High School Domains Model Course 1 – Chemistry

Narrative and Rationale: This Chemistry model course map is the first in a three-year course sequence that uses a customized version of the Modified High School Domains Model from NGSS Appendix K as the instructional year end goals. The four bundles in this model are characterized by the overarching ideas that materials gained from natural resources are composed of atoms with characteristic chemical and physical properties, and that those properties affect the way that natural resources are formed and used. Using phenomena related to the formation of elements and materials as a way to connect bundles allows for students not only to master PEs, but also to develop a deeper understanding of the crosscutting concepts (CCCs) that they built throughout their K-8 experiences in science.

This course model is written with the assumption that it will come first in a high school sequence of Chemistry, Physics, and Biology courses, each with Earth and Space Sciences and Engineering Design integrated into the courses. This Chemistry course model is intended to lay the foundation for all other high school courses, and assumes that students enter high school with proficiency in the middle school DCIs, Science and Engineering Practices, and crosscutting concepts from the NGSS.

This model gives students the opportunity to deepen their understanding and use of the Science and Engineering Practices (SEPs). It places special emphasis on developing and using models, planning and carrying out investigations, and constructing explanations and designing solutions. The SEPs emphasized here contribute to students' understanding of both the CCCs and DCIs they explore. Students continue to grow in their capabilities with science and engineering practices over the course of the year and the level of sophistication at which they are able to engage in them, over time.

The bundles in this domains model guide students through the use of the SEPs, CCCs, and DCIs to answer the essential questions for each unit listed in the bundles below. It is important to note that the practices and crosscutting concepts described are intended as end-of-instructional unit expectations and not curricular designations. Additional practices and crosscutting concepts should be used throughout instruction toward each bundle.

Bundle 1: Where do all the different elements come from? **~5 weeks**	**Bundle 2:** Why do we use gasoline for energy? **~5 weeks**	**Bundle 3:** How can we get energy to flow from one place to another? **~5 weeks**	**Bundle 4:** How and where do we get the materials we need? **~5 weeks**
HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.[1] **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. **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. **HS-ESS1-3**. Communicate scientific ideas about the way stars, over their life cycle, produce elements.	**HS-PS1-2** Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties. **HS-PS1-4**. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy. **HS-PS1-7.** Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. **HS-LS2-5.** Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.[1] **HS-ESS2-6.** Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.	**HS-PS2-5.** Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current. **HS-PS3-1.** Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known. **HS-PS3-3.** Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.* **HS-PS3-4.** Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within	**HS-PS1-5.** Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs. **HS-PS1-6.** Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.* **HS-ESS2-5.** Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.[1] **HS-ESS3-2**. Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.*

Bundle 1: Where do all the different elements come from? **~5 weeks**	**Bundle 2:** Why do we use gasoline for energy? **~5 weeks**	**Bundle 3:** How can we get energy to flow from one place to another? **~5 weeks**	**Bundle 4:** How and where do we get the materials we need? **~5 weeks**
	HS-ESS3-5. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems. **HS-ESS3-6.** Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.	a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).	**HS-ETS1-1**. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

1. The bundle only includes part of this PE; the PE is not fully assessable in a unit of instruction leading to this bundle.

High School Domains Model Course 1 (Chemistry) Flowchart

Bundle 1

PS1.A as found in HS-PS1-1
•Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons.
•The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states.

PS1.C as found in HS-PS1-8
•Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process.

PS3.D as found in HS-ESS1-1
•Nuclear Fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation.

ESS1.A as found in HS-ESS1-1
•The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years.

ESS1.A as found in HS-ESS1-3
•The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.
•Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode.

Bundle 2

PS1.A as found in HS-PS1-2
•The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states.

PS1.A as found in HS-PS1-4
•A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart.

PS1.B as found in HS-PS1-2 and HS-PS1-7
•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.

PS1.B as found in HS-PS1-4
•Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.

PS3.D as in HS-LS2-5
•The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis.

LS2.B as found in HS-LS2-5
•Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.

ESS2.D as found in HS-ESS2-6
• Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen.
• Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.

ESS2.D as found in HS-ESS3-6
•Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere.

ESS3.D as found in HS-ESS3-5
• Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts.

ESS3.D as found in HS-ESS3-6
• Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities.

Bundle 3

PS2.B as found in HS-PS2-5
•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.
•Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.

PS3.A as found in HS-PS2-5
•"Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents.

PS3.A as found in HS-PS3-1
•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.A as found in HS-PS3-3
•At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.

PS3.B as found in HS-PS3-1
•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.
•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.
•The availability of energy limits what can occur in any system.

PS3.B as found in HS-PS3-4
•Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
•Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down).

PS3.D as found in HS-PS3-3 and HS-PS3-4
•Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.

ETS1.A as found in HS-PS3-3
•Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.

Bundle 4

PS1.B as found in HS-PS1-5
•Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.

PS1.B as found in HS-PS1-6
•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.

ESS2.C as found in HS-ESS2-5
•The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks.

ESS3.A as found in HS-ESS3-2
•All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors.

ETS1.A as found in HS-ETS1-1
•Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.
•Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.

ETS1.B as found in HS-ESS3-2
•When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.

ETS1.C as found in HS-PS1-6
•Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed.

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