A Correlation of
Pearson
Chemistry
Foundation Edition
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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.

Build a solid foundation. The Foundation Edition of Pearson Chemistry is a new element of the program array that targets struggling students in your chemistry classroom. The Foundation Edition makes chemistry accessible to all your students by offering enhanced math support and proven reading strategies. The Foundation Edition offers the same content base as the on-level book, but with an extra emphasis on math and reading support to meet the needs of all the students.

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: Foundation Edition ©2012, supports the first draft of the Next Generation Science Standards (NGSS) for Grades 9-12. Correlation references are to the Student Editions, Teacher Editions, and Teacher Lab Resources.
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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, FOUNDATION EDITION: The citations below indicate areas in Pearson Chemistry: Foundation Edition where this idea is introduced.

The concept of stability is linked to the octet rule on SE/TE pages 181 (for ions) & 208 (for covalent bonding). The reason given for stability is just that atoms and molecules with the same electron configurations as noble elements are stable. Magnetic or electrical field energy is not referenced.

Students learn about electron configurations and energy levels on SE/TE page 124-126. They learn about ground state and energy levels on SE/TE page 132. Students examine a chart showing the electron configurations of the noble gas elements on SE/TE page 159. 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 181. Students are then ready to model the formation of cations using equations on TE page 182 (Explain). 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 page 209 (Explain-Visual Learning). Students practice different ways to represent molecules on TE page 209 (Explain –Apply Concepts) and distinguish between covalent and ionic bonding by drawing electron dot structures on TE only page 216 (Explore –Teacher Demo). In Quick Lab: Strengths of Covalent Bonds on SE/TE page 219, students model the dissociation energy of single, double, and triple covalent bonds.

Related Content: SE/TE:
180, Valence Electrons
187, Figure-Sodium Chloride Crystals
218, Resonance
219, Quick Lab: Strengths of Covalent Bonds

Related Content: TE Only:
183, Differentiated Instruction
183, Explore: Build Chemistry Concepts
184, Explain: Use Visuals, Build Chemistry Concepts
210, Explain: Build Chemistry Concepts
212, Explore - Active Learning

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.

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:
124-126, Electron Configurations
132, Atomic Emission Spectra
159, Electronic Configurations in Groups
186-187, Formation of Ionic Compounds
187, Figure-Sodium Chloride Crystals
208, The Octet Rule in Covalent Bonding
211, Chemistry Tutorial: Sample Problem 8.1
217, Bond Dissociation Energies
219, Quick Lab: Strengths of Covalent Bonds

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.

• [Clarification Statement for a: Stability is caused by minimization of energy.]

Related Content: SE/TE:
180-181, Valence Electrons
217, Bond Dissociation Energies

Related Content: TE Only:
217, Explore –Use Visuals
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**SE = Student Edition; TE = Teacher’s Edition**
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, FOUNDATION EDITION: The citations below indicate areas in Pearson Chemistry: Foundation Edition where this idea is introduced.

Energy needed to take molecules about is discussed in the section Bond Dissociation Energies on SE/TE page 217. Students obtain information about chemical bonding in Chapter 7, Ionic and Metallic Bonding, SE/TE pages 178-201 and Chapter 8, Covalent Bonding, SE/TE pages 202-235. Students learn about chemical reactions in Chapter 11, Chemical Reactions, SE/TE pages 314-351; heat in chemical reactions, Chapter 17, Thermochemistry, SE/TE pages 524-561, and collision theory, Chapter 18, Reaction Rates and Equilibrium, SE/TE pages 566-567.

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


- 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: TE Only:

217, Explore-Use Visuals 217, Active Learning

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 566, Figure-Collision Theory 567, Intepret Graphs

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 567, Intepret Graphs
**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, FOUNDATION EDITION:** Students **learn** about the patterns of electron in atoms in Chapter 5, Lesson 2, Electron Arrangement in Atoms, SE/TE pages 124-128. 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 148-153. 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 154-161.

Students **describe** how the modern periodic table is organized in 6.1 Lesson Check #3, 4, and 6 on SE/TE 153. Students **answer** questions about electron configurations and elements in Lesson Check 6.2 #13 and 14 on SE/TE page 161 and Chapter 6 Assessment #34 on SE/TE page 174. In the Performance Task on TE page 173, 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**

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.

**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:**
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:**
150, Today’s Periodic Table
156-157, Figure: Periodic Table
158, Electron Configurations in groups
159, Figure: Representative Elements
160, Figure: Electron Configuration
173, Lesson Check 6.2, #13, 15

**TE Only:**
173, Performance Tasks

**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.

- [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.]
### 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, FOUNDATION EDITION: The citations below indicate areas in *Pearson Chemistry: Foundation Edition* 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 Representations of an Ammonia Molecule on SE/TE page 205. 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 208-219. 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 220-223.

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, 7 on SE/TE page 207 and Lesson Check 8.3 #22-23, 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*:

**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:**
- 95-99, Structure of the Nuclear Atom
- 109, Lesson Check 4.2 -10, 12-14
- 118-123, Revising the Atomic Model

**TE Only:**
- 119, Teacher Demo
- 122, 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:**
- 221-222, VSEPR Theory
- 223 Hybrid Orbitals

**TE Only:**
- 222, Class Activity
- 243, Explain: visual Learning

**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:**
- 205, Figure: Representations of an Ammonia Molecule
- 224, Figure: Molecular Formulas and Structures
- 221-222, VSEPR Theory

**TE Only:**
- 181, Explore- Teacher Demo
- 222, Class Activity

SE = Student Edition; TE = Teacher’s Edition
### 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, FOUNDATION EDITION:** The citations below indicate areas in *Pearson Chemistry: Foundation Edition* where this idea is introduced.

The effects of the strength of interactions among particles in ionic compounds is explored in Chapter 7, Lesson 3 on SE/TE pages 193-196. The effects of the strength of interactions among particles in molecular compounds are covered in Chapter 8 on SE/TE pages 228-230. In Attractions Between Molecules on SE/TE pages 228-229, the attractive forces between molecules that accounts for what state of matter a molecular compound takes is presented. On SE/TE page 230, Intermolecular Attractions and Molecular Properties, students learn about the effects of molecular structure on melting and boiling points. In the same section, students obtain information about network solids and the effect of the strength of bonds on the melting point in network solids.

Students compare the electrical conductivity of different ionic compounds in solution and relate it to molecular structure in a Quick Lab on SE/TE page 192. Students compare the malleability of copper metal and a copper compound in the Teacher Demo on TE only page 194.

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

- **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:**

190-192, Properties of Ionic Compounds
192, Quick Lab
228-229, Attractions Between Molecules
230, Figure: Diamond

**TE Only:**

192, Teacher Demo
228, Teacher Demo
251, Explain – Build Chemistry Concepts

- **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.

**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:**

190-192, Properties of Ionic Compounds
192, Quick Lab
228-229, Attractions Between Molecules
230, Intermolecular Attractions and Molecular Properties
230, Figure: Diamond

**TE Only:**

192, Teacher Demo
228, Teacher Demo
251, Explain – Build Chemistry Concepts
### SE/TE:
- 180-183, Formation of Cations
- 184-185, Formation of Anions
- 186-189, Formation of Ionic Compounds
- 187, Figure: Formation of Sodium Chloride
- 193, Metallic Bonds and Metallic Properties
- 220, Molecular Orbitals
- 221-222, VSEPR Theory
- 223, Hybrid Orbitals
- 224-226, Bond Polarity
- 228-229, Attractions Between Molecules
- 230, Intermolecular Attractions
- 230, Figure: Diamond

### TE Only:
- 187, Explain – Use Visuals
- 207, Teacher Demo
- 221, Explain – Use Visuals, Visual Learning, & Build Chemistry concepts
- 225, Explain – Apply Concepts
- 250, Explain – Apply Concepts
- 228, Teacher Demo
- 251, Explain – Build Chemistry concepts
### 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, FOUNDATION EDITION:** The citations below indicate areas in the program where this idea is introduced.

Reaction rates are described in terms of collision theory on SE/TE pages 564-568. Factors affecting reaction rates are discussed on SE/TE pages 568-571. Zero and first order rate laws are presented in section 18.2, SE/TE pages 572–574. Sample problem 18.1 (SE/TE page 581) shows how to determine the order of the reaction from experimental data. Students answer questions about illustrations on analogies of reaction rates and common, everyday-life chemical events familiar to the student on SE/TE page 565; interpret graphs on SE/TE pages 567, 571, 573 and 574.

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:**
- 566-567, Collision Theory
- 566, Figure: Collision Theory
- 567, Figure: Energy Changes in Reactions
- 567, Factors Affecting Reaction Rates – Concentration
- 568, Figure: Effect of Concentration on Reaction Rate
- 570, Quick Lab: Does Steel Burn?

**TE Only:**
- 566, Explain –Use Visuals

- **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:**
- 566-567, Collision Theory
- 566, Figure: Collision Theory
- 567, Figure: Energy Changes in Reactions
- 567, Factors Affecting Reaction Rates – Concentration
- 568, Figure: Effect of Concentration on Reaction Rate
- 570, Quick Lab: Does Steel Burn?
**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, FOUNDATION EDITION:** Conservation of mass is introduced on SE/TE page 46. The concept of a skeleton reaction is introduced on SE/TE page 316 with a sample problem, and very specific directions for the process on SE/TE page 319. Balancing chemical equations is presented with an explanation of conservation of mass, using the space-filling molecular model on SE/TE pages 321-322. A summary of the five types of chemical reactions with equations demonstrating conservation of atoms and mass is presented on SE/TE page 338-339.

Students write the steps to write and balance chemical equations in Lesson Check 11.1-#10, 13-14 on SE/TE page 325. In Sample Problem 11.4 #16-19 on SE/TE page 329, Sample Problem 11.5-20-22 on ST/TE 331, Sample Problem 11.6-#23-26 on SE/TE page 333, and Sample Problem 11.7 on SE/TE page 335 students balance more equations. Students write the steps to write and balance chemical equations in Lesson Check 11.2-#34 on SE/TE page 339. In Assessment #52-58, on SE/TE page 348 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*:

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<th>PS1.B: Chemical Reactions</th>
<th>Cause and Effect</th>
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<tr>
<td>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.</td>
<td>• 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.</td>
<td>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.</td>
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<tr>
<td>• Use multiple types of models to represent and explain phenomena and move flexibly between model types based on merits and limitations.</td>
<td><strong>SE/TE:</strong></td>
<td><strong>TE Only:</strong></td>
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<td><strong>SE/TE:</strong> 320-321, Balancing Chemical Equations</td>
<td>46, Conservation of Mass</td>
<td>321, Speed Bump</td>
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<td><strong>SE/TE:</strong> 320-321, Balancing Chemical Equations</td>
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<td>333, Sample Problem 11.6</td>
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### 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, FOUNDATION EDITION**: The citations below indicate areas in *Pearson Chemistry: Foundation Edition* where this idea is introduced.

The concepts of reversible reactions and equilibrium are presented in Chapter 18, Lesson 3 on SE/TE page 575-577. Factors affecting equilibrium are covered on SE/TE pages 578-581. Students learn about equilibrium between acids and bases in a solution and buffers on SE/TE pages 645-649.

Students interpret graphs depicting the concentrations of reactants and products as a reaction reaches equilibrium on SE/TE page 576. Students interpret a model of the effect of changing pressure on a reaction in the figure Effect of Pressure on Equilibrium on SE/TE page 580. Students predict the changes in chemical processes after conditions are changed in Sample Problem 18.2 #15 and 16 on SE/TE page 581. An analogy of optimization in chemical processes to commercial egg farming and to retail bakeries is made in Build Connections on SE/TE page 578. Students interpret a graph depicting acid-base titrations on SE/TE page 646. Students write equations describing how buffers work in acid and base solutions in Sample Problem 19.8 on SE/TE page 649.

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:**

576, Establishing Equilibrium  
580, Effect of Pressure on Equilibrium  
577-581, Factors Affecting Equilibrium: Le Châtelier’s Principle  
578, Build Connections  
579, Figure: An Equilibrium System in Blood  
580, Figure: Effect of Pressure on Equilibrium  
582, Figure: Effect of Temperature  
645-647, Salt Hydrolysis  
648-649, Buffers  

**TE Only:**

576, Explain: Visual Learning  
577, Explain: Apply Concepts  
579, Explain: Use Visuals  
580, Explain: Use Visuals

**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:**

579, An Equilibrium System in Blood  
580, Effect of Pressure on Equilibrium  

**TE Only:**

580, Explain
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, FOUNDATION EDITION: The citations below indicate areas in Pearson Chemistry: Foundation Edition 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 526-531, where exo- and endothermic reactions are explained. The changes of enthalpy in a chemical reaction and their detection as temperature changes are discussed in lesson 17.2, SE/TE page 533-540.

Students manipulate units of energy and calculate enthalpy changes in calorimetric experiments SE/TE page 564. 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
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.

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:
566-567, Collision Theory
566, Figure: Collision Theory
567, Figure: Energy Changes in Reactions
567, Factors Affecting Reaction Rates – Concentration
568, Figure: Effect of Concentration on Reaction Rate
570, Quick Lab: Does Steel Burn?

TE Only:
527,529,530 Explain
527, 538,529 Explore –Teacher Demo
534, Focus on ELL
566, Explain –Use Visuals

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:
526, Energy Transformations
<table>
<thead>
<tr>
<th>PS3.A: Definitions of Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>• “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.</td>
</tr>
</tbody>
</table>

**SE/TE:**
526, Energy Transformations
## 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, FOUNDATION EDITION:** A summary of the five types of chemical reactions is presented on SE/TE pages 338-339. Reactions in aqueous solutions and the prediction of the formation of a precipitate are covered in Chapter 11, Lesson 3, SE/TE pages 341-345.

Students **answer** questions about types of chemical reactions in Lesson Check 11.2 on SE/TE page 339 and Lesson Check 11.3 on SE/TE page 345, Students **predict** and **balance** chemical equations in Sample Problems 11.2-11.10 on SE/TE pages 323, 324, 328, 331, 333, 3335, 337, 342, 344.

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

- **SE/TE:** 46, Conservation of Mass
- 320-323, Balancing Chemical Equations
- 323, Sample Problem 11.2
- 324, Sample Problem 11.3
- 326-339, Classifying Reactions
- 328, Sample Problem 11.4
- 331, Sample Problem 11.5
- 333, Sample Problem 11.6
- 335, Sample Problem 11.7
- 337, Sample Problem 11.8
- 342, Sample Problem 11.9
- 344, Sample Problem 11.10

**TE Only:**

- 330, Explain: Build Chemistry Concepts

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### Patterns

Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. 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 identify some patterns.

**SE/TE:**

- 326, Key Questions: What are the five general types of 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 CO₂ and H₂O 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, FOUNDATION EDITION:** That the properties of water are determined by its structure is explained in Chapter 15, Lesson 1 on SE/TE pages 462-466. 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 782-815, with topics ranging from photosynthesis, on SE/TE pages 784-786, to the role of ATP in cellular energetics, on SE/TE pages 806-808.

Students **review** the concepts of hydrogen bonding and polarity in the Activate Prior Knowledge feature on TE only page 462. They **communicate** an explanation of the importance of water to life in Lesson Check 15.1 #9 on SE/TE page 467. Students **apply** the concept of endothermic reaction to photosynthesis (TE only page 786). Students **answer questions** related to the role of chemical processes in biological systems in Lesson Check 24.1 #2, 6 on SE/TE page 786 and Lesson Check 24.6 #38-41 on SE/TE page 810.

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.

- **Patterns**
  Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. 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 identify some patterns.

**SE/TE:**
465, Quick Lab: Surface Tension
467, Lesson Check 15.1 #9
807, Figure: ATP

**TE Only**
463, Explain –Use Visuals
466, Explain –Use Visuals
467, Explain –Visual Learning
786, Evaluate
786, Lesson Check 24.1 #2, 6
806, Explain –Apply Concepts
810, Lesson Check 24.6 #38-41

**PS1.B: Chemical Reactions**
- Chemical processes and properties of materials underlie many important biological and geophysical phenomena.

**SE/TE:**
462-488, Water and Its Properties
462, Figure: Chemistry & You
463, Figure: Polarity of H₂O
463, Figure: Hydrogen Bonding in Water
464, Figure: Surface Tension of Water
465, Quick Lab: Surface Tension
466, Figure: Structure of Ice
467, Figure: Ice Floats in Liquid Water
784-786, Energy and Carbon Cycle
786, Figure: Carbon Cycle
806-807, ATP
806, Figure: ATP
807-808, Metabolism Reactions
809-810, The Nitrogen Cycle

**TE Only**
467, Explain –Visual Learning
807, Explain –Apply Concepts

**SE/TE Only**
786, Evaluate -Reteach
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, FOUNDATION EDITION:** Drawings depicting the number of molecules of reactants and products in forward and reverse reactions of systems at equilibrium are shown in section 18.3 on SE/TE pages 575-582.

Students **analyze** a model of a reversible reaction in Figure: Establishing Equilibrium on SE/TE page 576. Students **explain** the effects of adding or removing CO₂ to the blood on SE/TE page 579. They **explain** the shift in the equilibrium position when the pressure is increased over a mixture of nitrogen, hydrogen and ammonia in Figure: Effect of Pressure on Equilibrium on SE/TE page 580.

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**
- Construct, revise, and use models to predict and explain relationships between systems and their components.
  - 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:**
- 576, Figure: Establishing Equilibrium
- 577, Figure: Equilibrium Analogy
- 579, Figure: Effect of Concentration on Equilibrium
- 579, Figure: An Equilibrium System in Blood
- 580, Figure: Effect of Pressure on Equilibrium
- 582, Figure: Effect of Temperature

**TE Only:**
- 579, Explain - Use Visuals
- 580, Explain - Use Visuals

**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:**
- 575-577, Reversible Reactions
- 576, Figure: Establishing Equilibrium
- 577, Figure: Equilibrium Analogy
- 578-581, Factors Affecting Equilibrium: Le Châtelier’s Principle
- 579, Figure: An Equilibrium System in Blood
- 580, Figure: Effect of Pressure on Equilibrium
- 582, Effect of Temperature

**TE Only:**
- 576, Explain - Visual Learning
- 579, Explain - Use Visuals
- 580, Explain - Use Visuals

**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.}
<table>
<thead>
<tr>
<th>Constructing Explanations and Designing Solutions</th>
<th>PS2.C: Stability and Instability in Physical Systems</th>
<th>Cause and Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
<td>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).</td>
<td>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.</td>
</tr>
<tr>
<td>SE/TE: 396, Kinetic Theory and a Model for Gases 400, Kinetic Energy and Temperature</td>
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<tr>
<td>HS.PS-NP.a. Nuclear Processes</td>
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<tr>
<td>Students who demonstrate understanding can:</td>
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</tr>
</tbody>
</table>
| 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, FOUNDATION EDITION:** Nuclear reactions are described and compared to chemical reactions in Chapter 25, Lesson 1 on SE/TE page 818-820, 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 822-829. Fission and fusion are discussed in Chapter 25, Lesson 3 on SE/TE pages 830-833. Students apply concepts as they complete nuclear equations in Lesson Check 25.2, #19 on SE/TE page 829.

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:**
829, Lesson Check 25.2 #19

**PS1.C: Nuclear Processes**
- Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve changes in nuclear binding energies.

**SE/TE**
818, Radioactivity
819-820, Types of Radiation
819, Figure: Alpha Decay
819, Figure: Beta Decay
830-831, Nuclear Stability and Decay
830, Figure: Fission of Uranium
833, Nuclear Fusion
833, Figure: Fusion in the Sun

**TE Only:**
819, Explain –Build Chemistry Concepts
819, Explain –Use Visuals
831, Explain –Use Visuals

- The total number of neutrons plus protons does not change in any nuclear process.

**SE/TE:**
818, Radioactivity
819-820, Types of Radiation
839, Math Tune-up

**TE Only:**
821, Evaluate –Reteach

- Strong and weak nuclear interactions determine nuclear stability and processes.

**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:**
818, Key Questions: What are three types of nuclear radiation?
821, Lesson Check 25.1
840, Chapter Assessment -25.1

**TE Only:**
819, Focus on ELL
821, Evaluate
**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, FOUNDATION EDITION:** The citations below indicate areas in *Pearson Chemistry: Foundation Edition* where this idea is introduced.

The mathematical model of radioactive decay is discussed in Chapter 25, Lesson 2 on SE/TE page 825. Students answer questions about radioactive decay and dating in the Chapter 25 Assessment #54-56 on SE/TE page 841 and #65-67 on SE/TE page 842.

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, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution.

- 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.

- **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:**
822-823, Nuclear Stability and Decay
822, Figure: Comparing Stable Nuclei
824, Figure: Radioactive Decay Curve
825, Figure: Decay Series of U-238
825, Build Connections

**TE Only:**
823, Explain- Visual Learning Evaluate
824, Active Learning
825, Build Chemistry Concepts

- **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:**
822-823, Nuclear Stability and Decay
822, Figure: Comparing Stable Nuclei
824, Figure: Radioactive Decay Curve
825, Figure: Decay Series of U-238

**TE Only:**
829, Evaluate- Informal Assessment, Reteach
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, FOUNDATION EDITION: The citations below indicate areas in *Pearson Chemistry: Foundation Edition* where this idea is introduced.

The use of nuclear fission to generate electricity is presented in Chapter 25, Lesson 3 on SE/TE pages 830-832.

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

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>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.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analyzing and Interpreting Data</td>
<td>All forms of electricity generation and transportation fuels have associated economic, social, and environmental costs and benefits, both short and long term.</td>
<td></td>
</tr>
<tr>
<td>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.</td>
<td>SE/TE: 830-832, Nuclear Fission 830, Fission of Uranium 831, Figure: Nuclear Reactor 832, Figure: Disposal of Fuel Rods</td>
<td></td>
</tr>
<tr>
<td>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.</td>
<td>TE Only: 832, Explain – Real World Connection</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Influence of Engineering, Technology, and Science on Society and the Natural World</td>
<td></td>
</tr>
<tr>
<td></td>
<td>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.</td>
<td></td>
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<tr>
<td></td>
<td>SE/TE: 832, Nuclear Waste</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TE Only: 832, Explain – Real World Connection</td>
<td></td>
</tr>
<tr>
<td><strong>HS.PS-IF.a. Interactions of Forces</strong></td>
<td><strong>Using Mathematics and Computational Thinking</strong></td>
<td><strong>PS2.B: Types of Interactions</strong></td>
</tr>
<tr>
<td>--------------------------------------</td>
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</tr>
</tbody>
</table>
| Students who demonstrate understanding can: | 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. |  
- 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. |  
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. |

**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.
### 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, Foundation Edition:** Models of ionic compounds that explain their properties abound throughout Chapter 7, SE/TE pages 178-201. Figures depicting the correlation between intermolecular attractions and molecular properties are shown in Chapter 8, Lesson 4 on SE/TE pages 224-230. 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 462-466.

Students **use** electron dot structures to **predict** the formulas of ionic compounds in the Chem Tutor feature on SE/TE page 189. Students **draw** electron dot formulas of molecular compounds in Chemistry Tutorial: Sample Problem 8.1 on SE/TE page 211 and in Extend-Additional Problems on TE only page 211. Students **explain** bond angles and geometric shapes using VSEPR theory in Lesson Check 8.3 #26 on SE/TE page 223.

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:**
  - 228, Figure: Dipole Interactions
  - 229, Figure: Hydrogen Bonds in Water
  - 230, Figure: Diamond
  - 462, How can you describe the structure of ice?
  - 463, Figure: Polarity of H₂O
  - 463, Figure: Hydrogen Bonding in Water
  - 464, Figure: Surface Tension of Water
  - 466, Figure: Structure of ice
  - 469, Figure: Solvation of an Ionic Solid

  **TE Only:**
  - 189: Extend-Additional Problems
  - 467, Evaluate –Informal Assessment

- **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:**
  - 186-188, Formation of Ionic Compounds
  - 187, Figure: Sodium Chloride Crystals
  - 189, Chemistry Tutorial: Sample Problem 7.1
  - 190-191, Properties of Ionic Compounds
  - 191, Figure: Comparing NaCl and CsCl
  - 193-194, Metallic Bonds and Metallic Properties
  - 193, Figure: Comparing Metals and Ionic Compounds
  - 208-212, The Octet Rule in Covalent Bonding
  - 211, Chemistry Tutorial: Sample Problem 8.1
  - 213-215, Coordinate Covalent Bonds
  - 220, Molecular Orbitals
  - 221-222, VSEPR Theory
  - 223, Hybrid Orbitals
  - 495, Figure 15.8: Solvation on an Ionic Solid
  - 228-229, Attractions Between

- **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:**
  - 495, Figure 15.8: Solvation on an Ionic Solid
  - 228, Figure: Dipole Interactions
  - 229, Figure: Hydrogen Bonds in Water
  - 462-465, Water in the Liquid State
  - 463, Figure: Polarity of H₂O
  - 463, Figure: Hydrogen Bonding in Water
  - 464, Figure: Surface Tension of Water
  - 464, Quick Lab: Surface Tension
  - 468-469, Solutions
  - 469, Figure: Solvation on an Ionic Solid

  **TE Only:**
  - 228, Explore –Teacher Demo
  - 248, Explain -Bond Polarity
  - 467, Explain–Visual Learning
<table>
<thead>
<tr>
<th>Molecules</th>
</tr>
</thead>
<tbody>
<tr>
<td>228, Figure: Dipole Interactions</td>
</tr>
<tr>
<td>229, Figure: Hydrogen Bonds in Water</td>
</tr>
<tr>
<td>230, Intermolecular Attractions and Molecular Properties</td>
</tr>
<tr>
<td>230, Figure: Diamond</td>
</tr>
<tr>
<td>462-465, Water in the Liquid State</td>
</tr>
<tr>
<td>463, Figure: Polarity of H₂O</td>
</tr>
<tr>
<td>463, Figure: Hydrogen Bonding in Water</td>
</tr>
<tr>
<td>464, Figure: Surface Tension of Water</td>
</tr>
<tr>
<td>464, Quick Lab: Surface Tension</td>
</tr>
<tr>
<td>466-468, Water in the Solid State</td>
</tr>
<tr>
<td>466, Figure: Structure of ice</td>
</tr>
<tr>
<td>466, Figure 15.6: Structure of ice</td>
</tr>
<tr>
<td>468-469, Solutions</td>
</tr>
<tr>
<td>469, Figure: Solvation on an Ionic Solid</td>
</tr>
</tbody>
</table>

**TE Only:**

| 225, Explain–Use Visuals |  
| 467, Explain–Visual Learning |  

SE = Student Edition; TE = Teacher’s Edition
### 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*:

<table>
<thead>
<tr>
<th>Planning and Carrying Out Investigations</th>
<th>PS2.B: Types of Interactions</th>
<th>Cause and Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
<td>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.</td>
<td>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.</td>
</tr>
<tr>
<td>• 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.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### 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, FOUNDATION EDITION:** The citations below indicate areas in *Pearson Chemistry: Foundation Edition* 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 822-823.

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:**
  - 822-823, Nuclear Stability and Decay

- **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.e. Interactions of Forces

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, FOUNDATION EDITION:** The citations below indicate areas in *Pearson Chemistry: Foundation Edition* 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 227.

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 227. Students **discuss** the impact of consumer concerns on technological advances in the automotive industry in Chemistry & You on TE only page 227.

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

<table>
<thead>
<tr>
<th>Obtaining, Evaluating, and Communicating Information</th>
<th>PS2.B: Types of Interactions</th>
<th>Connections to Engineering, Technology, and Applications of Science</th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
<td>• 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.</td>
<td>Science and engineering complement each other in the cycle known as research and development (R&amp;D). Many R&amp;D projects may involve scientists, engineers, and others with wide ranges of expertise.</td>
</tr>
<tr>
<td>SE/TE: 227, Chemistry &amp; You: Technology -Powder Coating (Take It Further)</td>
<td><strong>SE/TE:</strong> 227, Chemistry &amp; You: Technology -Powder Coating</td>
<td><strong>SE/TE:</strong> 227, Chemistry &amp; You: Technology -Powder Coating</td>
</tr>
<tr>
<td>TE Only: 227, Build Chemistry Concepts</td>
<td><strong>TE Only:</strong> 227, Explain –Lead Discussion</td>
<td><strong>TE Only:</strong> 227, Explain- Chemistry &amp; You</td>
</tr>
</tbody>
</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, FOUNDATION EDITION: 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 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
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.

PS3.A: Definitions of Energy
- 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.

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.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, FOUNDATION EDITION:** 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*:

#### Asking Questions and Defining Problems

- Asking questions in grades 9–12 builds on 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 designs 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.

#### 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.
### HS.PS-E.c. Energy

Students who demonstrate understanding can:

- Analyze data to support claims that closed systems move toward more uniform energy distribution.

**PEARSON CHEMISTRY, FOUNDATION EDITION:** 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.

|---------------------------------|--------------------------------------------------|---------------------------|
| 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. | - 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 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, FOUNDATION EDITION: The citations below indicate areas in Pearson Chemistry: Foundation Edition where this idea is introduced.

The use of nuclear fission to generate electricity is presented in Chapter 25, Lesson 3 on SE/TE pages 830-832. Students learn the processes of neutron moderation and neutron absorption as a means of controlling the nuclear reaction on SE/TE page 831. The problem of storing nuclear waste from the spent fuel rods is brought up on SE/TE page 832.

Students observe a modeled chain reaction in Explore –Teacher Demo on TE page 832. They analyze the ‘Fission of Uranium’ figure and identify the slow-moving neutron in Explain: Use Visuals on TE page 831. They infer about the impact of nuclear waste on the environment in Explain: Build Understanding on TE page 832. 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 reactor in Lesson Check 25.3#20-21 on SE/TE page 833.

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.
- Apply scientific knowledge to solve design problems by taking into account possible unanticipated effects.

**PS3.B: Conservation of Energy and Energy Transfer**
- 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**
822-823, Nuclear Stability and Decay
824-825, Half-Life
825, Decay Series of U-238

**TE Only:**
824, Explain- Active Learning, Use Visuals

**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.e. Energy

Students who demonstrate understanding can:

- 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, FOUNDATION EDITION:** 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 785-786. 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 806-808. Students learn about the nitrogen cycle as an example of the transfer of energy between living organisms on SE/TE page 809.

Students interpret a model of the carbon cycle on SE/TE page 786. They compare models of the carbon cycle and nitrogen cycle in Evaluate- Informal Assessment on TE page 810.

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**
  - 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.
- **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 systems must be defined.]

**SE/TE:**
- 786, Figure: Carbon Cycle
- 806, Figure: ATP
- 808, Figure: Catabolism and Anabolism
- 809, Figure: Nitrogen Cycle

**TE Only:**
- 809, Explain –The Nitrogen Cycle

**SE/TE:**
- 806-808, ATP
- 808, Figure: Catabolism and Anabolism
- 809, Figure: Nitrogen Cycle

**TE Only:**
- 807, Explain- Apply Concepts
- 809, Explain –Use Visuals
- 810, Evaluate- Informal Assessment
- 810, 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:**
- 526, Law of Conservation of Energy

- 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).

**SE = Student Edition; TE = Teacher’s Edition**
### 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:**
785-786, 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:**
806, ATP
806, Figure: ATP
808, Figure: Catabolism and Anabolism
809, Figure: Nitrogen Cycle

**TE Only:**
807, Explain- Apply Concepts
809, Explain –Use Visuals
810, Evaluate- Informal Assessment
810, 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, FOUNDATION EDITION:** The citations below indicate areas in *Pearson Chemistry: Foundation Edition* 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 129-139. Students obtain information about kinetic energy of moving particles in matter in Chapter 13, SE/TE pages 394–419, 426 and in Chapter 14, SE/TE pages 431-436. They learn about nuclear radiation in Chapter 25, Lesson 1 on SE/TE pages 818-821.

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.

**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:**

129-139, Atomic Emission Spectra and the Quantum Mechanical Model
394-419, States of Matter
426, Temperature
431-432, Charles’ Law
434-436, Gay-Lussac’s Law
818-821, Nuclear Radiation

**TE Only:**

426, Explain, Visual Learning; Informal Assessment

**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.]

**SE/TE:**

454, Figure: Pressure and Temperature
### HS.PS-E.g. Energy

Students who demonstrate understanding can:

9. 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, FOUNDATION EDITION:** The citations below indicate areas in *Pearson Chemistry: Foundation Edition* 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 129-139. The kinetic energy of moving particles in matter is presented in Chapter 13 on SE/TE pages 394–419. Students **obtain information** about nuclear radiation in Chapter 25, Lesson 1 on SE/TE pages 818-821.

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:**

129-139, Atomic Emission Spectra and the Quantum Mechanical Model 394-419, States of Matter 818-821, 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 systems 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, FOUNDATION EDITION:** 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, 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**

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.A: Definitions of Energy**

- 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.
- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. "Mechanical energy" generally refers to some combination of motion and stored energy in an operating machine.

**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 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-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, FOUNDATION EDITION: The citations below indicate areas in Pearson Chemistry: Foundation Edition where this idea is introduced.

Wave properties and electromagnetic radiation are described on SE/TE page 129-131. Light acting as a particle and photons are presented on SE/TE pages 134. Students explain how light can behave like a particle in Lesson Check 5.3 #33 on SE/TE page 139.

<table>
<thead>
<tr>
<th>Engaging in Argument from Evidence</th>
<th>PS4.B: Electromagnetic Radiation</th>
<th>Structure and Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
<td>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.)</td>
<td>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.</td>
</tr>
<tr>
<td>• Construct a counter-argument that is based in data and evidence that challenges another proposed argument.</td>
<td></td>
<td>• [Clarification Statement for a: The way something (e.g. visible light) functions can be best understood through a particular representation of its structure.]</td>
</tr>
</tbody>
</table>


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, FOUNDATION EDITION:** The citations below indicate areas in *Pearson Chemistry: Foundation Edition* where this idea is introduced.

The speed of light is a constant is simply stated on SE/TE page 129. 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.

<table>
<thead>
<tr>
<th>Obtaining, Evaluating, and Communicating Information</th>
<th>PS4.B: Electromagnetic Radiation</th>
<th>Structure and Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
<td>• 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.</td>
<td>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.</td>
</tr>
<tr>
<td>• 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.</td>
<td><strong>SE/TE:</strong> 129-130, Light and Atomic Emission Spectra</td>
<td></td>
</tr>
</tbody>
</table>

**SE = Student Edition; TE = Teacher’s Edition**
### 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, FOUNDATION EDITION:** Gamma radiation’s penetrating power is discussed on SE/TE page 818 and associated ionizing properties on SE/TE page 834.

Students **obtain** recent articles in medical journals about the harmful consequences of radiation exposure in the Engage –Build Background section on TE only page 834.

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:**

834, Build Background

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### Obtaining, Evaluating, and Communicating Information

**HS.PS-ER.c. 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:**

819-821, Three types of radiation

**TE Only:**

834, Build Background

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### Connections to Engineering, Technology, and Applications of Science

**PS4.B: Electromagnetic Radiation**

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- Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells.

**SE/TE:**

819-821, Three types of radiation

**TE Only:**

834, Build Background

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**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.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, FOUNDATION EDITION:** The concept of atomic emission spectrum is defined on TE/SE: page 132, Build Vocabulary. Two types of spectra are compared, white light and helium lamp on TE/SE: page 132, Comparing Spectra. Students **differentiate** between two types of spectra on TE only page 132, Explain: Use Visuals.

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**

134, Quick Lab: Flame Tests

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<td>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.</td>
<td>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.</td>
<td>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.</td>
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| • 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:**
132, Atomic Emission Spectra
132, Figure: Comparing Spectra
132, Figure: Atomic Emission Concepts
132, Explain- Build Chemistry Concepts
132, Explain- Use Visuals |
| **TE Only:**
132, Explain- Use Visuals | **SE/TE:**
132, Atomic Emission Spectra
132, Figure: Comparing Spectra |
| **TE Only:**
132, Explain- Use Visuals | **TE Only:**
132, Explain- Use Visuals |
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<td>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.</td>
<td>Photovoltaic materials emit electrons when they absorb light of a high-enough frequency.</td>
<td>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.</td>
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<td>• Construct and revise explanations and arguments based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories) and peer review.</td>
<td>PS4.C: Information Technologies and Instrumentation</td>
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<td>• Photovoltaic materials emit electrons when they absorb light of a high-enough frequency.</td>
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<td>• 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.</td>
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**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, FOUNDATION EDITION:** 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.
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, FOUNDATION EDITION: 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

- Critical reading of 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, FOUNDATION EDITION:** The citations below indicate areas in *Pearson Chemistry: Foundation Edition* where this idea is introduced.

Students **obtain information** about wavelength in Sizing up the Atom on SE/TE pages 93-94. They **learn** about the speed of light in Light and Atomic Emission Spectra on SE/TE pages 129-130.

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| 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. | **• 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.** | **Influence of Engineering, Technology, and Science on Society and the Natural World**
<p>| <strong>• Construct and revise explanations and arguments based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories) and peer review.</strong> | <strong>SE/TE:</strong> 93-94, Sizing up the Atom 94, Figure: Moving Atoms | 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. |
| <strong>TE Only:</strong> 94, Explain-Visual Learning | <strong>• 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.</strong> | <strong>SE/TE:</strong> 129-130, Light and Atomic Emission Spectra |
| <strong>• When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat).</strong> | <strong>• When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat).</strong> | <strong>• When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat).</strong> |
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<td>• 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.)</td>
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