A Model of Matter: Part 3

Last week, we explained evaporation using our model of matter (tiny particles in motion). We left you with this question:

You have noticed that puddles dry up faster when the weather is warm than when it is cooler.

How do you explain that?

If you recall, we explained **evaporation** by assuming that some of the water molecules at the surface of water were moving fast enough to be able to overcome the attractive forces that water molecules have for each other and escape from the puddle into the atmosphere. You have observed water evaporates more quickly when the water is warm than when the water is cool.

Can we use our model of molecules in motion to explain this observation? If the water is evaporating more rapidly in the warmer water, then the rate at which molecules are escaping into the atmosphere is greater in warm water than in cold water. How can this be? According to our model, more of the molecules must have speeds great enough to escape the attractive forces of the other water molecules.

So we observe that the rate of evaporation increases with the temperature of the liquid.

Scientists tell us and can show us that the temperature of a sample of a substance is related to the speed of the substance's molecules. Actually, that's the basis for the scientific description of temperature:

Temperature of a substance **is a measure of the average kinetic energy of the molecules** of the substance.

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How did we get from speed to energy? Let's think this through.

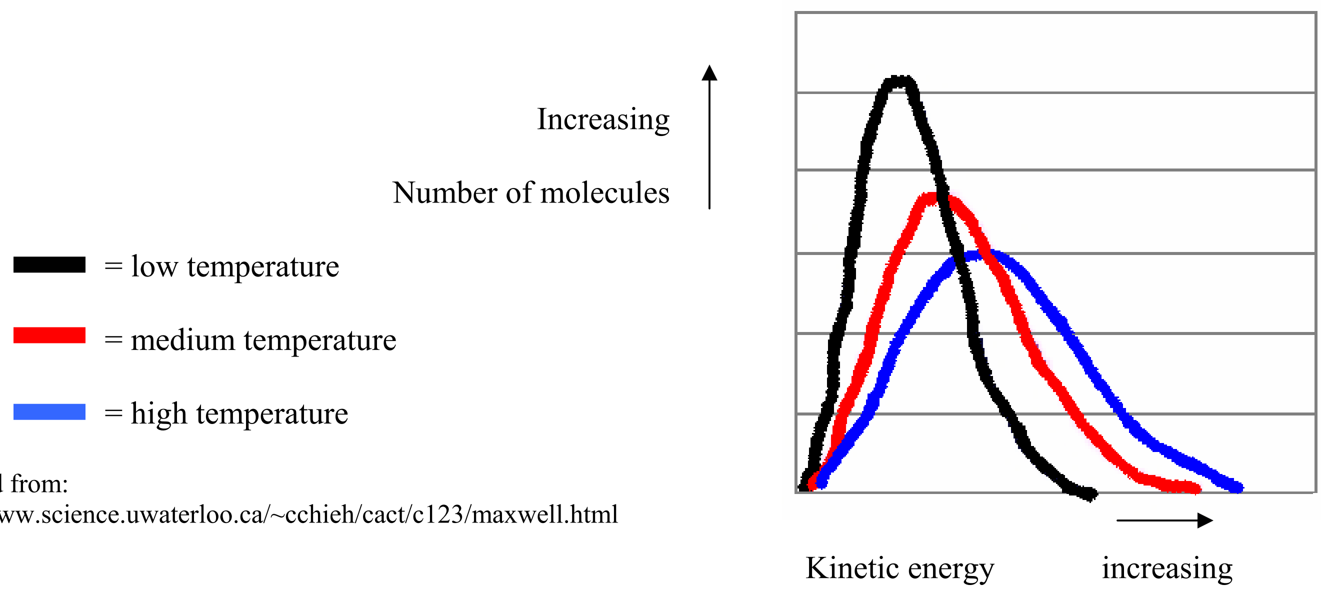
- Molecules have mass. The mass of the water in our 1m by 25cm puddle is equal to the mass of the $7x10^{27}$ molecules in the puddle.
- If water molecules have **mass** and are **in motion**, they have **kinetic energy**. (For a review of **kinetic energy**, check out the email from October 8, 2003: *Energy Part II: Kinds of Energy* at **www.crsep.org**)

Scientists can show us that the **temperature** of a substance **is measure of the average kinetic energy of the molecules** of the substance.

We use the term *average* because not all the particles have the same kinetic energy. They actually fall into an almost normal distribution (also known as a Bell curve). A few of the molecules have very high kinetic energy, some have very low kinetic energy, but most have kinetic energies in the middle.

Look at the figure below; it's a graph of kinetic energy of molecules. It shows that at a lower temperature (the black line), there are many molecules moving at a slow rate; the line peaks quite sharply. A relatively few molecules are moving very fast. When we compare this to molecules at a higher temperature (the red line), we find that the graph spreads out, indicating that more molecules are moving fast. The blue line, which indicates the highest temperature, is the most spread out, illustrating an even greater number of fast-moving molecules.

Kinetic Energy of Molecules at Three Temperatures



Adapted from:
http://www.science.uwaterloo.ca/~cchieh/cact/c123/maxwell.html

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Let's see how that plays out on a sunny day. The sun is shining on the puddle. The light energy from the sun is converted into heat energy, and the temperature at the surface of the puddle increases. So, according to our model, the speed of the molecules at the surface increases, as does their kinetic energy. More molecules are moving fast enough to "break away" quickly and become water vapor. We therefore are able to observe that the water evaporates more rapidly than it did in the morning before the sun warmed the water.

We've discussed differences in temperature and kinetic energy within a puddle. What if we change the dimensions of the puddle, but keep the amount of water in it the same?

Puddle problem

Our original puddle had a length of 1m and a depth of 25cm. What if:

- we *increase* the length to 2m but keep the volume of water the same?
- we *decrease* the length to 50cm but keep the volume of water the same?

Consider these questions for next week:

- **Compared to the original puddle, what happens to the rate of evaporation for each puddle?**
- **How does our model of matter (tiny particles in motion) help us to explain this?**

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What do the New York State standards say?

In the Elementary Core Curriculum, Standard 3, The Physical Setting,

Major Understandings state:

- 3.1a Matter takes up space and has mass. Two objects cannot occupy the same place at the same time.
- 3.1c Objects have properties that can be observed, described and/or measured: length, width, volume, size, shape, mass or weight, temperature, flexibility, reflectiveness of light.
- 3.1f Objects and/or materials can be sorted or classified according to their properties.
- 3.2b Temperature can affect the state of matter of a substance.
- 3.2c Changes in the properties or materials of objects can be observed and described.
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In the Intermediate Core Curriculum, Standard 3, The Physical Setting,

Major Understandings state:

- 3.1a Substances have characteristic properties. Some of these properties include color, odor, phase at room temperature, density, solubility, heat and electrical conductivity, hardness, and boiling and freezing points.
- 3.1d The motion of particles helps to explain the phases (states) of matter as well as changes from one phase to another. The phase in which matter exists depends on the attractive forces among particles.
- 3.3b Atoms and molecules are perpetually in motion. The greater the temperature, the greater the motion.
- 3.3a All matter is made up of atoms. Atoms are far too small to see with a light microscope.
- 3.3c Atoms may join together in well-defined molecules or may be arranged in regular geometric patterns.

Send questions or comments to: mailto:crsep@schenectady.k12.ny.us

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