## Reading for Activity 2.4
## How Does Lightning Happen?

Lightning is a dazzling natural phenomenon. It occurs during heavy thunderstorms and snowfalls, volcanic eruptions, and tornadoes. Lightning is often accompanied by loud thunder. From your discussions in class, you know that light and sound are both evidence of energy transfer. So energy must be involved in the production of lightning. Where does this energy come from?

The first thing needed for lightning to form is a cloud. Heat from Earth's surface warms up the air and water vapor above it. Warm air and water vapor rise. The temperature of the air decreases as the distance from Earth's surface increases. When the temperature is cool enough some of the water vapor condenses to form small water droplets and, sometimes, ice crystals and form a cloud. These drops and/or crystals collide with each other inside the cloud. Initially, the particles in the drops and/or crystals are neutral. However, multiple collisions can cause electrons to be knocked off the neutral particles, producing positively and negatively charged particles. This is similar to the tape experiment you performed in the previous unit. Initially, the tape is neutral. But separating the two pieces of tape knocks some of the electrons off one of the pieces, which makes that piece positively charged and the other piece negatively charged.

Most lightning strikes happen within a cloud. Evidence shows that positively charged particles tend to gather at the top of the cloud, and negatively charged particles tend to gather at the bottom of the cloud. There are many hypotheses about why this happens, but it is not completely understood at this time. Whatever the cause, the result is that positive and negative charges within the cloud become separated. As the charges build up, the electric potential energy in the electric field increases.

Why can't charge separation within the cloud exist forever?

The charges keep building up until the energy of the system gets too high. Imagine if you were holding a basketball that kept getting heavier and heavier. Eventually, you would drop the ball. A similar thing happens with charges in a cloud. The electric potential energy stored in the cloud increases as the charges build up, and eventually, the charge separation can't be maintained by the

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system. When this happens, some of the electric potential energy stored in the cloud is transferred to the surroundings. Heat , light and sound are all evidence of this transfer.

A similar thing happens on a smaller scale when the Van de Graaff generator creates a spark. The VDG accumulates charge on its surface, which can interact with charges on other objects that are nearby, causing electric potential energy to be stored in the electric field surrounding the VDG. When another object, such as a grounding wand, is close enough to the VDG, charges jump from the VDG to the other object. When this happens, some of the electric potential energy stored in the electric field is converted to other forms of energy and transferred to other objects. The flash of light is evidence of this energy conversion and transfer. As the air around the flash heats up, the kinetic energy of the molecules in the air increases. The increase in the speed of the air molecules can create sound waves. The sound is another form of evidence that energy was transferred and converted. Is it possible to have lightning without thunder? Explain your answer using the concepts of energy and the particle nature of matter.

Sometimes lightning strikes Earth's surface. This happens when there is a charge separation between the ground and a cloud. Often during thunderstorms, the ground has a positive charge, and the bottom part of the cloud has a negative charge. As a result, electric potential energy is stored in the electric field of the system that includes the ground and the cloud. In order to minimize this energy, lightning strikes the ground, which reduces the separation of charges and reduces the amount of electric potential energy that is stored in the field.

Do you think more energy is released when lightning strikes inside a cloud or when lightning strikes the ground? Use your understanding of electric potential energy to support your answer.

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