SC DEPARTMENT OF EDUCATION

Bundling Guide for Chemistry

Office of Assessment and Standards

Purpose and Use

This document is intended to be a guide to provide examples of ways Performance Expectations (PEs) could be bundled. For this purpose, a bundle as defined by Pruit (2014), is, "a set of PEs that provide students with coherent connections among concepts within and across disciplines." This document is not intended to be read from cover to cover, but to be used, when needed, to support teacher professional learning and curriculum decisions. This is not intended for student use, and thus is not written in student-friendly language. This is not a curriculum or a means to limit instruction in the classroom. The bundles presented in this guide are not ordered for instruction. Although each PE states a dedicated Science and Engineering Practice (SEP) and Crosscutting Concept (CCC), students will need to use the whole range of SEPs and CCCs to achieve success by the end of instruction.

The bundles in this document do not represent the only way the PEs can be bundled. PEs bundled together may change depending upon the selected anchoring phenomenon that students are working to explain. The bundles presented in this guide were developed using an iterative process informed by the work of Krajick and colleagues (2014). This process is summarized in the steps below:

1. Review bundles that already exist.
2. Build bundles around an anchoring phenomenon.
   a. The "Example anchoring phenomena to support 3D instruction" provided in this resource is just that, an example. There are myriad phenomena to support 3D instruction, and different phenomena may be more appropriate for different learning contexts.
3. Explore and look for unexpected relationships among the PEs, including bundling across disciplines (Earth and Space Science, Life Science, Physical Science) when appropriate. This can include identification of PEs that are only partially met in the bundle.
   a. PEs within a bundle marked with an asterisk (*) share an authentic connection with the bundle but may not fully met.
   b. PEs from additional high school content areas with a close connection to the bundle are listed. This is not intended to add to the instructional demand, but instead to provide teachers with additional content to build upon and/or support student sensemaking.
4. Make sure each PE in the grade/course is found in at least one bundle.

Structure and Properties of Matter

All matter is composed of atoms, which have three subatomic particles – the proton, the neutron, and the electron. Positively charged protons and electrically neutral neutrons are found in a densely packed nucleus at the center of the atom, while the negatively charged electrons surround the nucleus. The periodic table arranges elements based on the number of protons in their nuclei, with similar elements grouped into columns. This organization reflects patterns in the arrangement of electrons in the outermost energy levels of atoms. At a larger scale, the structure and behavior of matter are determined by various forces within and between atoms. The interaction between electric charges, such as attraction and repulsion, explains how matter is structured, its properties, and how it changes.

PEs aligned to this bundle:

- C-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.
- C-PS1-3. Plan and conduct an investigation to gather evidence to compare the structure of substances at a bulk scale to infer the strength of various forces between particles.
- C-PS2-6. Communicate scientific and technical information about why the molecular structure determines the functioning of designed materials.

Connected PEs from additional content areas:

- B-LS1-6. Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and other large carbon-based molecules necessary for essential life processes.
- P-PS2-6. Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.
- P-PS3-2. Develop and use models to illustrate that energy can be explained by the combination of motion and position of objects at the macroscopic scale and the motion and position of particles at the microscopic scale.
- E-ESS2-5. Investigate the ways that water (given its unique physical and chemical properties) impacts various Earth systems.

Example anchoring phenomena to support 3D instruction:

- How do geckos stick to glass?
- Garlic smell on hands and stainless steel “soap”
- Brinicles

Chemical Reactions & Thermodynamics

Chemical processes, their rates, and whether energy is stored or released can be understood in terms of collisions between molecules and the rearrangement of atoms into new molecules. This results in changes in the total bond energies within the molecules, matched by changes in kinetic energy. When atoms combine to form stable molecules, the resulting molecule has less energy than the individual atoms when separated. To break apart a stable molecule, a system must provide at least this amount of energy. Energy cannot be created or destroyed, but it can be transferred between systems or transported from one place to another. Uncontrolled systems tend to move toward more stable states, where energy is distributed more uniformly.

PEs aligned to this bundle:

- C-PS1-4. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.
- C-PS3-4. Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperatures are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).
- C-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.*
- C-PS1-6. Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.*

Connected PEs from additional content areas:

- B-LS1-5 Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.
- B-LS1-7. Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules are broken and the bonds in new compounds are formed, resulting in a net transfer of energy.
- E-ESS2-6. Develop a quantitative model to describe the cycling of carbon through the hydrosphere, atmosphere, geosphere, and biosphere.
- E-ESS3-2. Evaluate competing design solutions that address the impacts of developing, managing, and using Earth’s energy and mineral resources.
- E-ESS3-3. Use computational representation to illustrate the relationships among the management of Earth’s resources, the sustainability of human populations, and biodiversity.

Example anchoring phenomena to support 3D instruction:

- Dry ice
- Reusable hot packs

Stability & Change in Chemical Systems

During a chemical reaction, the total mass, and therefore the total number of each atom, are conserved. The conservation of atoms, along with our understanding of the chemical properties of elements, allows us to describe and predict chemical reactions. These reactions occur when molecules collide and atoms rearrange to form new molecules. During these processes, there are changes in the total energy stored in the bonds of the molecules involved, which are matched by changes in kinetic energy. In many cases, there is a dynamic balance between a reaction and its reverse reaction, which determines the numbers of different types of molecules present.

PEs aligned to this bundle:

- C-PS1-2. Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.
- C-PS1-5. Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.
- C-PS1-6. Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.
- C-PS1-7. Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
- C-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.*

Connected PEs from additional content areas:

- B-LS1-5 Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.
- B-LS1-7. Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules are broken and the bonds in new compounds are formed, resulting in a net transfer of energy.
- P-PS3-1. Create a computational model to calculate the change in the energy of one component in a system when the following are known: 1) the change in energy of the other component(s) and 2) the energy flowing in and out of the system.
- E-ESS2-6. Develop a quantitative model to describe the cycling of carbon through the hydrosphere, atmosphere, geosphere, and biosphere.
- E-ESS2-7. Communicate scientific information that illustrates how Earth's systems and life on Earth change and influence each other over time.

- E-ESS3-2. Evaluate competing design solutions that address the impacts of developing, managing, and using Earth's energy and mineral resources.
- E-ESS3-3. Use computational representation to illustrate the relationships among the management of Earth's resources, the sustainability of human populations, and biodiversity.

Example anchoring phenomena to support 3D instruction:

- Color change equilibrium (chromate/dichromate, NO_2/N_2O_4)
- Polyurea
- Ocean Acidification

Nuclear Chemistry

Nuclear processes, like fusion (where two atomic nuclei combine to form a heavier nucleus), fission (where a heavy nucleus splits into lighter nuclei), and radioactive decay (where unstable nuclei emit radiation), involve the release or absorption of energy. While the total number of neutrons and protons does not change during a nuclear reaction, a small amount of matter is converted to energy in many nuclear reactions resulting in the production of energy according to Einstein's equation ($E=mc^2$).

PEs aligned to this bundle:

- C-PS1-8. Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.
- C-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.*

Connected PEs from additional content areas:

- E-ESS1-1. Develop a model based on evidence to illustrate that energy generated by nuclear fusion within the sun (and other stars) radiates to and influences orbiting planets.
- E-ESS1-3. Construct an explanation using evidence to explain the ways elements are produced over the life cycle of a star.

Example anchoring phenomena to support 3D instruction:

- Star life cycle
- Band of Stability
- Special relativity

Applications of the Electromagnetic Spectrum

When matter absorbs light or other forms of electromagnetic radiation, it often transforms into thermal energy, commonly known as heat. However, more energetic forms of radiation like ultraviolet, X-rays, and gamma rays can actually cause damage to living cells by ionizing atoms. Each element emits and absorbs light at specific frequencies, like a unique signature. This is also true for nuclear transitions, which emit gamma rays with specific wavelengths, helping scientists identify different elements. Some materials, known as photoelectric materials, release electrons when they absorb light with enough energy. Understanding these interactions between energy and matter is crucial for various technologies we use every day, such as medical imaging machines, communication devices, and scanners. They help transmit, capture, and interpret signals, making them essential tools in both everyday life and scientific research.

PEs aligned to this bundle:

- C-PS4-4. Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.
- C-PS4-5. Communicate technical information about how some technological devices use the principles of the electromagnetic spectrum to cause matter to transmit and capture information and energy.

Connected PEs from additional content areas:

- P-PS4-1. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.
- P-PS4-3. Evaluate the claims, evidence, and reasoning about how electromagnetic radiation can be described either by a wave model or a particle model, and in some situations one model is more useful than the other.
- P-PS4-4. Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.
- P-PS-4-5. Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.
- E-ESS1-2. Construct an explanation of the Big Bang Theory based on evidence to show that the universe is changing over time.

Example anchoring phenomena to support 3D instruction:

- Photoelectron spectroscopy
- Redshift in the Universe
- Solar car

References

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