HIGH SCHOOL CHEMISTRY: ATOMS AND NUCLEAR CHEMISTRY

Standards Bundle:

Standards are listed within the bundle. Bundles are created with potential instructional use in mind, based upon the potential for related phenomena that can be used throughout a unit.

HS-PS1-8 Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay. (SEP: 2; DCI: PS1.C; CCC: Energy/Matter) [Clarification Statement: Emphasis is on simple qualitative models, such as pictures or diagrams, and on the scale of energy released in nuclear processes relative to other kinds of transformations.] *[Assessment Boundary: Assessment does not include quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decay.]*

HS-ESS1-1 Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation. (SEP: 2; DCI: ESS1.A, PS3.D; CCC: Scale/Prop.) [Clarification Statement: Emphasis is on the energy transfer mechanisms that allow energy from nuclear fusion in the sun's core to reach Earth. Examples of evidence for the model include observations of the masses and lifetimes of other stars, as well as the ways that the sun's radiation varies due to sudden solar flares ("space weather"), the 11-year sunspot cycle, and non-cyclic variations over centuries.] *[Assessment Boundary: Assessment does not include details of the atomic and subatomic processes involved with the sun's nuclear fusion.]*

HS-ESS1-3 Communicate scientific ideas about the way stars, over their life cycle, produce elements. (SEP: 8; DCI: ESS1.A; CCC: Energy/Matter) [Clarification Statement: Emphasis is on the way nucleosynthesis, and therefore the different elements created, varies as a function of the mass of a star and the stage of its lifetime.] *[Assessment Boundary: Details of the many different nucleosynthesis pathways for stars of different masses are not assessed.]*

Content Overview

This section provides a generic overview of the content or disciplinary core ideas as an entry point to the standards.

Nuclear processes that include the splitting, joining, and breakdown of unstable nuclei, involve interactions between attractive and repulsive forces between the components (protons and neutrons) of the nucleus. When unstable nuclei decay, there are changes in the composition of the nucleus and energy. The focus of radioactive decay is limited to alpha, beta, and gamma radiation.

The initial mass of the star determines the life cycle of a star. Average size stars, like our sun, will go through the stages of red giant, planetary nebula, and white dwarf. Whereas, massive stars go through the stages of red supergiant, supernova, and then either a black hole or neutron star. Nuclear fusion of hydrogen and other elements in the stars produces vast amounts of energy which eventually reach the Earth in the form of radiation. The energy released from the sun has varied over time and will continue to vary. These changes can be observed in sunspots.
Elements are produced during the life cycles of a star, and those elements exist on our periodic table. Elements lighter than iron on the periodic table are made through nuclear fusion reactions in the stars. Elements heavier than iron are produced through supernova explosions. The nuclear reactions that occur in our sun produce vast amounts of energy that reach the Earth through radiation.

Phenomena

Phenomena can be used at varying levels of instruction. One could be used to anchor an entire unit, while another might be more supplemental for anchoring just a unit. Please remember that phenomena should allow students to engage in the SEP and use the CCC/DCI to understand and explain the phenomenon.

- A Geiger counter is used to detect ionizing radiation in one's surroundings. A student turns on the Geiger counter and notices a change in its readings, yet the radioactive source is nowhere near the counter.
- Many radioactive isotopes are used in medical testing. I-131 is used to detect thyroid function. TC-99 is used in 80% of all medical testing.
- When purchasing a new smoke detector, I noticed that it had an expiration date. In 10 years, I will have to replace the smoke detector. Americium-241 is used in smoke detectors.
- A potential homebuyer orders a radon test kit for their new home. The report shows that the radon levels outside the home are at normal levels, but the radon level for the basement was 5.0 picocuries/L.
- Cobalt-60 and Cesium-137 are used to sterilize medical, dental, and household products and are also used for the treatment of cancer.
- The accident at the Chornobyl nuclear plant accident is still leaking radiation and causing problems with life in that area.
- Animals that are exposed to nuclear radiation have more mutations and birth defects than animals that are not exposed to nuclear radiation.

Storyline

This section aims to decode not only the DCI connections but also the SEP and CCC in a detailed account of how they possibly fit together in a progression for student learning, including both rationale and context for the bundle.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models ● Develop a model based on evidence to illustrate the relationships between systems or between components of a system. **Obtaining, Evaluating, and Communicating Information** ● Communicate scientific ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).	**PS1.C Nuclear Processes** ● Nuclear processes, including fusion, fission, and radioactive decay of unstable nuclei, involve the release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process. **ESS1.A: The Universe and Its Stars** ● The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years. **PS3.D: Energy in Chemical Processes and Everyday Life** ● Nuclear fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. (Secondary)	**Energy and Matter** ● In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. **Scale, Proportion, and Quantity** ● The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.

Models may be used to examine systems that are too small or too large to observe directly. The boundaries and initial conditions of the system need to be defined. Internal changes in subatomic particles as well as energy changes can be illustrated for the processes of fission, fusion, and radioactive decay. When developing a model based on evidence to illustrate the changes in the nuclear composition of the atom during the processes of fission, fusion, and radioactive decay, changes may be tracked in the number of protons and neutrons from the original atom to the atoms produced. The conservation of total number of protons and neutrons is observed. In addition, the flow of energy into, out of, and within the models of fission, fusion, and radioactive decay may be modeled.

Hydrogen is the sun's fuel. Through nuclear fusion, various elements are formed in the star's core throughout its lifespan. As the sun ages, the proportion of hydrogen to helium changes. Models based on evidence are used to illustrate these nuclear changes and make predictions in determining the lifespan of the sun. Through nuclear fusion, the sun's core releases energy that reaches Earth as radiation. The transfer by radiation of the sun's energy produced through fusion follows the second law of thermodynamics. This phenomenon can be quantified. The energy released far exceeds the energy produced by chemical reactions.

Astronomical evidence can be used to construct an explanation of the Big Bang theory. Communications about this phenomenon may be made through oral, written, or graphical media. The lifespan of a star is dependent upon its initial mass. As stars progress through their life cycle, various elements are produced up to iron. Elements heavier than iron can be formed through supernova explosions. The composition of stars can be determined through the use of emission and absorption spectra. Students explain these phenomena through oral, written, or graphical media.

Formative Assessment

Formative Question Prompts *Formative assessment is crucial because all learners benefit from timely and focused feedback from others. It promotes self-reflection, self-explanation, and social learning. It can also make learning more relevant. Each of the questions below might be used throughout the formative assessment process. Specific prompts may focus on individual practices, core ideas, or crosscutting concepts, but, together, the components need to support inferences about students' three-dimensional science learning as described in a given bundle, standard or lesson-level performance expectation.*

SEP Developing and Using Models

- Develop a model based on evidence to illustrate the changes in the nuclear composition and energetics of the atom during the processes of fission, fusion, and radioactive decay.
- Construct a model of the sun's life cycle to demonstrate that energy from the sun reaches Earth.
- Develop a scaled model that will allow you to gain insight into the life cycle of the sun.
- Develop a model showing an atom undergoing alpha, beta, and gamma decay indicating the new particles formed as well as the energy changes.
- Model how low molecular weight atoms such as hydrogen and helium form heavier elements through the input of collision energy.

SEP Obtaining, Evaluating, and Communicating Information

- Using two different media, construct an explanation of the Big Bang theory using astronomical evidence.
- Construct an explanation of how stars produce different elements and communicate these phenomena to a given audience.
- Demonstrate, through visual presentations, the initial conditions required in space for a star to be able to form.
- Explain how electromagnetic radiation is used to analyze the composition of the star and where that electromagnetic energy comes from.

CCC Energy and Matter

- How does the subatomic structure and energy in a given atom change as the atom goes through alpha decay to reach the final atom produced?
- How does the subatomic structure and energy in a given atom change as the atom goes through beta decay to reach the final atom produced?
- How does the subatomic structure and energy in a given atom change as the atom goes through gamma radiation to reach the final atom produced?
- What evidence is there that matter is conserved during fission, fusion, and radioactive decay?
- Which nuclear equations show the energy changes in nuclear reactions and the formation of alpha, beta, and gamma particles?
- How can the quantity of energy transferred in nuclear processes be demonstrated?

CCC Scale, Proportion, and Quantity

- How does the amount of energy produced by fusion in the sun compare to the amount of energy produced in an exothermic chemical reaction?
- Why can we observe the life cycle of stars when using a telescope and spectroscope, but not with the naked eye as the conditions of fuel consumption change?
- How can a good measure of energy changes be developed to investigate the phenomenon presented in nuclear reactions?

- Use a model to show the relative proportions of hydrogen to helium changing as the sun ages.
- Use a model to explain the differences in the energy output between chemical versus nuclear reactions in the sun.
- Determine the correlation between the mass of a star, its stage of development, and the types of elements it can produce.

Performance Outcomes

These are statements of how students use knowledge and are similar to the standards in how they blend DCI, SEP, and CCC, but at a smaller grain size. These are potential outcomes for instruction as it plays out in lessons and activities in the classroom. It is important to also think of these as smaller outcomes that build toward the larger goal of mastering the standards.

- **Create models** representing changes in an atom's nucleus during the processes of fission, fusion, and radioactive decay that also *illustrate the conservation of matter.*
- **Create models** representing changes in energy during the processes of fission, fusion, and radioactive decay while still *illustrating the conservation of matter.*
- **Develop a model** based on astronomical evidence to illustrate the life span of the sun according to the Big Bang Theory *while discussing or labeling the boundaries of the system.*
- ***Construct an explanation*** *of how elements lighter than Iron are made as opposed to elements heavier than Iron are made in the solar system.*
- **Develop a model** of the role of nuclear fusion in the sun's core to release thermal energy that eventually reaches Earth in the form of radiation *while discussing or labeling the boundaries of the system.*
- **Communicate scientific ideas in multiple formats** about the way stars, over their life cycle, produce elements through fusion while conserving numbers of protons and neutrons.
- **Construct an explanation** of how stars produce elements through fusion and *compare the energy released during fusion to the energy released during a chemical reaction.*