HS-PS1-4

Students who demonstrate understanding can:

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.** [Clarification Statement: Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.] [*Assessment Boundary: Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.*]

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

Science and Engineering Practices

Developing and Using Models
Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

- Develop a model based on evidence to illustrate the relationships between systems or between components of a system.

Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter

- 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: 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 the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.

Crosscutting Concepts

Energy and Matter

- 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.

Observable features of the student performance by the end of the course:			
1	Components of the model		
	a	Students use evidence to develop a model in which they identify and describe the relevant components, including:	
		i.	The chemical reaction, the system, and the surroundings under study;
		ii.	The bonds that are broken during the course of the reaction;
		iii.	The bonds that are formed during the course of the reaction;
		iv.	The energy transfer between the systems and their components or the system and surroundings;
		v.	The transformation of potential energy from the chemical system interactions to kinetic energy in the surroundings (or vice versa) by molecular collisions; and
		vi.	The relative potential energies of the reactants and the products.
2	Relationships		
	a	In the model, students include and describe the relationships between components, including:	
		i.	The net change of energy within the system is the result of bonds that are broken and formed during the reaction (Note: This does not include calculating the total bond energy changes.);
		ii.	The energy transfer between system and surroundings by molecular collisions;
		iii.	The total energy change of the chemical reaction system is matched by an equal but opposite change of energy in the surroundings (Note: This does not include calculating

			the total bond energy changes.); and
		iv.	The release or absorption of energy depends on whether the relative potential energies of the reactants and products decrease or increase.
3	Connections		
	a	Students use the developed model to illustrate:	
		i.	The energy change within the system is accounted for by the change in the bond energies of the reactants and products. (Note: This does not include calculating the total bond energy changes.)
		ii.	Breaking bonds requires an input of energy from the system or surroundings, and forming bonds releases energy to the system and the surroundings.
		iii.	The energy transfer between systems and surroundings is the difference in energy between the bond energies of the reactants and the products.
		iv.	The overall energy of the system and surroundings is unchanged (conserved) during the reaction.
		v.	Energy transfer occurs during molecular collisions.
		vi.	The relative total potential energies of the reactants and products can be accounted for by the changes in bond energy.