE/TE:** 613, Figure 18.15: Effect of Concentration on Equilibrium 614, Figure 18.16: Effect of Pressure on Equilibrium **TE Only:** 614, Explain –Use Visuals & Make a Connection

	R30, Swimming Pool Chemistry **TE Only:** 610, Explain –Reversible Reactions 616, Explain –Interpret a Diagram	

HS.PS-CR.d. Chemical Reactions

Students who demonstrate understanding can:

d. Construct mathematical models to explain how energy changes in chemical reactions are caused by changes in binding energy as the reactants form products and in which changes in the kinetic energy of the system can be detected as change in temperature. [*Assessment Boundary: Limited to calculating the change in binding energy and resulting change in thermal energy for simple chemical reactions, i.e. reactions of simple hydrocarbons with oxygen.*]

PEARSON CHEMISTRY: The citations below indicate areas in ***Pearson Chemistry*** where this idea is introduced.

The forms of energy and the flow of energy during physical and chemical processes are covered in Lesson 17.1, SE/TE page 556-561, where exothermic and endothermic reactions are explained. The changes of enthalpy in a chemical reaction and their detection as temperature changes are explored in Lesson 17.2, SE/TE page 562-568.

Students **manipulate** units of energy and **calculate** enthalpy changes in calorimetric experiments (SE/TE page 564). Then, students **answer** questions about determining and expressing enthalpy changes for a reaction and **calculate** enthalpy changes using the heat of reaction.

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

Developing and Using Models	PS1.B: Chemical Reactions	Cause and Effect
Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world. • Use models (including mathematical and computational) to generate data to explain and predict phenomena, analyze systems, and solve problems. **SE/TE:** 596, Figure 18.4: Collision Theory 597, Figure 18.5: Interpret Graphs	• 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 total binding energy (i.e., the sum of all bond energies in the set of molecules) that are matched by changes in kinetic energy. **SE/TE:** 596-598, Collision Theory 596, Figure 18.4: Collision Theory 597, Figure 18.5: Interpret Graphs 598, Factors Affecting Reaction Rates – Concentration 598, Figure 18.6: Effect of Concentration on Reaction Rate 600, Quick Lab: Does Steel Burn? **TE Only:** 596, Explain –Use Visuals 596, Explain –Misconception Alert 596, Explain –An Analogy 598, Explain –Critical Thinking 597, Check for Understanding 600, Quick Lab: Does Steel Burn 567, Explain –Sample Practice Problem	Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Systems can be designed to cause a desired effect. Changes in systems may have various causes that may not have equal effects. **SE/TE:** 556, Energy Transformations **TE Only:** 560, Explain –Critical Thinking

	PS3.A: Definitions of Energy • "Chemical energy" generally is used to mean the energy that can be released or stored in chemical processes, and "electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. Historically, different units and names were used for the energy present in these different phenomena, and it took some time before the relationships between them were recognized. **SE / TE:** 556, Energy Transformations 556, Figure 17.1: Chemical Potential Energy **TE Only:** 557, Explain –Use Visuals	

HS.PS-CR.e. Chemical Reactions

Students who demonstrate understanding can:

e. Construct and communicate explanations using the structure of atoms, trends in the periodic table and knowledge of the patterns of chemical properties to predict the outcome of simple chemical reactions. [***Assessment Boundary: Only those chemical reactions readily predictable from the element's position on the periodic table and combustion reactions are intended.***]

PEARSON CHEMISTRY: A summary of the five types of chemical reactions is presented on SE/TE pages 366-367. Students **obtain information** about reactions in aqueous solutions and the prediction of the formation of a precipitate in Chapter 11, Lesson 3, SE/TE pages 369-374.

Students **answer** questions about types of chemical reactions in Lesson Check 11.2 on SE/TE page 367 and Lesson Check 11.3 on SE/TE page 373. Students **predict** and **balance** chemical equations in Sample Problems 11.2-11.9 on SE/TE pages 352, 353, 359, 361, 363, 365, 371, and 373. Students **conduct** a lab related to precipitation reactions in the Small Scale Lab: Precipitation Reactions: Formation of Solids on SE/TE page 374.

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

Constructing Explanations and Designing Solutions	PS1.B: Chemical Reactions	Patterns
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 knowledge, principles, and theories. • Construct and revise explanations and arguments based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories) and peer review. **SE / TE:** 374, Small Scale Lab: Precipitation Reactions: Formation of Solids • Construct, revise, and use models to predict and explain relationships between systems and their components. **SE / TE:** 349-351, Balancing Chemical Equations 357, Figure 11.4: Magnesium Ribbon 358, Figure 11.5: Decomposition Reaction 360, Figure 11.6: Alkali Metals 362, Figure 11.7: Double-Replacement Reactions 364, Figure 11.8: Methane Gas	• 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. **SE / TE:** 50, Conservation of Mass 349-351, Balancing Chemical Equations 352, Sample Problem 11.2 353, Sample Problem 11.3 356-367, Classifying Reactions 359, Sample Problem 11.4 361, Sample Problem 11.5 363, Sample Problem 11.6 365, Sample Problem 11.7 371, Sample Problem 11.8 373, Sample Problem 11.9 **TE Only:** 349, Explain: Sample Practice Problem 349, Explain: Balancing Chemical Equations 351, Misconception Alert 351, Check for Understanding 352, Explain: Balancing Chemical Equations 352, Explore –Teacher Demo 359, Misconception Alert 361, Explain: Sample Practice Problem 365, Explore: Sample Practice Problem	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. Classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced; thus requiring improved investigations and experiments. Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system. Mathematical representations are needed to identity some patterns. **SE / TE:** 356-367, Classifying Reactions

HS.PS-CR.f. Chemical Reactions

Students who demonstrate understanding can:

f. Construct and communicate explanations that show how chemical processes and/or properties of materials are central to biological and geophysical systems. **[Clarification Statement: Chemical processes can include oxidation of hydrocarbons, and the reaction of CO_2 and H_2O to give hydrocarbons. Properties of materials can include water expanding when freezing.]** **[*Assessment Boundary: Restricted to overall chemical processes (for example, oxidation of carbon compounds), or construction of carbon compounds (photosynthesis); details of biochemical pathways are not required (for example, Krebs Cycle).*]**

PEARSON CHEMISTRY: Students **learn** that the properties of water are determined by its structure in Chapter 15, Lesson 1 on SE/TE pages 488-493. The significance of the properties of water to the Earth's system is also described in this section. Chemical processes related to metabolism and the roles that the chemical processes play in it are introduced in Chapter 24 on SE/TE pages 836-873, with topics ranging from photosynthesis, on SE/TE pages 839-840, to the role of ATP in cellular energetics, on SE/TE pages 862-864.

Students **review** the concepts of hydrogen bonding and polarity in the Activate Prior Knowledge feature on TE only page 488. Students **communicate** an explanation of the nature of physical properties of water in Lesson Check 15.1 #1, 3, 5 on SE/TE page 493. Students **relate** the concept of endothermic reaction to photosynthesis in the Informal Assessment feature on TE page 840. Students **answer questions** related to the role of chemical processes in biological systems in Lesson Check 24.1 #2, 6 on SE/TE page 840 and Lesson Check 24.6 #36-40 on SE/TE page 866.

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

Constructing Explanations and Designing Solutions	PS1.B: Chemical Reactions	Patterns
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 knowledge, principles, and theories. • Construct and revise explanations and arguments based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories) and peer review. **SE / TE:** 489, Figure 15.2: Polarity of H_2O 489, Figure 15.3: Hydrogen Bonding in Water 490, Figure 15.5: Effect of a Surfactant 491, Quick Lab: Surface Tension #4 493, Lesson Check 15.1 #1 3, 5 840, Lesson Check 24.1 #2, 6 862, Figure 24.24: ATP 863, Figure 24.25: Glucose Catabolism 866, Lesson Check 24.6 #36-40	• Chemical processes and properties of materials underlie many important biological and geophysical phenomena. **SE / TE:** 488-493, Water and Its Properties 489, Figure 15.2: Polarity of H_2O 489, Figure 15.3: Hydrogen Bonding in Water 490, Figure 15.4: Surface Tension of Water 491, Quick Lab: Surface Tension 492, Figure 15.6: Structure of Ice 493, Figure 15.7 Ice Floats in Liquid Water 839-840, Energy and Carbon Cycle 840, Figure 24.3: Energy and Carbon Cycles 862-863, ATP 862, Figure 24.24: ATP 863-864, Metabolism Reactions 863, Figure 24.25: Glucose Catabolism 865-866, The Nitrogen Cycle **TE Only:** 489, Explain –Use Visuals 489, Explain –Apply Concepts	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. Classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced; thus requiring improved investigations and experiments. Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system. Mathematical representations are needed to identity some patterns. **SE / TE:** 489, Figure 15.2: Polarity of H_2O 489, Figure 15.3: Hydrogen Bonding in Water 492, Figure 15.6: Structure of Ice **TE Only:** 493, Extend, Connect to Social Studies 840, Evaluate -Reteach

TE Only: 492, Explain –Water in the Solid State 840, Evaluate –Informal Assessment 863, Explain –ATP	492, Explain –Water in the Solid State 863, Explain-ATP	

HS.PS-CR.g. Chemical Reactions		
Students who demonstrate understanding can: **g. Use system models (computers or drawings) to construct molecular-level explanations to predict the behavior of systems where a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present.** [*Assessment Boundary: Limited to simple reactions, adding or removing one reactant or product at a time.*] **PEARSON CHEMISTRY:** Drawings depicting the number of molecules of reactants and products in forward and reverse reactions of systems at equilibrium are presented in Chapter 18, Lesson 3, on SE/TE pages 609-616. Students **analyze** a model of a reversible reaction in Figure 18.12, Opposite Reactions on SE/TE page 609. Students **explain** the effects of adding or removing CO_2 to the blood on SE/TE page 613. They **explain** the shift in the equilibrium position when the pressure is increased over a mixture of nitrogen, hydrogen, and ammonia in Figure 18.16 Effect of Pressure on Equilibrium on SE/TE page 614.		
The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:		
Developing and Using Models Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world. • Construct, revise, and use models to predict and explain relationships between systems and their components. **SE/TE:** 609, Figure 18.12: Opposite Reactions 611, Figure 18.14: Equilibrium Positions 613, Figure 18.15: Effect of Concentration on Equilibrium 614, Figure 18.16: Effect of Pressure on Equilibrium 616, Figure 18.17: Favoring Reactants or Products **TE Only:** 613, Explain –Use Visuals 616, Explain –Interpret a Diagram	**PS1.B: Chemical Reactions** • 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. **SE/TE:** 609-611, Reversible Reactions 609, Figure 18.12: Opposite Reactions 611, Figure 18.14: Equilibrium Positions 612-615, Factors Affecting Equilibrium: Le Châtelier's Principle 613, Figure 18.15: Effect of Concentration on Equilibrium 614, Figure 18.16: Effect of Pressure on Equilibrium 616, Figure 18.17: Favoring Reactants or Products **TE Only:** 610, Explain –Reversible Reactions 613, Explain –Use Visuals 616, Explain –Interpret a Diagram	**Energy and Matter** The total amount of energy and matter in closed systems is conserved. 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. Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. Energy drives the cycling of matter within and between systems. In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. • [Clarification Statement for g: Dynamic and condition-dependent balances are dependent on matter and energy flows.]

HS.PS-CR.h. Chemical Reactions

Students who demonstrate understanding can:

h. Construct explanations using data from system models or simulations to support the claim that systems with many molecules have predictable behavior, but that the behavior of individual molecules is unpredictable.

PEARSON CHEMISTRY: The citations below indicate areas in ***Pearson Chemistry*** where this idea is introduced.

Students **discuss** stability and varying strengths between elements in Explain, Molecules and Molecular Compounds, TE: 223. In Using Visuals, students **construct explanations** for stability of atoms.

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

Constructing Explanations and Designing Solutions	PS2.C: Stability and Instability in Physical Systems	Cause and Effect
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 knowledge, principles, and theories. • Make quantitative claims regarding the relationship between dependent and independent variables.	• When a system has a great number of component pieces, one may not be able to predict much about its precise future. For such systems (e.g., with very many colliding molecules), one can often predict average but not detailed properties and behaviors (e.g., average temperature, motion, and rates of chemical change but not the trajectories or other changes of particular molecules). **SE / TE:** 420, Kinetic Theory and a Model for Gases 423, Kinetic Energy and Temperature	Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Systems can be designed to cause a desired effect. Changes in systems may have various causes that may not have equal effects.

HS.PS-NP.a. Nuclear Processes		
Students who demonstrate understanding can: **a. Construct models to explain changes in nuclear energies during the processes of fission, fusion, and radioactive decay and the nuclear interactions that determine nuclear stability.** [***Assessment Boundary: Models to exclude mathematical representations. Radioactive decays limited to alpha, beta, and gamma.***] **PEARSON CHEMISTRY:** Nuclear reactions are described and compared to chemical reactions in Chapter 25, Lesson 1 on SE/TE page 876-879, along with alpha, beta, and gamma radiation. Students **learn** about the process of nuclear decay in Chapter 25, Lesson 2 on SE/TE on pages 880-887. Fission and fusion are explored in Chapter 25, Lesson 3 on SE/TE pages 888–893. Students **apply** concepts as they **complete** nuclear equations in Lesson Check 25.2, #14, on SE/TE page 886.		
The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:		
Developing and Using Models Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world. • Construct, revise, and use models to predict and explain relationships between systems and their components. **SE/TE:** 886, Lesson Check 25.2, #14	**PS1.C: Nuclear Processes** • Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve changes in nuclear binding energies. **SE/TE:** 876, Radioactivity 877-879, Types of Radiation 877, Figure 25.2: Alpha Decay 878, Figure 25.3: Beta Decay 880-881, Nuclear Stability and Decay 885-886, Transmutation Reactions 888, Nuclear Fission 888, Figure 25.11: Fission of Uranium 891, Nuclear Fusion 891, Figure 25.14: Fusion in the Sun **TE Only:** 877, Explain –Radioactivity 877, Misconception Alert 877, Explain –Types of Radiation 878, Explore –Teacher Demo 878, Check for Understanding 889, Explain –Nuclear Fission 889, Explore –Teacher Demo • The total number of neutrons plus protons does not change in any nuclear process. **SE/TE:** 876, Radioactivity 877-879, Types of Radiation 899, Math Tutor **TE Only:** 879, Evaluate –Reteach	**Energy and Matter** The total amount of energy and matter in closed systems is conserved. 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. Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems. Energy drives the cycling of matter within and between systems. In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. **SE/TE:** 876-879, Types of radiation 899, Math Tutor **TE Only:** 876, Focus on ELL 879, Evaluate

	• Strong and weak nuclear interactions determine nuclear stability and processes. **TE Only:** 883, Extend	

HS.PS-NP.b. Nuclear Processes

Students who demonstrate understanding can:

b. Analyze and interpret data sets to determine the age of samples (rocks, organic material) using the mathematical model of radioactive decay. [*Assessment Boundary: Mathematical model limited to graphical representations.*]

PEARSON CHEMISTRY: The mathematical model of radioactive decay is presented in Chapter 25, Lesson 2, on SE/TE page 883. Students **determine** the age of fossils in the Connect to Mathematics feature in the Extend section, on TE page 884. Students **answer** questions about radioactive decay and dating in the Chapter 25 Assessment, #47 on SE/TE page 900, #61 and 65 on SE/TE page 901, and #98-100 on SE/TE page 903.

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. • Use tools, technologies, and models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution. **SE / TE:** 903, Chapter 25 Assessment #98-100 **TE Only:** 884, Extend, Connect to Mathematics **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. Students also use and create simple computational simulations based on mathematical models of basic assumptions. • Use statistical and mathematical techniques and structure data (e.g., displays, tables, and graphs) to find regularities, patterns (e.g., fitting mathematical curves to data), and relationships in data. **SE / TE:** 903, Chapter 25 Assessment #98-100 **TE Only:** 884, Extend, Connect to Mathematics	**PS1.C: Nuclear Processes** • Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials from the isotope ratios present. **SE / TE:** 880-881, Nuclear Stability and Decay 881, Figure 25.6: Interpret Graphs 882, Figure 25.7: Interpret Graphs 883, Figure 25.8: Decay Series of U-238 887, Small Scale Lab: Radioactivity and Half-Lives **TE Only:** 882-883, Explain –Half-Life 882, Differentiated Instruction 884, Explain –Sample Practice Problem 25.1 884, Extend, Connect to Mathematics 884, Foundations for Math	**Stability and Change** Much of science deals with constructing explanations of how things change and how they remain stable. Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. Feedback (negative or positive) can stabilize or destabilize a system. Systems can be designed for greater or lesser stability. **SE / TE:** 880-881, Nuclear Stability and Decay 881, Figure 25.6: Interpret Graphs 882, Figure 25.7: Interpret Graphs 883, Figure 25.8: Decay Series of U-238 **TE Only:** 882-883, Explain –Half-Life 882, Differentiated Instruction

HS.PS-NP.c. Nuclear Processes

Students who demonstrate understanding can:

c. Ask questions and make claims about the relative merits of nuclear processes compared to other types of energy production. **[Clarification Statement: Students are given data about energy production methods, such as burning coal versus using nuclear reactors.] [*Assessment Boundary: Students only analyze data provided. Merits only include economic, safety, and environmental.*]**

PEARSON CHEMISTRY: The citations below indicate areas in ***Pearson Chemistry*** where this idea is introduced.

The use of nuclear fission to generate electricity is presented in Chapter 25, Lesson 3, on SE/TE pages 888-890. In Chemistry & You on SE/TE page 892, students **learn** about small-scale nuclear power plants in a comparison to traditional nuclear power plants. The TE features Use Visuals and Start a Conversation prompt students to **differentiate** and **discuss.**

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

Asking Questions and Defining Problems	PS3.D: Energy in Chemical Processes and Everyday Life	*Connections to Engineering, Technology, and Applications of Science*
Asking questions and defining problems in grades 9–12 builds from grades K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and explanatory models and simulations. • Ask questions that challenge the premise of an argument, the interpretation of a data set, or the suitability of a design. **Analyzing and Interpreting Data** Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. • Use tools, technologies, and models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution.	• All forms of electricity generation and transportation fuels have associated economic, social, and environmental costs and benefits, both short and long term. **SE / TE:** 888-890, Nuclear Fission 889, Figure 25.12: Nuclear Reactor 890, Figure 25.13: Disposal of Fuel Rods 892, Chemistry & You: Technology -Small-Scale Nuclear Power **TE Only:** 890, Explain –Nuclear Fission 892, Explain –Use Visuals, Start a Conversation 893, Extend, Connect to History, Analyze Data	**Influence of Engineering, Technology, and Science on Society and the Natural World** Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. Engineers continuously modify these systems to increase benefits while decreasing costs and risks. New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. **SE / TE:** 890, Nuclear Waste 892, Chemistry & You: Technology -Small-Scale Nuclear Power **TE Only:** 892, Explain –Use Visuals, Start a Conversation 893, Extend -Connect to History, Analyze Data

HS.PS-IF.a. Interactions of Forces		
Students who demonstrate understanding can: **a. Use mathematical expressions to determine the relationship between the variables in Newton's Law of Gravitation and Coulomb's Law and use these to predict the electrostatic and gravitational forces between objects.** ***[Assessment Boundary: Only situations with two objects are predicted.]*** **PEARSON CHEMISTRY:** The focus of this program is to enable all learners to comprehend and connect chemistry topics and concepts to their daily lives. This expectation falls outside of the program scope and sequence. See ***Pearson Physical Science, Concepts in Action,*** isbn: 9780133163971, Chapter 12, Section 4 and Chapter, 20 Section 1.		
The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:		
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. • Use mathematical expressions to represent phenomena or design solutions in order to solve algebraically for desired quantities.	**PS2.B: Types of Interactions** • Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects.	**Cause and Effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Systems can be designed to cause a desired effect. Changes in systems may have various causes that may not have equal effects.

HS.PS-IF.b. Interactions of Forces

Students who demonstrate understanding can:

b. Use models to demonstrate that electric forces at the atomic scale affect and determine the structure, properties (including contact forces), and transformations of matter. **[Clarification Statement: Models can include graphical and computer models. Examples of properties and transformations of matter can include intermolecular forces, chemical bonding, and enzyme-substrate interaction.] [*Assessment Boundary: Only a qualitative understanding is expected.*]**

PEARSON CHEMISTRY: Models of ionic compounds that explain their properties abound throughout Chapter 7, SE/TE pages 192-219. Figures depicting the correlation between intermolecular attractions and molecular properties are shown in Chapter 8, Lesson 4 on SE/TE pages 247-253. The correlation between the structure and the properties of water is explained in terms of electrical forces in Chapter 15, Lesson 1 on SE/TE pages 488-492.

Students **explain** the stability of ionic compounds from their structure in Figure 7.7: Formation of Sodium Chloride on SE/TE page 202. They **use** electron dot structures to **predict** the formulas of ionic compounds in the Chem Tutor feature on SE/TE page 203. Students **draw** electron dot formulas of molecular compounds in the Chem Tutor feature on SE/TE page 229 and **predict** bond angles and geometric shapes using VSEPR theory in Lesson Check 8.3 #26 on SE/TE page 246. Students **correlate** intermolecular attraction with specific molecules in the Draw a Diagram section of the Chemistry & You feature on TE page 251.

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

Developing and Using Models	**PS2.B: Types of Interactions**	**Cause and Effect**
Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world. • Construct, revise, and use models to predict and explain relationships between systems and their components. **SE / TE:** 248, Figure 8.23: Electron Cloud Model of a Polar Bond 250, Figure 8.24: Polar Molecules in an Electric Field 250, Figure 8.25: Dipole Interactions 251, Figure 8.26: Hydrogen Bonds in Water 252, Figure 8.28: Diamond 488, How can you describe the structure of ice? 489, Figure 15.2: Polarity of H_2O 489, Figure 15.3: Hydrogen Bonding in Water 490, Figure 15.4: Surface Tension of Water 492, Figure 15.6: Structure of ice 495, Solvation of an Ionic Solid 496, Figure 15.10: Conductivity of Solutions	• Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. **SE / TE:** 201-203, Formation of Ionic Compounds 202, Figure 7.7: Formation of Sodium Chloride 203, Chem Tutor: Sample Problem 7.1 204-206, Properties of Ionic Compounds 205, Figure 739: Coordination Numbers 209-210, Metallic Bonds and Metallic Properties 209, Figure 7.12: Comparing Metals and Ionic Compounds 226-231, The Octet Rule in Covalent Bonding 229, Chem Tutor: Sample Problem 8.1 232-233, Coordinate Covalent Bonds 240-241, Molecular Orbitals 242-243, VSEPR Theory 244-246, Hybrid Orbitals 247-250, Bond Polarity 250, Figure 8.24: Polar Molecules	Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Systems can be designed to cause a desired effect. Changes in systems may have various causes that may not have equal effects. **SE / TE:** 247-250, Bond Polarity 250, Figure 8.24: Polar Molecules in an Electric Field 251, Figure 8.26: Hydrogen Bonds in Water 488-491, Water in the Liquid State 489, Figure 15.2: Polarity of H_2O 489, Figure 15.3: Hydrogen Bonding in Water 490, Figure 15.4: Surface Tension of Water 491, Quick Lab: Surface Tension 494-495, Solutions 495, Figure 15.8: Solvation on an Ionic Solid **TE Only:** 251, Explain –Draw a Diagram 489, Explain –Apply Concepts

TE Only: 489, Explain –Apply Concepts 495, Explain –Use Visuals	in an Electric Field 250-251, Attractions Between Molecules 250, Figure 8.25: Dipole Interactions 251, Figure 8.26: Hydrogen Bonds in Water 252, Intermolecular Attractions and Molecular Properties 252, Figure 8.28: Diamond 488-491, Water in the Liquid State 489, Figure 15.2: Polarity of H_2O 489, Figure 15.3: Hydrogen Bonding in Water 490, Figure 15.4: Surface Tension of Water 491, Quick Lab: Surface Tension 492-493, Water in the Solid State 492, Figure 15.6: Structure of ice 494-495, Solutions 495, Figure 15.8: Solvation on an Ionic Solid **TE Only:** 248, Explain -Bond Polarity 251, Explain –Draw a Diagram 489, Explain –Use Visuals, Apply Concepts 490, Explain –Use Visuals 492, Check for Understanding 495, Explain –Use Visuals	490, Explain –Use Visuals

HS.PS-IF.c. Interactions of Forces		
Students who demonstrate understanding can: **c. Plan and carry out investigations to demonstrate the claim that magnets, electric currents, or changing electric fields cause magnetic fields and electric charges or changing magnetic fields cause electric fields. [*Assessment Boundary: Qualitative observations only.*]** **PEARSON CHEMISTRY:** The focus of this program is to enable all learners to comprehend and connect chemistry topics and concepts to their daily lives. This expectation falls outside of the program scope and sequence. See ***Pearson Physical Science, Concepts in Action,*** isbn: 9780133163971, Chapter 21, Section 2.		
The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:		
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 build, test, and revise conceptual, mathematical, physical and empirical models. • Plan and carry out investigations individually and collaboratively and test designs as part of building and revising models, explaining phenomena, or testing solutions to problems. Consider possible confounding variables or effects, and ensure that the investigation's design has controlled for them.	**PS2.B: Types of Interactions** • Forces at a distance are explained by fields permeating space that can transfer energy through space. Magnets or changing electric fields cause magnetic fields; electric charges or changing magnetic fields cause electric fields.	**Cause and Effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Systems can be designed to cause a desired effect. Changes in systems may have various causes that may not have equal effects.

HS.PS-IF.d. Interactions of Forces		
Students who demonstrate understanding can: **d. Obtain, evaluate, and communicate information to show that strong and weak nuclear interactions inside atomic nuclei determine which nuclear isotopes are stable, and that the pattern of decay of an unstable nucleus can often be predicted. [Clarification Statement: Types of decay in unstable nuclei can include alpha or beta radiation.] [*Assessment Boundary: Only a qualitative understanding of nuclear interactions is expected.*]** **PEARSON CHEMISTRY:** The citations below indicate areas in ***Pearson Chemistry*** where this idea is introduced. The relationship between the neutron to proton ratio and nuclear stability, as well as the type of decay determined by this ratio are discussed in Chapter 25, Lesson 2 on SE/TE pages 880-881. Students **research** the four types of forces and make a chart showing the distances over which each force operates in the Extend section on TE page 883.		
The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:		
Obtaining, Evaluating, and Communicating Information Obtaining, evaluating, and communicating information in 9–12 builds on 6–8 and progresses to evaluate the validity and reliability of the claims, methods, and designs. • Generate, synthesize, communicate, and critique claims, methods and designs that appear in scientific and technical texts or media reports.	**PS2.B: Types of Interactions** • The strong and weak nuclear interactions are important inside atomic nuclei—for example, they determine the patterns of which nuclear isotopes are stable and what kind of decays occur for unstable ones. **SE/TE:** 880-881, Nuclear Stability and Decay **TE Only:** 883, Extend	**Cause and Effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Systems can be designed to cause a desired effect. Changes in systems may have various causes that may not have equal effects.

<table>
<tr><th colspan="3">HS.PS-IF.e. Interactions of Forces</th></tr>
<tr><td colspan="3">Students who demonstrate understanding can:
e. Obtain, evaluate, and communicate information to show how scientists and engineers take advantage of the effects of electrical and magnetic forces in materials to design new devices and materials through a process of research and development. [Clarification Statement: Designed devices can include magnetic strips on credit cards, laser printers, and photo copiers.]

PEARSON CHEMISTRY: The citations below indicate areas in Pearson Chemistry where this idea is introduced.

An application of the principle of attraction between opposite charges is presented through the technology reading Chemistry & You: Powder Coating on SE/TE page 239.

Students analyze the benefits of powder coating and infer the role of the attraction between opposite charges in this type of painting technology in the Take It Further feature on SE/TE page 239. Students simulate creating a campaign designed to convince a major plastics manufacturer to switch to powder coating in the 21st Century Learning feature on TE only page 239. Students discuss the impact of consumer concerns on technological advances in the automotive industry in Chemistry & You on TE only page 239.</td></tr>
<tr><td colspan="3">The performance expectation above was developed using the following elements from the NRC document A Framework for K-12 Science Education:</td></tr>
<tr>
<td>Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 9–12 builds on 6–8 and progresses to evaluate the validity and reliability of the claims, methods, and designs.
• Generate, synthesize, communicate, and critique claims, methods and designs that appear in scientific and technical texts or media reports.

SE / TE:
239, Chemistry & You: Technology -Powder Coating: Take It Further

TE Only:
239, 21st Century Learning</td>
<td>PS2.B: Types of Interactions
• Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.

SE / TE:
239, Chemistry & You: Technology -Powder Coating

TE Only:
239, Explain –Start a Conversation</td>
<td>Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology
Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise.

SE / TE:
239, Chemistry & You: Technology -Powder Coating

TE Only:
239, Chemistry & You
239, 21st Century Learning</td>
</tr>
</table>

HS.PS-E.a. Energy

Students who demonstrate understanding can:

a. Construct and defend models and mathematical representations that show that over time the total energy within an isolated system is constant, including the motion and interactions of matter and radiation within the system. [*Assessment Boundary: Computational accounting for energy in a system limited to systems of two or three components.*]

PEARSON CHEMISTRY: The focus of this program is to enable all learners to comprehend and connect chemistry topics and concepts to their daily lives. This expectation falls outside of the program scope and sequence. See ***Pearson Physical Science, Concepts in Action,*** isbn: 9780133163971, Chapter 7, Section 3 and Chapter 15, Section 2.

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

Developing and Using Models	PS3.A: Definitions of Energy	Systems and System Models
Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world. • Use multiple types of models to represent and explain phenomena and move flexibly between model types based on merits and limitations. **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. • Use mathematical or algorithmic representations of phenomena or design solutions to create explanation, computational models, or simulations.	• 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** • 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. • 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.	Systems can be designed to do specific tasks. 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. Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. 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. • [Clarification Statement for all PEs: Energy transfer cannot be directly studied – a model must be used. In design for maximal or minimal energy transfer, the boundaries of systems must be defined.]

HS.PS-E.b. Energy

Students who demonstrate understanding can:

b. Identify problems and suggest design solutions to optimize the energy transfer into and out of a system. **[Clarification Statement: Design solution examples can include insulation, microchip temperature control, cooking electronics, and roller coaster design.] [*Assessment Boundary: Limited to mechanical and thermal systems.*]**

PEARSON CHEMISTRY: The citations below indicate areas in ***Pearson Chemistry*** where this idea is introduced.

The use of geothermal energy and various types of geothermal power plants are explored in Chemistry & You, SE/TE page 576-577.

Students **identify** the system and its surroundings and **classify** the process as exothermic or endothermic in the Take It Further section of Chemistry & You on SE/TE page 576-577. Students **research** the potential environmental effects of geothermal power plants versus comparable fossil fuel plants on TE page 577, Extend, Connect to Earth Science. Students **research** and **present** their findings on binary cycle geothermal power plants in Differentiated Instruction, Advanced Students, on TE page 577.

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Asking Questions and Defining Problems Asking questions and defining problems in grades 9–12 builds from grades K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and explanatory models and simulations. • Ask questions that challenge the premise of an argument, the interpretation of a data set, or the suitability of a design. **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 knowledge, principles, and theories. • Apply scientific knowledge to solve design problems by taking into account possible unanticipated effects.	**PS3.B: Conservation of Energy and Energy Transfer** • Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. **SE / TE:** 576, Chemistry & You –Green Chemistry: Geothermal Energy 577, Chemistry & You –Green Chemistry: Geothermal Energy: Take It Further **TE Only:** 577, Differentiated Instruction, Advanced **PS3.D: Energy in Chemical Processes** • Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. Machines are judged as efficient or inefficient based on the amount of energy input needed to perform a particular useful task. Inefficient machines are those that produce more waste heat while performing the task and thus require more energy input. It is therefore important to design for high efficiency so as to reduce costs, waste materials, and many environmental impacts.	**Connections to Engineering, Technology, and Applications of Science** **Influence of Engineering, Technology, and Science on Society and the Natural World** Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. Engineers continuously modify these systems to increase benefits while decreasing costs and risks. New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. **TE Only:** 577, Extend, Connect to Earth Science

	SE / TE: 576, Chemistry & You –Green Chemistry: Geothermal Energy 577, Chemistry & You –Green Chemistry: Geothermal Energy: Take It Further **TE Only:** 577, Differentiated Instruction, Advanced	

HS.PS-E.c. Energy		
Students who demonstrate understanding can: **c. Analyze data to support claims that closed systems move toward more uniform energy distribution.** **PEARSON CHEMISTRY:** The focus of this program is to enable all learners to comprehend and connect chemistry topics and concepts to their daily lives. This expectation falls outside of the program scope and sequence. See ***Pearson Physical Science, Concepts in Action,*** isbn: 9780133163971, Chapter 16, Section 2.		
The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:		
Analyzing and Interpreting Data Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. • Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims.	**PS3.B: Conservation of Energy and Energy Transfer** • Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. • 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. • 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).	**Systems and System Models** Systems can be designed to do specific tasks. 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. Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. 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. • [Clarification Statement for all PEs: Energy transfer cannot be directly studied – a model must be used. In design for maximal or minimal energy transfer, the boundaries of a system must be defined.]

HS.PS-E.d. Energy

Students who demonstrate understanding can:

d. Design a solution to minimize or slow a system's inclination to degrade to identify the effects on the flow of the energy in the system. [Clarification Statement: Examples of system degradation can include wearing down due to friction, increase in disorder, and radioactive decay.]

PEARSON CHEMISTRY: The citations below indicate areas in ***Pearson Chemistry*** where this idea is introduced.

The use of nuclear fission to generate electricity is presented in Chapter 25, Lesson 3 on SE/TE pages 888-890. Students **learn** the processes of neutron moderation and neutron absorption as a means of controlling the nuclear reaction on SE/TE page 889. The problem of storing nuclear waste from the spent fuel rods is explored on SE/TE page 890. The role of heavy water in some nuclear reactors is introduced on SE/TE page R35 -Appendix A Elements Handbook.

Students **observe** a modeled chain reaction in Explore –Teacher Demo on TE page 889. They **make a connection** between the half-lives of the isotopes produced as a waste in nuclear reactors and the difficulty of storing spent fuel rods in Explain: Nuclear Fission on TE page 890. Students **answer** questions relating radioactive decay to the difficulty of storage of spent fuel rods, and about using heavy water to optimize the control of the chain reaction in the nuclear reactor in Lesson Check 25.3, #20-21, on SE/TE page 891.

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

Constructing Explanations and Designing Solutions	PS3.B: Conservation of Energy and Energy Transfer	Systems and System Models
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 knowledge, principles, and theories. • Apply scientific knowledge to solve design problems by taking into account possible unanticipated effects.	• The availability of energy limits what can occur in any system. • 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). • Any object or system that can degrade with no added energy is unstable. Eventually it will do so, but if the energy releases throughout the transition are small, the process duration can be very long (e.g., long-lived radioactive isotopes). **SE / TE** 880-881, Nuclear Stability and Decay 882-883, Half-Life 883, Figure 25.8: Decay Series of U-238 **TE Only:** 882-883, Explain	Systems can be designed to do specific tasks. 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. Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. 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. • [Clarification Statement for all PEs: Energy transfer cannot be directly studied – a model must be used. In design for maximal or minimal energy transfer, the boundaries of a system must be defined.]

HS.PS-E.e. Energy
Students who demonstrate understanding can: **e. Construct models to show that energy is transformed and transferred within and between living organisms.** *[Assessment Boundary: Does not mean particular biological processes such as Krebs cycle.]* **PEARSON CHEMISTRY:** Photosynthesis as an example of an energy transformation within a living organism and the carbon cycle as an example of energy transferred between living organisms are explained in Chapter 24, Lesson 1 on SE/TE pages 839-840. The function of ATP in the cell and various metabolic reactions are discussed as examples of transformations of energy within living organisms in Chapter 24, Lesson 6 on SE/TE pages 862-867. Students **learn** about the nitrogen cycle as an example of the transfer of energy between living organisms on SE/TE page 865. Students **interpret** a model of the carbon cycle on SE/TE page 840. **Students** interpret models of transformation of energy within a cell in Figure 24.25: Glucose Catabolism on SE/TE page 863. They **compare** models of the carbon cycle and nitrogen cycle in Evaluate- Informal Assessment on TE only page 866.
The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Developing and Using Models	**PS3.A: Definitions of Energy**	**Systems and System Models**
Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world. • Construct, revise, and use models to predict and explain relationships between systems and their components. **SE / TE:** 840, Figure 24.3: Energy and Carbon Cycles 862, Figure 24.24: ATP 863, Figure 24.25: Glucose Catabolism 864, Figure 24.27: Catabolism and Anabolism 865, Figure 24.28: Nitrogen Cycle **TE Only:** 865, Explain –The Nitrogen Cycle	• 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. **SE / TE:** 862-863, ATP 864, Figure 24.27: Catabolism and Anabolism 865, Figure 24.28: Nitrogen Cycle **TE Only:** 863, Explain- ATP 865, Explain –The Nitrogen Cycle 866, Evaluate- Informal Assessment 866, Reteach **PS3.B: Conservation of Energy and Energy Transfer** • Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. **SE / TE:** 557, Endothermic and Exothermic Processes • 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).	Systems can be designed to do specific tasks. 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. Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. 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. • [Clarification Statement for all PEs: Energy transfer cannot be directly studied – a model must be used. In design for maximal or minimal energy transfer, the boundaries of a systems must be defined.] **SE / TE:** 839, Figure 24.2: Chloroplast 840, Figure 24.3: Energy and Carbon Cycles 865, Figure 24.28: Nitrogen Cycle **TE Only:** 839, Explain: Use Visuals 865, Explain –The Nitrogen Cycle

	PS3.D: Energy in Chemical Processes • The main way in which that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. **SE / TE:** 839-840, The Energy and Carbon Cycle • A variety of multistage physical and chemical processes in living organisms, particularly within their cells, account for the transport and transfer (release or uptake) of energy needed for life functions. **SE / TE:** 862, ATP 862, Figure 24.24: ATP 864, Figure 24.27: Catabolism and Anabolism 865, Figure 24.28: Nitrogen Cycle **TE Only:** 863, Explain- ATP 865, Explain –The Nitrogen Cycle 866, Evaluate- Informal Assessment, Reteach	

HS.PS-E.f. Energy

Students who demonstrate understanding can:

f. Construct models to represent and explain that all forms of energy can be viewed as either the movement of particles or energy stored in fields. [*Assessment Boundary: Models representing field energies need not be mathematical.*]

PEARSON CHEMISTRY: The citations below indicate areas in ***Pearson Chemistry*** where this idea is introduced.

Content on different forms of energy appear throughout the textbook. Electromagnetic radiation and Planck's quantization of energy is discussed in Chapter 5, Lesson 3 on SE/TE pages 138-149. Students **obtain information** about the kinetic energy of moving particles in matter in Chapter 13 on SE/TE pages 418-447 and 454 and in Chapter 14 on SE/TE pages 458-461. They learn about nuclear radiation in Chapter 25, Lesson 1 on SE/TE pages 876-879.

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

Developing and Using Models	PS3.A: Definitions of Energy	Systems and System Models
Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world. • Use multiple types of models to represent and explain phenomena and move flexibly between model types based on merits and limitations.	• These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as either motions of particles or energy stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. **SE/TE:** 138-149, Atomic Emission Spectra and the Quantum Mechanical Model 418–447, States of Matter 454, Temperature 458-459, Charles' Law 460-461, Gay-Lussac's Law 876-879, Nuclear Radiation **TE Only:** 454, Extend, Connect to Physics 459, Chemistry & You	Systems can be designed to do specific tasks. 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. Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. 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. • [Clarification Statement for all PEs: Energy transfer cannot be directly studied – a model must be used. In design for maximal or minimal energy transfer, the boundaries of a system must be defined.] **SE/TE:** 454, Figure 14.7: Temperature and Pressure

HS.PS-E.g. Energy		
Students who demonstrate understanding can: **g. Construct representations that show that some forms of energy may be best understood at the molecular or atomic scale.** **[Clarification Statement: Forms of energy represented can include thermal, electromagnetic, and sound.] [*Assessment Boundary: Limited to conceptual understanding; quantitative representations are not required.*]** **PEARSON CHEMISTRY:** The citations below indicate areas in ***Pearson Chemistry*** where this idea is introduced. Students **learn** about different forms of energy appear throughout the textbook. Electromagnetic radiation and Planck's quantization of energy is discussed in Chapter 5, Lesson 3 on SE/TE pages 138-149. Students **obtain information** about the kinetic energy of moving particles in matter in Chapter 13 on SE/TE pages 418–447. Nuclear radiation is discussed in Chapter 25, Lesson 1 on SE/TE pages 876-879.		
The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:		
Developing and Using Models Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world. Construct, revise, and use models to predict and explain relationships between systems and their components.	**PS3.A: Definitions of Energy** • These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as either motions of particles or energy stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. **SE/TE:** 138-149, Atomic Emission Spectra and the Quantum Mechanical Model 418 – 447, States of Matter 876-879, Nuclear Radiation	**Systems and System Models** Systems can be designed to do specific tasks. 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. Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. 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. • [Clarification Statement for all PEs: Energy transfer cannot be directly studied – a model must be used. In design for maximal or minimal energy transfer, the boundaries of a system must be defined.]

HS.PS-E.h. Energy

Students who demonstrate understanding can:

h. Design, build, and evaluate devices that convert one form of energy into another form of energy. [Clarification Statement: Examples of devices can include roller coasters, Rube Goldberg devices, wind turbines, and generators.]

PEARSON CHEMISTRY: The focus of this program is to enable all learners to comprehend and connect chemistry topics and concepts to their daily lives. This expectation falls outside of the program scope and sequence. See ***Pearson Physical Science, Concepts in Action,*** isbn: 9780133163971 in Chapter 21, Application Lab.

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

Constructing Explanations and Designing Solutions	PS3.A: Definitions of Energy	Systems and System Models
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 knowledge, principles, and theories. • Apply scientific knowledge to solve design problems by taking into account possible unanticipated effects.	• 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** • 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. • Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. **PS3.D: Energy in Chemical Processes** • Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy. • Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. Machines are judged as efficient or inefficient based on the amount of energy input needed to perform a particular useful task. Inefficient machines are those that produce more waste heat while performing the task and thus require more energy input. It is therefore important to design for high efficiency so as to reduce costs, waste materials, and many environmental impacts.	Systems can be designed to do specific tasks. 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. Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. 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. • [Clarification Statement for all PEs: Energy transfer cannot be directly studied – a model must be used. In design for maximal or minimal energy transfer, the boundaries of a system must be defined.]

HS.PS-ER.a. Electromagnetic Radiation		
Students who demonstrate understanding can: **a. Use arguments to support the claim that electromagnetic radiation can be described using both a wave model and a particle model, and determine which model provides a better explanation of phenomena.** [*Assessment Boundary: Limited to the understanding that the quantum theory relates the two models, but students do not need to know the specifics of the quantum theory.*] **PEARSON CHEMISTRY:** The citations below indicate areas in ***Pearson Chemistry*** where this idea is introduced. Wave properties and electromagnetic radiation are described on SE/TE page 138-139. Students **learn** how light acts as a particle and photons are on SE/TE pages 142-143. Students **explain** how light can behave like a particle in Lesson Check 5.3, #20-21, on SE/TE page 148.		
The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:		
Engaging in Argument from Evidence Engaging in argument from evidence in 9–12 builds from K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about natural and designed world. Arguments may also come from current scientific or historical episodes in science. • Construct a counter-argument that is based in data and evidence that challenges another proposed argument.	**PS4.B: Electromagnetic Radiation** • Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. Quantum theory relates the two models. (Boundary: Quantum theory is not explained further at this grade level.) **SE/TE:** 138-139, Light and Atomic Emission Spectra 142-143, The Quantum Concept and Photons	**Structure and Function** Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. • [Clarification Statement for a: The way something (e.g. visible light) functions can be best understood through a particular representation of its structure.] **SE/TE:** 138-139, Light and Atomic Emission Spectra 142-143, The Quantum Concept and Photons

HS.PS-ER.b. Electromagnetic Radiation

Students who demonstrate understanding can:

b. Obtain, evaluate, and communicate scientific literature to show that all electromagnetic radiation travels through a vacuum at the same speed, called the speed of light.

PEARSON CHEMISTRY: The citations below indicate areas in ***Pearson Chemistry*** where this idea is introduced.

The speed of light is a constant is simply stated on SE/TE page 139. The focus of this program is to enable all learners to comprehend and connect chemistry topics and concepts to their daily lives. This expectation falls outside of the program scope and sequence. See ***Pearson Physical Science, Concepts in Action,*** isbn: 9780133163971, Chapter 18, Section 1.

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

Obtaining, Evaluating, and Communicating Information	**PS4.B: Electromagnetic Radiation**	**Structure and Function**
Obtaining, evaluating, and communicating information in 9–12 builds on 6–8 and progresses to evaluate the validity and reliability of the claims, methods, and designs. • Critically read scientific literature adapted for classroom use to identify key ideas and major points and to evaluate the validity and reliability of the claims, methods, and designs.	• All electromagnetic radiation travels through a vacuum at the same speed, called the speed of light. Its speed in any other given medium depends on its wavelength and the properties of that medium. **SE / TE:** 138-139, Light and Atomic Emission Spectra	Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials.

HS.PS-ER.c. Electromagnetic Radiation		
Students who demonstrate understanding can: **c. Obtain, evaluate, and communicate scientific literature about the effects different wavelengths of electromagnetic radiation have on matter when the matter absorbs it.** [*Assessment Boundary: Only IR, UV, and gamma radiation are intended; qualitative descriptions only.*] **PEARSON CHEMISTRY:** The effect of UV radiation on matter is presented in the Explain section on TE page 139, and on SE/TE pages R27 and R41. Students **learn** gamma radiation's penetrating power on SE/TE page 877 and associated ionizing properties on SE/TE page 894. Gamma rays content is also located on TE page 139, Explain. The importance of the absorption of UV radiation by the ozone layer is discussed on SE/TE page R27. Students **obtain** recent articles in medical journals about the harmful consequences of radiation exposure in the Engage –Build Background section on TE page 894. **They** have the opportunity to **research** the consequences of over-exposure to alpha, beta, and gamma radiation and **present** their findings in a poster in the Extend, Connect to Medicine on TE page 897.		
The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:		
Obtaining, Evaluating, and Communicating Information Obtaining, evaluating, and communicating information in 9–12 builds on 6–8 and progresses to evaluate the validity and reliability of the claims, methods, and designs. • Critically read scientific literature adapted for classroom use to identify key ideas and major points and to evaluate the validity and reliability of the claims, methods, and designs. **TE Only:** 894, Engage –Build Background 897, Extend, Connect to Medicine	**PS4.B: Electromagnetic Radiation** • When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). • Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells. **SE / TE:** 877-879, Three types of radiation **TE Only:** 894, Engage –Build Background 897, Extend, Connect to Medicine	***Connections to Engineering, Technology, and Applications of Science*** **Influence of Engineering, Technology, and Science on Society and the Natural World** Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. Engineers continuously modify these systems to increase benefits while decreasing costs and risks. New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. **SE / TE:** R27, Appendix A, Elements Handbook: Ozone

HS.PS-ER.d. Electromagnetic Radiation		
Students who demonstrate understanding can: **d. Analyze and interpret data of both atomic emission and absorption spectra of different samples to make claims about the presence of certain elements in the sample.** [*Assessment Boundary: Identification of elements to be based on comparison of spectral lines.*] **PEARSON CHEMISTRY:** The concept of atomic emission spectrum is defined on SE/TE page 140. Two types of spectra are compared, white light and helium lamp in Comparing Spectra on SE/TE page 140. Students **identify** various substances in a solution using flame tests in Quick Lab: Flame Tests on SE/TE page 142.		
The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:		
Analyzing and Interpreting Data Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. • Use tools, technologies, and models (e.g. computational and mathematical) to plan, gather, and analyze data to make valid and reliable scientific claims or justify an optimal solution. **SE/TE** 142, Quick Lab: Flame Tests	**PS4.B: Electromagnetic Radiation** • Atoms of each element emit and absorb characteristic frequencies of light, and nuclear transitions have distinctive gamma ray wavelengths. These characteristics allow identification of the presence of an element, even in microscopic quantities. **SE/TE:** 140, Atomic Emission Spectra 140, Figure 5.9: Comparing Spectra 140, Figure 5.10: Atomic Emission Spectra **TE Only:** 140, Explain- Use Visuals	**Structure and Function** Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. • [Clarification Statement for d: From the spectra (the way they function) the structure can be inferred.] **SE/TE:** 140, Atomic Emission Spectra 140, Figure 5.9: Comparing Spectra **TE Only:** 140, Explain- Use Visuals

HS.PS-ER.e. Electromagnetic Radiation		
Students who demonstrate understanding can: **e. Construct an explanation of how photovoltaic materials work using the particle model of light, and describe their application in everyday devices.** **[Clarification Statement: Everyday devices can include solar cells and barcodes.] [*Assessment Boundary: Qualitative descriptors only.*]** **PEARSON CHEMISTRY:** The focus of this program is to enable all learners to comprehend and connect chemistry topics and concepts to their daily lives. This expectation falls outside of the program scope and sequence.		
The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:		
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 knowledge, principles, and theories. • Construct and revise explanations and arguments based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories) and peer review.	**PS4.B: Electromagnetic Radiation** • Photovoltaic materials emit electrons when they absorb light of a high-enough frequency. **PS4.C: Information Technologies and Instrumentation** • Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them.	**Structure and Function** Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials.

HS.PS-ER.f. Electromagnetic Radiation		
Students who demonstrate understanding can: **f. Obtain, evaluate, and communicate scientific literature about the differences and similarities between analog and digital representations of information to describe the relative advantages and disadvantages.** **[*Assessment Boundary: Qualitative explanations only.*]** **PEARSON CHEMISTRY:** The focus of this program is to enable all learners to comprehend and connect chemistry topics and concepts to their daily lives. This expectation falls outside of the program scope and sequence See ***Pearson Physical Science, Concepts in Action,*** isbn: 9780133163971, Chapter 20, Section 4.		
The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:		
Obtaining, Evaluating, and Communicating Information Obtaining, evaluating, and communicating information in 9–12 builds on 6–8 and progresses to evaluate the validity and reliability of the claims, methods, and designs. • Critically read scientific literature adapted for classroom use to identify key ideas and major points and to evaluate the validity and reliability of the claims, methods, and designs.	**PS4.A: Wave Properties** • Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. **PS4.C: Information Technologies and Instrumentation** • Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them.	**Connections to Engineering, Technology, and Applications of Science** **Influence of Engineering, Technology, and Science on Society and the Natural World** Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. Engineers continuously modify these systems to increase benefits while decreasing costs and risks. New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.

HS.PS-ER.g. Electromagnetic Radiation

Students who demonstrate understanding can:

g. Construct explanations for why the wavelength of an electromagnetic wave determines its use for certain applications. **[Clarification Statement: Examples of wavelength determining applications can include visible light not being used to observe atoms, and x-rays being used for bone imaging.] [*Assessment Boundary: Only qualitative descriptors in the explanation are intended.*]**

PEARSON CHEMISTRY: The citations below indicate areas in ***Pearson Chemistry*** where this idea is introduced.

Students **obtain information** about wavelength in Sizing up the Atom on SE/TE pages 102-103. They **learn** about the speed of light in Light and Atomic Emission Spectra on SE/TE pages 138-139.

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

Constructing Explanations and Designing Solutions	PS4.B: Electromagnetic Radiation	*Connections to Engineering, Technology, and Applications of Science*
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 knowledge, principles, and theories. • Construct and revise explanations and arguments based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories) and peer review.	• Because a wave is not much disturbed by objects that are small compared with its wavelength, visible light cannot be used to see such objects as individual atoms. **SE / TE:** 102-103, Sizing up the Atom 104, Figure 4.3: Model of a Nanocar **TE Only:** 104, Explain 110, Chemistry & You • All electromagnetic radiation travels through a vacuum at the same speed, called the speed of light. Its speed in any other given medium depends on its wavelength and the properties of that medium. **SE / TE:** 138-139, Light and Atomic Emission Spectra • When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). • Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells. **SE / TE:** R41, Appendix A, Elements Handbook: Ti, Sunscreens	**Influence of Engineering, Technology, and Science on Society and the Natural World** Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. Engineers continuously modify these systems to increase benefits while decreasing costs and risks. New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. **SE / TE:** 146, Chemistry & You: Technology: Light Emitting Diodes **TE Only:** 143, Explain 146, Extend, Connect to Economics 146, 21st Century Learning

	PS4.C: Information Technologies and Instrumentation • Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them. • Knowledge of quantum physics enabled the development of semiconductors, computer chips, and lasers, all of which are now essential components of modern imaging, communication, and information technologies. (Boundary: Details of quantum physics are not formally taught at this grade level.)	