PS1.B: Chemical Reactions – 3

Energy Transfer in Chemical Reactions

**PS1.B-3**

[Some chemical reactions release energy, others store energy. (MS-PS1-6)](http://www.nap.edu/openbook.php?record_id=13165&page=109)

**NGSS Evidence Statement:**[MS-PS1-6](http://www.nextgenscience.org/sites/default/files/evidence_statement/black_white/MS-PS1-6%20Evidence%20Statements%20June%202015%20asterisks.pdf)

**Framework Text:**

Core Idea PS1

**Matter and Its Interactions**

*How can one explain the structure, properties, and interactions of matter?*

The existence of atoms, now supported by evidence from modern instruments, was first postulated as a model that could explain both qualitative and quantitative observations about matter (e.g., Brownian motion, ratios of reactants and products in chemical reactions). Matter can be understood in terms of the types of atoms present and the interactions both between and within them. The states (i.e., solid, liquid, gas, or plasma), properties (e.g., hardness, conductivity), and reactions (both physical and chemical) of matter can be described and predicted based on the types, interactions, and motions of the atoms within it. Chemical reactions, which underlie so many observed phenomena in living and nonliving systems alike, conserve the number of atoms of each type but change their arrangement into molecules. Nuclear reactions involve changes in the types of atomic nuclei present and are key to the energy release from the sun and the balance of isotopes in matter.

PS1.B: CHEMICAL REACTIONS

*How do substances combine or change (react) to make new substances? How does one characterize and explain these reactions and make predictions about them?*

Many substances react chemically with other substances to form new substances with different properties. This change in properties results from the ways in which atoms from the original substances are combined and rearranged in the new substances. However, the total number of each type of atom is conserved (does not change) in any chemical process, and thus mass does not change either. The property of conservation can be used, along with knowledge of the chemical properties of particular elements, to describe and predict the outcomes of reactions. Changes in matter in which the molecules do not change, but their positions and their motion relative to each other do change also occur (e.g., the forming of a solution, a change of state). Such changes are generally easier to reverse (return to original conditions) than chemical changes.

“Collision theory” provides a qualitative model for explaining the rates of chemical reactions. Higher rates occur at higher temperatures because atoms are typically moving faster and thus collisions are more frequent; also, a larger fraction of the collisions have sufficient energy to initiate the process. Although a solution or a gas may have constant chemical composition—that is, be in a steady state—chemical reactions may be occurring within it that are dynamically balanced with reactions in opposite directions proceeding at equal rates.

Any chemical process involves a change in chemical bonds and the related bond energies and thus in the total chemical binding energy. This change is matched by a difference between the total kinetic energy of the set of reactant molecules before the collision and that of the set of product molecules after the collision (conservation of energy). Some reactions release energy (e.g., burning fuel in the presence of oxygen), and others require energy input (e.g., synthesis of sugars from carbon dioxide and water).

Understanding chemical reactions and the properties of elements is essential not only to the physical sciences but also is foundational knowledge for the life sciences and the earth and space sciences. The cycling of matter and associated transfers of energy in systems, of any scale, depend on physical and chemical processes. The reactivity of hydrogen ions gives rise to many biological and geophysical phenomena. The capacity of carbon atoms to form the backbone of extended molecular structures is essential to the chemistry of life. The carbon cycle involves transfers between carbon in the atmosphere—in the form of carbon dioxide—and carbon in living matter or formerly living matter (including fossil fuels). The proportion of oxygen molecules (i.e., oxygen in the form O2) in the atmosphere also changes in this cycle.

**Main Concepts**

* All chemical reactions involve energy
* During a chemical reaction, bonds are broken, atoms are rearranged, new bonds are formed
* Energy is required to break bonds and energy is released when new bonds form. (Focus on heat and light as the forms of energy that can be absorbed or released.)
* During a chemical reaction, energy is transformed from another form of energy (thermal energy or light) into chemical energy; or transformed from chemical energy into thermal energy or light.
* Endothermic chemical reactions require more energy than they release. These reactions absorb energy from the surroundings. If the energy is thermal energy, the reaction causes a drop in temperature of the surroundings.
* Exothermic chemical reactions release more energy than they require. These reactions give off energy to the surroundings, often in the form of thermal energy, resulting in an increase in temperature.
* Examples of endothermic reactions include photosynthesis.
* Examples of exothermic reactions include combustion.
* When energy is absorbed by a reaction, it is stored as chemical energy in the products.
* The energy that is released in a reaction can be used for other purposes (e.g., melting snow). The absorption of energy by a reaction can also be used to solve problems (e.g., cold pack on an injury).

**Related Concepts and Applications**

Examples:

* + - * Dissolving ammonium chloride (NH4Cl)
      * Dissolving calcium chloride (CaCl2)
      * Chemical reactions in heat packs and cold packs (cold packs feel cold because the reaction is absorbing energy from the surroundings; heat packs feel hot because the reaction is releasing energy to the surroundings)
      * Chemical reaction in a glow stick
      * Photosynthesis: CO2 + H2O + light → C6H12O6 + O2
      * Respiration: C6H12O6 + O2→ CO2 + H2O + energy
      * Combustion reactions that release thermal energy

**Related Crosscutting Concepts**

* **Cause and Effect** Some chemical reactions cause a change in temperature of the surroundings and of the reacting substances. Some reactions release energy in the form of light.
* **Energy and Matter** Energy can be absorbed or released during a chemical reaction, but is not created or destroyed; it takes energy to break bonds.
* **Stability and Change**  Although energy is not created or destroyed, it is transformed and transferred during a chemical reaction.

**Practices of Science and Engineering**

Teachers will impressed if the game teaches students about or, better, involves students in one or more of the following:

* **Defining Problems and Designing Solutions** Design a device that absorbs or releases thermal energy in order to solve a problem (e.g., melting ice, keeping an injury cold).
* **Planning or Carrying Out Investigations** Plan how to observe or measure absorption or release of energy during a reaction.
* **Analyzing and Interpreting Data** Analyze and interpret temperature measurements; interpret observations (e.g., seeing light).
* **Constructing Explanations** Explain why a reaction absorbs or releases energy (in a very general way).
* **Engaging in Argument rom Evidence** Use temperature measurements and observations about light to support a claim that energy is released or absorbed during a reaction.
* **Using Mathematics and Computational Thinking** Analyze graphs of temperature change over time.

**Grade Bands:**

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| **K-2**  You can assume that students already know that  . . . | **3-5**  Students should have learned this, but it is fine to review it . . . | **6-8**  **This is what students need to learn:** | **9-12**  You don’t need to go into this much depth  (but it is ok to go this far if it makes sense to do so . . .) |
| • Heating or cooling a substance may cause changes that can be observed. Sometimes these changes are reversible, and sometimes they are not. (2-PS1-4) | • When two or more different substances are mixed, a new substance with different properties may be formed. (5-PS1-4)  • No matter what reaction or change in properties occurs, the total weight of the substances does not change. (Boundary: Mass and weight are not distinguished at this grade level.) (5-PS1-2) | • Some chemical reactions release energy, others store energy. (MS-PS1-6)  [Covered in other topics:  • Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (MS-PS1-2),(MS-PS1-3),(MS-PS1-5)  • The total number of each type of atom is conserved, and thus the mass does not change. (MS-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. (HSPS1-4),(HS-PS1-5)  • 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. (HS-PS1-6)  • 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. (HS-PS1-2),(HS-PS1-7) |

**Middle School Level Resources:**

These are examples of what middle schoolers are learning.

Textbook resources:

* Text for Middle School:  <http://www.ck12.org/book/CK-12-Physical-Science-For-Middle-School/section/4.0/>
  + Chemical Reactions and Energy:<http://www.ck12.org/book/CK-12-Physical-Science-For-Middle-School/section/8.4/>
  + Changes in Matter: <http://www.ck12.org/book/CK-12-Physical-Science-For-Middle-School/section/3.3/>
  + Chemical Reactions: <http://www.ck12.org/book/CK-12-Physical-Science-For-Middle-School/section/8.0/>
  + Biochemical Reactions: <http://www.ck12.org/book/CK-12-Physical-Science-For-Middle-School/section/9.4/>
  + Chemical Bonding: <http://www.ck12.org/book/CK-12-Physical-Science-For-Middle-School/section/7.0/>
  + Acid and Base Reactions: <http://www.ck12.org/book/CK-12-Physical-Science-For-Middle-School/section/10.3/>

Other Resources: