

## **STAAR Science Tutorial 23** **TEK 6.9C: Energy Forms & Conversions**

***TEK 6.9C: Demonstrate energy transformations such as energy in a flashlight battery changes from chemical energy to electrical energy to light energy.***

### **Energy Forms**

- Energy is the ability to do work or cause change. Unlike matter, energy does not have mass or take up space. It is visible only through the motion of matter or other changes to matter that it causes.
- As discussed in Tutorial 19: Potential and Kinetic Energy, energy can be classified into two broad categories, kinetic energy (energy presently performing work) and potential energy (stored energy not presently performing work).
- Energy can also be classified by its **energy form**, the physical appearance that it takes when observed interacting with matter. Energy form is a different classification category from the kinetic-potential classification category. Just as people can be classified by gender (male or female), age or by race, so too can energy be classified both by form, as discussed in this tutorial, and by its active or stored state, as discussed in Tutorial 19.
- Energy is found in six different forms: mechanical energy, chemical energy, thermal energy, electrical energy, radiant (or electromagnetic) energy, and nuclear energy:
  - **Mechanical energy**, in its kinetic, working state, is the energy of motion of large objects, or the motion of a mass of particles moving in unison. A moving car, wind, ocean wave, earthquake or sound wave are all examples of kinetic mechanical energy. In the potential, stored state, mechanical energy is the energy stored in large objects or a mass of particles, because of their position, such as height above the ground (gravitational potential energy), or stored in its internal condition, such as compression or tension (elastic potential energy). A body of water stored behind a high dam, and a roller coaster car sitting at the top of the hill, are examples of gravitational potential energy. A compressed spring, stretched rubber band, and deformed rock along a fault line, which when released causes an earthquake, are all examples of elastic potential mechanical energy.
  - **Chemical energy** is the energy stored in the bonds between atoms, such as ionic or covalent bonds. Chemical energy is always potential energy, never kinetic energy, because the chemical energy form must be converted to another form before it can do work or be observed as causing change. Every chemical reaction either stores chemical energy (endothermic reactions) or releases energy (exothermic reactions). The photosynthesis chemical

reaction in plants uses radiant energy from sunlight and converts and stores that energy in the atomic bonds within the sugar created by the plant. When that sugar is eaten by an animal and digested, the cellular respiration reaction breaks the atomic bonds in sugar and converts the chemical energy, usually into thermal energy or mechanical energy.

- **Thermal energy** is the energy of vibrational motion in atoms and molecules. The greater the rate of vibration, the greater the thermal energy the particles have. Thermal energy is measured as temperature. Any atom or molecule above absolute zero ( $-273^{\circ}\text{C}$ ) has thermal energy. The vibration of thermal energy is why substances have a melting point and a boiling point. Matter with low thermal energy is found as a solid—there is not enough vibration (thermal energy) to allow the atoms to move around in relation to one another. As the thermal energy increases, the atoms vibrate more and can move around more easily—the solid melts into a liquid. As still more thermal energy is added, the atoms vibrate so violently that they can leave their container and fly around as a gas. Most energy transformation processes eventually produce thermal energy as the final energy form.
- **Electrical energy** is the energy found in charged particles—protons (+) or electrons (-). If the charges are not moving, we call it static electricity (potential energy). Examples of static electrical energy are the charge a person picks up when walking across carpet, charges in a cloud just before a lightning discharge, and the charge stored in a capacitor in an electrical circuit. If the particles (usually electrons) are moving through a conductor, it is an electrical current (kinetic energy). Electrical energy is easy to transport, and can easily be converted into other energy forms. For this reason, modern civilization is built around electric generation and electrical devices such as motors and computers.
- **Radiant** or **electromagnetic energy** is the only form of energy that does not need matter to be transmitted. Radio waves, microwaves, infrared waves, visible light, ultraviolet light, x-rays and gamma rays are all types of radiant or electromagnetic energy, differing only in their wavelengths. Electromagnetic waves move at a very fast constant speed (the “speed of light”), and thus can only be kinetic, not potential, energy.
- **Nuclear energy** is the energy stored in the nucleus of atoms released either in the nuclear fusion (fusing two nuclei into one nucleus) or fission (breaking one nucleus into two nuclei). The sun uses nuclear fusion to create other energy forms. Nuclear electric power plants use nuclear fission to create other energy forms.

### **Law of Conservation of Energy**

- The **law of conservation of energy** states that energy cannot be destroyed, but only transformed (converted) into different forms. For example, when sunlight (radiant energy) falls on a plant, the chlorophyll within the plant converts the radiant energy into chemical energy, stored in the atomic bonds of the sugar produced by photosynthesis. The mechanical energy of motion, such as in a roller

coaster car, is usually transformed into thermal energy by friction (a force that opposes motion).

## **Energy Transformations**

- In stars and our Sun, nuclear energy is transformed by the nuclear fusion process (fusing four hydrogen nuclei into one helium nucleus) into electromagnetic / radiant energy. This electromagnetic (radiant) energy can travel through the vacuum of space to Earth, where it is transformed (converted) into other energy forms.
- Sunlight, which is electromagnetic / radiant energy, strikes the Earth's surface and greenhouse gas molecules in the atmosphere, and are transformed into thermal energy, as the Earth is warmed by sunlight.
- As thermal energy is transferred by conduction from the land surface to air molecules, the air becomes less dense and rises, thus transforming some of the thermal energy into mechanical energy (convection currents and wind).
- When sunlight (electromagnetic / radiant energy) falls on a plant leaf containing chlorophyll, the radiant energy is converted into chemical energy stored in the chemical bonds between the atoms in sugar, assembled from the carbon, oxygen and hydrogen atoms from water and carbon dioxide. This is the photosynthesis reaction.
- When animals eat plants and the sugar they contain, the chemical energy is converted into either mechanical energy (movement of the animal) or thermal energy (body heat). A small amount of the chemical energy is also converted into electrical energy for the nervous system. Some animals, such as fireflies and deep-sea fish, can convert chemical energy into light (electromagnetic energy).
- In a flashlight, chemical energy in the batteries is converted to electrical energy when the circuit including the batteries, switch and light bulb is completed. The electrical energy is converted to light (electromagnetic / radiant energy) and some heat (thermal energy) by the light bulb.
- In an electric motor, electrical energy is converted to motion (mechanical energy) and some heat (thermal energy).
- In a gasoline engine such as those found in an automobile, the chemical energy in the gasoline is converted into thermal energy (heat) when it burns, which in turn expands the gases in the cylinder and turns the engine (mechanical energy), moving the car.
- In a wind-powered electric generator, the wind (mechanical energy) turns the propeller, which then turns the electric generator, converting mechanical energy into electrical energy.

- In a coal- or natural gas-powered electric generator, the chemical energy contained in the coal or natural gas is converted into thermal energy, which moves the turbine (mechanical energy), which turns the electric generator, creating electrical energy. In a nuclear-powered electric generator, nuclear energy in the uranium (rather than the chemical energy in coal or natural gas) is converted to thermal energy.

### **Practice Questions**

1. The ability to do work or cause change is called \_\_\_\_\_.
2. The two main categories of energy are \_\_\_\_\_ energy (stored energy) and \_\_\_\_\_ energy (energy presently doing work or causing change).
3. The form of energy that is found in large moving objects is \_\_\_\_\_ energy.
4. The form of energy that is stored in large objects because of its position above the ground is \_\_\_\_\_ energy.
5. The form of energy that is stored in large objects because of its internal condition, such as compression or tension, is called \_\_\_\_\_ energy.
6. The form of energy stored in the bonds between atoms is \_\_\_\_\_ energy.
7. The form of energy stored in the nucleus of atoms is \_\_\_\_\_ energy.
8. Light and radio are examples of the \_\_\_\_\_ or \_\_\_\_\_ energy form.
9. Moving electrons in a conductor are an example of \_\_\_\_\_ energy.
10. Vibrating molecules and atoms are an example of \_\_\_\_\_ energy.
11. The two kinds of nuclear reactions are \_\_\_\_\_ and \_\_\_\_\_.
12. In a roller coaster, both the kinetic and potential energy in the car decreases at each successive hill because of \_\_\_\_\_, which converts \_\_\_\_\_ energy into \_\_\_\_\_ energy.

13. The energy transformation in the Sun is from \_\_\_\_\_ to \_\_\_\_\_ energy.
14. The energy conversion that causes wind is from \_\_\_\_\_ energy in \_\_\_\_\_ to \_\_\_\_\_ energy in the wind.
15. The energy transformation in a flashlight is from \_\_\_\_\_ energy contained in the battery to \_\_\_\_\_ energy in the circuit, to \_\_\_\_\_ and \_\_\_\_\_ energy released by the light bulb.
16. The energy transformation in photosynthesis is from \_\_\_\_\_ energy from \_\_\_\_\_ to \_\_\_\_\_ energy made by the chlorophyll in the plant.
17. The energy transformation in cellular respiration is from \_\_\_\_\_ in the food that animals eat into the \_\_\_\_\_ energy of their motion and \_\_\_\_\_ energy of their body heat.