Objective: The objective of this lesson is for students to understand the relationship between kinetic/potential energy of the structure of water as it experiences phase changes from solid through melting, and from melting through boiling.

Target student audience: High School College Prep Chem

ChemSense User Level: INTERMEDIATE/advanced

ChemSense Tools used: DRAWING & ANIMATION

TEXT NOTES –EXPLAIN

FEEDBACK – TEACHER / PEER

Specialized Tools needed: none

Classroom Implementation

Time:	about 2 class periods
Student Grouping:	pairs
Activity type:	computer animation project

Chemistry Concepts in Activity (linked to CA stds & ChemSense 5 themes):
http://chemsense.sir.com/classroom/index.html#themes
connectivity
molecular geometry/shape
state
aggregation
http://www.cde.ca.gov/standards/science/chemistry.html

Chemical bonds
2. Biological, chemical, and physical properties of matter result from the ability of atoms to form bonds from electrostatic forces between electrons and protons and between atoms and molecules. As a basis for understanding this concept:

d. *Students know* the atoms and molecules in liquids move in a random pattern relative to one another because the intermolecular forces are too weak to hold the atoms or molecules in a solid form.

f.* *Students know* how to predict the shape of simple molecules and their polarity [from Lewis dot structures].

h.* *Students know* how to identify solids and liquids held together by Van der Waals forces or hydrogen bonding and related these forces to volatility and boiling/melting point temperatures.

Gases and Their Properties
4. The kinetic molecular theory describes the motion of atoms and molecules and explains the properties of gases.

Chemical Thermodynamics
7. Energy is exchanged or transformed in all chemical reactions and physical changes of matter. As a basis for understanding this concept:

a. *Students know* how to describe temperature and heat flow in terms of the motion of molecules (or atoms).
c. *Students know* energy is released when a material condenses or freezes and is absorbed when a material evaporates or melts.

Pre-requisite Chemistry Concepts:

1. Shape of water molecule.
2. Kinetic energy of molecules as they relate to temperature.
3. Phase change temperatures of water and how they map to kinetic energy on a kinetic energy vs. phase change graph of water from ice to gas as kinetic energy continually increases.
4. Hydrogen bonding between water molecules.

Inquiry Skills (linked to NSES):
Develop descriptions, explanations, predictions, and models using evidence.

ACTIVITY Summary:
Student is to construct a graph showing the phase change vs. kinetic energy diagram for water. The graph will have a marker to indicate what portion of the graph is to be animated. The student is instructed to create a minimum of 6 frames of animation per line of the phase change diagram (ice melting, phase change from ice→water, water heating, phase change from water→gas). The student is to annotate the animation.
Sources:
Reference picture of ice molecule obtain on internet site.

Application: How could this activity could be used in Earth Science, Physical Science, Biology/Life Science, Physics?

Earth Science: The structure of water, hydrogen bonding and the temperature at which phase changes occur is a basis for the water cycle. The behavior of water also relates to erosion, weather, atmospheric conditions and patterns and some oceanography concepts.

Physical Science: The chemical properties of water relate to the physical structure of water.

Biology/Life Science: All living systems are composed of water. The properties and characteristics of water allow living systems to be dynamic and fluid systems. Much of the construction as well as the constraints of living systems are based upon the properties of water.

ACTIVITY (several pages): See activity lesson handout.

Rubric/s for scoring:

Scoring Rubric for Water Wiggles
I scored this on a fifteen point scale with the points distributed amongst the below listed parameters. I subtracted from 1/2 to 2 points from the total for each item missing. It is easy to adapt your own scoring system based on these requirements.

- There are the required minimum number of animations, 6 per seqment on the phase change graph, total of 24 frames.

Water Wiggles: 2.2 Irene/Tina

- Phase change graph is correctly represented and indicator on the graph correctly correlates with the frames in which molecules are being animated.
- Ice frame demonstrates 6 water molecules connected by hydrogen bonds in a crystal lattice ring structure x 2.
- Ice frame shows increased wiggling activity as kinetic energy increases, while maintaining the basic crystal structure (some hydrogen bonds may break).
- The transition from ice→ liquid shows hydrogen bonds breaking and crystal lattice structure collapsing into a denser form.
- As the temperature increases, the speed of the molecules moving in the liquid phase increases, but the volume does not increase.
- When the phase change occurs from liquid to gas, at 100 degrees centigrade, molecules begin to break free of each other, in all directions, diffusing into space.
- Frames are correctly annotated.

Water Wiggles

Handout

ChemSense: Animation of the State of Matter Phases of Water Molecules

The purpose of this ChemSense activity is to allow you to learn in a deeper, more visual way what is taking place at the molecular level during phase changes. If, in addition to that, you can also apply the knowledge that you have learned about the energy changes that take place while a substance is raising temperature and while it is changing phases, that would be great! Please try to think about these two areas while creating your animation.

Task

1. You are to make an animation of at least 12 water molecules as they change temperature and change phases from ice at -25 ^{o} C to gas water molecules at 100 ^{o} C.

Each phase, as they increase in temperature, should be ***a minimum of six animation frames*** to show the dynamic motion between the molecules. Phase changes should be animated to correlate with the phase change diagram of water provided.

2. Draw a small graph of the temperature vs. time, like the one provided on the back. Indicate on the graph you've drawn what temperature and time with which your animation correlates. The graph and the animation will both appear in each frame together.

You will be expected to annotate your animation appropriately with text.

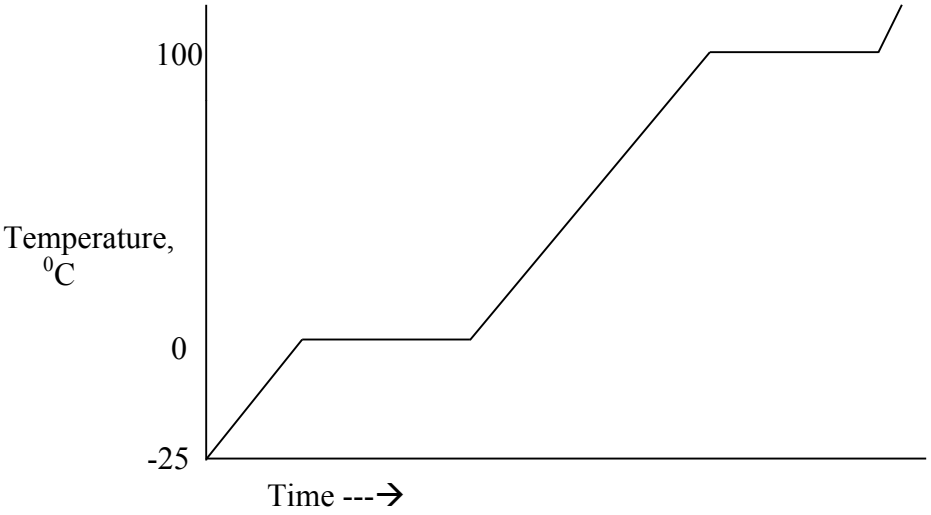
You may focus upon aspects of phase changes *of your choice*:

- You may focus upon temperature changes and explain what is happening with the overall structure of the H_2O during each of the lines of the phase change diagram.
- You may focus your annotation on the energy associated with the phase changes. For example, you may choose to use any of the topics that you have studied associated with energy changes and phase change: endothermic, exothermic, specific heat, molar heat of fusion, molar heat of vaporization, that you are illustrating in your animation.
- Your annotation may focus upon explaining the concepts you are illustrating by writing text with some chosen parts of your annotation.
- If you think of anything else creative, appropriate and relevant, go for it!

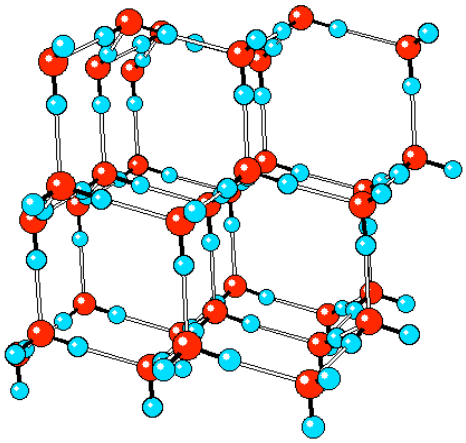
You will be scored on the following components of your animations: 15 pnts total

- Number of frames of each part of each animation should meet minimum required. (6)
- Accuracy of animation; it must reflect scientific principles, structures and concepts.
- Appropriateness, creativity and/or depth of annotation accompanying animation.
- Collaboration with peers and use of other resources.

This is a graph of the temperature of the H_2O as there is a steady amount of energy being added from the Bunsen burner.



This is a diagram of water in the solid phase, ice. Six molecules of H_2O are joined by hydrogen bonds in a hexagonal crytal structure, that is joined by others of this shape.



Hints on how to do ChemSense Water Wiggles animation:

- Water's shape is a bent molecule. Remember VSEPR?
- While ice is warming, from -25^{o}C to O^{o}C, the crystal lattice structure remains intact, but the individual water molecules will vibrate and/or rotate with the structure.
- The higher the temperature, the more the KE increases, the faster the molecular movement will be.
- The density of ice is less than the density of water, therefore, your water should occupy less space than your crystal representation.
- H_2O appears as a solid, a liquid and a gas molecule. The difference in the different phases is the difference in the aggregation of the molecules (how they are arranged together; geometry and connectivity).
- Hydrogen bonds exist between adjacent H_2O molecules in the ice and the liquid phases, but not the gas phase.