Energy

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Concept 1 Energy

Lesson Objectives

The student will:

- explain the difference between kinetic and potential energy.
- state the law of conservation of matter and energy.
- define heat.
- define work.

Vocabulary

- chemical potential energy
- energy
- kinetic energy
- law of conservation of energy
- law of conservation of matter and energy
- potential energy
- work

Introduction

Just like matter, energy is a term that we are all familiar with and use on a daily basis. Before you go on a long hike, you eat an *energy* bar; every month, the *energy* bill is paid; on TV, politicians argue about the *energy* crisis. But have you ever wondered what energy really is? If you stop to think about it, energy is very complicated. When you plug a lamp into an electric socket, you see energy in the form of light, but when you plug a heating pad into that same socket, you only feel warmth. Without energy, we couldn't turn on lights, we couldn't brush our teeth, we couldn't make our lunch, and we couldn't travel to school. In fact, without energy, we couldn't even wake up because our bodies require energy to function. We use energy for every single thing that we do, whether we're awake or asleep. Although we all use energy, very few of us understand what it is.

Types of Energy: Kinetic and Potential

Energy is the ability to do work or cause change. Machines use energy, our bodies use energy, energy comes from the sun, energy causes forest fires, and energy helps us to grow food. With all these seemingly different types of energy, it's hard to believe that there are really only two different forms of energy: kinetic energy and potential energy.

Kinetic energy is energy associated with motion. When an object is moving, it has kinetic energy, and when the object stops moving, it has no kinetic energy. Although all moving objects have kinetic energy, not all moving objects have the same amount of kinetic energy. The amount of kinetic energy possessed by an object is determined by its mass and its speed. The heavier an object is and the faster it is moving, the more kinetic energy it has.

Kinetic energy is very common and is easy to spot in the world around you. Sometimes we even capture kinetic energy and use it to power things like our home appliances. Have you ever seen windmills lining the slopes of a hill like the ones in **Figure** 1.1? These windmills capture the kinetic energy of the wind to provide power that people can use in their homes and offices. As wind rushes along the hills, the kinetic energy of the blowing air particles turns the windmills, which convert the wind's kinetic energy into electricity.

FIGURE 1.1
This is a photograph of a wind farm in Southern California. Kinetic energy from the rushing air particles turns the windmills, allowing us to capture the wind's kinetic energy and use it.

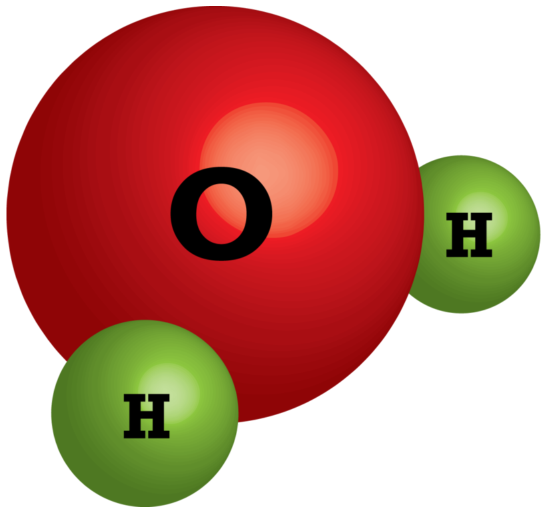
Capturing kinetic energy can be very effective, but you may already realize that there is a small problem: kinetic energy is only available when something is moving. When the wind stops blowing, there's no kinetic energy available. Imagine what it would be like trying to power your television set using the wind's kinetic energy. You could turn on the TV and watch your favorite program on a windy day, but every time the wind stopped blowing, your TV screen would flicker off because it would run out of energy.

You'd have noticed, however, that you can usually rely on your TV to stay on. This is largely because we don't rely on kinetic energy alone for power. Instead, we primarily use energy in its other form as potential energy. **Potential energy** is stored energy that remains available until we choose to use it. Think of a battery in a flashlight. If you leave a flashlight on, the battery will run out of energy within a couple of hours. If, instead, you only use the flashlight when you need it and turn it off when you don't, the battery will last for days or even months. Because the battery stores potential energy, you can choose to use the energy all at once, or you can save it and use a small amount at a time.

Any stored energy is potential energy and has the "potential" to be used at a later time. Unfortunately, there are a lot of different ways in which energy can be stored, making potential energy very difficult to recognize. Generally speaking, an object has potential energy due to its position relative to another object. For example, when you hold a rock above the earth, it has more potential energy than a rock on the ground. As long as you're holding the rock, the rock has potential energy stored. Once you drop the rock, though, the stored energy is released. This can confuse students because it doesn't seem like a falling rock is releasing energy. Remember, however, that energy is defined as the ability to do work or cause change.

For some examples of potential energy, though, it's harder to see how "position" is involved. In chemistry, we are often interested in what is called chemical potential energy. **Chemical potential energy** is energy stored in the atoms, molecules, and chemical bonds that make up matter. How does this depend on position? As you learned earlier, the world and all of the chemicals in it are made up of atoms. These atoms store potential energy that is dependent on their positions relative to one another. Although we cannot see atoms, scientists know a lot about the ways in which atoms interact. This allows them to figure out how much potential energy is stored in a specific quantity of a particular chemical. *Different chemicals have different amounts of potential energy* because they are made up of different atoms, and those atoms have different positions relative to one another.

The image below represents two hydrogen atoms chemically joined to an oxygen atom to form a water molecule. Scientists use their knowledge of what the atoms and molecules look like and how they interact to determine the potential energy that can be stored in any particular chemical substance.



Since different chemicals have different amounts of potential energy, scientists will sometimes say potential energy depends on not only position but also composition. Composition affects potential energy because it determines which molecules and atoms end up next to each other. For example, the total potential energy in a cup of pure water is different than the total potential energy in a cup of apple juice because the cup of water and the cup of apple juice are composed of different amounts of different chemicals.

The Law of Conservation of Matter and Energy

While it's important to understand the difference between kinetic energy and potential energy, the truth is energy is constantly changing. Kinetic energy is constantly being turned into potential energy, and potential energy is constantly being turned into kinetic energy. Even though energy can change form, it must still follow the fundamental law: *energy cannot be created or destroyed*, it can only be changed from one form to another. This law is known as the **law of conservation of energy**. In a lot of ways, energy is like money. You can exchange quarters for dollar bills and dollar bills for quarters, but no matter how often you convert between the two, you won't end up with more or less money than you started with.

Think about what happens when you throw a ball into the air. When the ball leaves your hand, it has a lot of kinetic energy. At some point, the ball will stop momentarily in the air and then falls back down. When the ball stops, it no longer has any kinetic energy. According to the law of conservation of energy, the initial kinetic energy that the ball had does not just disappear. Instead, as the ball moves higher and higher into the sky, the kinetic energy is converted to potential energy. When the ball stops moving upward, all of the kinetic energy has been converted to potential energy. The ball then starts to fall back down, and the potential energy is once again changed into kinetic energy.

As it turns out, the law of conservation of energy isn't completely accurate. Energy and matter are actually interchangeable. In other words, energy can be created (made out of matter) and destroyed (turned into matter).

As a result, the law of conservation of energy has been changed into the **law of conservation of matter and energy**. This law states that: *the total amount of mass and energy in the universe is conserved (does not change)*. This is one of the most important laws you will ever learn. Nevertheless, in chemistry we are rarely concerned with converting matter to energy or energy to matter. Instead, chemists deal primarily with converting one form of matter into another form of matter (through chemical reactions) and converting one form of energy into another form of energy.

Heat and Work

When we talk about using energy, we are really referring to transferring energy from one place to another. When you use energy to throw a ball, you transfer energy from your body to the ball, which causes the ball to fly through the air. When you use energy to warm your house, you transfer energy from the furnace to the air in your home, which causes the temperature in your house to rise. Although energy is used in many kinds of different situations, all of these uses rely on energy being transferred in one of two ways: as heat or as work. Unfortunately, both "heat" and "work" are used commonly in everyday speech, so you might think that you already know their meanings. In science, the words "heat" and "work" have very specific definitions that may be different from what you expect. Do not confuse the everyday meanings of the words "heat" and "work" with the scientific meanings.

When scientists speak of heat, they are referring to energy that is transferred from an object with a higher temperature to an object with a lower temperature as a result of the temperature difference. Heat will "flow" from the hot object to the cold object until both end up at the same temperature. When you cook with a metal pot, you witness energy being transferred in the form of heat. Initially, only the stove element is hot; the pot and the food inside the pot are cold. As a result, heat moves from the hot element to the cold pot, as illustrated in **Figure** 1.2. After a while, enough heat is transferred from the element to the pot, raising the temperature of the pot and all of its contents.

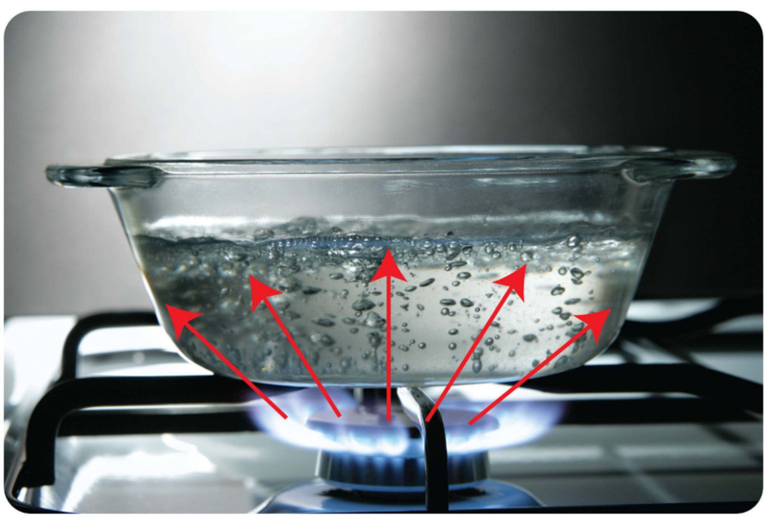
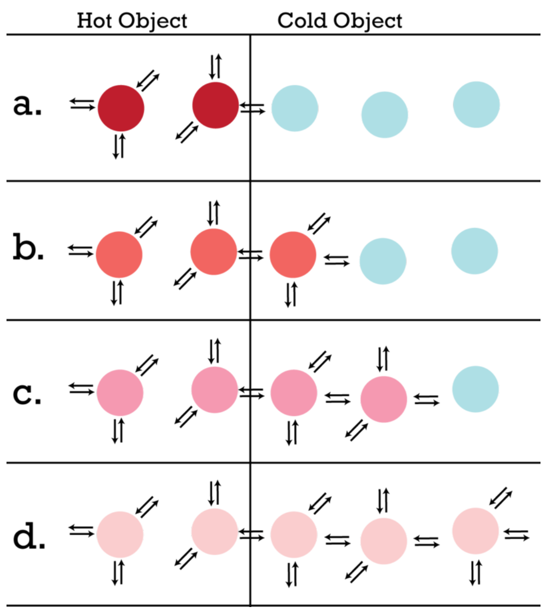


FIGURE 1.2

Energy is transferred as heat from the hot stove element to the cooler pot until the pot and its contents become just as hot as the element.

We've all observed heat moving from a hot object to a cold object, but you might wonder how the energy actually travels. Whenever an object is hot, the molecules within the object are shaking and vibrating vigorously. The hotter an object is, the more the molecules jiggle around. Anything that is moving has energy, and the more it's moving, the more energy it has. Hot objects have a lot of energy, and it's this energy that is transferred to the colder objects when the two come in contact.

The easiest way to visualize heat transfer is to imagine a domino effect. When the vibrating molecules of the hot object bump into the molecules of the colder object, they transfer some of their energy, causing the molecules in the colder object to start vibrating vigorously as well. In the image below, the red molecules are jiggling around and vibrating. As these molecules vibrate, they bump into their neighbors (the blue molecules) and transfer some of their energy. These colder molecules begin to heat up and begin to vibrate faster. Just like dominoes, the heat gets passed along the chain until the energy is spread equally between all of the molecules. At the end, all of the molecules will be at the same temperature.



Heat is only one way in which energy can be transferred. Energy can also be transferred as work. The scientific definition of **work** is force (any push or pull) applied over a distance. Whenever you push an object and cause it to move, you've done work and transferred some of your energy to the object. At this point, it is important to warn you of a common misconception. Sometimes we think that the amount of work done can be measured by the amount of effort put in. This may be true in everyday life, but this is not true in science. By definition, scientific work requires that force be applied over a distance. It doesn't matter how hard you push or pull. If you haven't moved the object, you haven't done any work. For example, no matter how much you sweat, if you cannot lift a heavy object off the ground, you have not done any work.

Lesson Summary

- Energy is the ability to do work or cause change.
- The two forms of energy are kinetic energy and potential energy.
- Kinetic energy is energy associated with motion.
- Potential energy is stored energy.
- Kinetic energy is constantly being turned into potential energy, and potential energy is constantly being turned into kinetic energy.
- Even though energy can change form, it must still follow the law of conservation of energy.
- The law of conservation of energy states that energy cannot be created or destroyed, it can only be changed from one form to another.
- When scientists speak of heat, they are referring to energy that is transferred from an object with a higher temperature to an object with a lower temperature as a result of the temperature difference.
- Heat will "flow" from the hot object to the cold object until both end up at the same temperature.
- Energy can also be transferred as work.
- Work is force (any push or pull) applied over a distance.

Further Reading / Supplemental Links

Summary of concepts of matter and energy and benchmark review.

- http://broncho2.uco.edu/funeral/Bill%20Lewis/BoardReview/ChemLessons/Lesson%201.pdf

Classroom videos about energy.

- http://www.energyclassroom.com/

Review Questions

1. Classify each of the following as energy primarily transferred as heat or energy primarily transferred as work.
   a. The energy transferred from your body to a shopping cart as you push the shopping cart down the aisle.
   b. The energy transferred from a wave to your board when you go surfing.
   c. The energy transferred from the flames to your hot dog when you cook your hot dog over a campfire.
2. Decide whether each of the following statements is true or false.
   a. When heat is transferred to an object, the object cools down.
   b. Any time you raise the temperature of an object, you have done work.
   c. Any time you move an object by applying force, you have done work.
   d. Any time you apply force to an object, you have done work.
3. Rank the following scenarios in order of *increasing* work.
   a. You apply 100 N of force to a boulder and successfully move it by 2 m.
   b. You apply 100 N of force to a boulder and successfully move it by 1 m.
   c. You apply 200 N of force to a boulder and successfully move it by 2 m.
   d. You apply 200 N of force to a boulder but cannot move the boulder.
4. In science, a vacuum is defined as space that contains absolutely no matter (no molecules, no atoms, etc.) Can energy be transferred as heat through a vacuum? Why or why not?
5. Classify each of the following energies as kinetic energy or potential energy:
   a. the energy in a chocolate bar.
   b. the energy of rushing water used to turn a turbine or a water wheel.
   c. the energy of a skater gliding on the ice.
   d. the energy in a stretched rubber band.
6. Decide which of the following objects has more kinetic energy.
   a. A 200 lb man running at 6 mph or a 200 lb man running at 3 mph.
   b. A 200 lb man running at 7 mph or a 150 lb man running at 7 mph.
   c. A 400 lb man running at 5 mph or a 150 lb man running at 3 mph.
7. A car and a truck are traveling along the highway at the same speed.
   a. If the car weighs 1500 kg and the truck weighs 2500 kg, which has more kinetic energy, the car or the truck?
   b. Both the car and the truck convert the potential energy stored in gasoline into the kinetic energy of motion. Which do you think uses more gas to travel the same distance, the car or the truck?

References

1. Photograph by Stan Shebs. Tehachapi wind farm. CC-BY-SA-3.0
2. Image copyrighted by Roman Sigaev, modified by Christopher Auyeung. Glass Saucepan on the Gas Stove. Used under 2010 license from Shutterstock.com