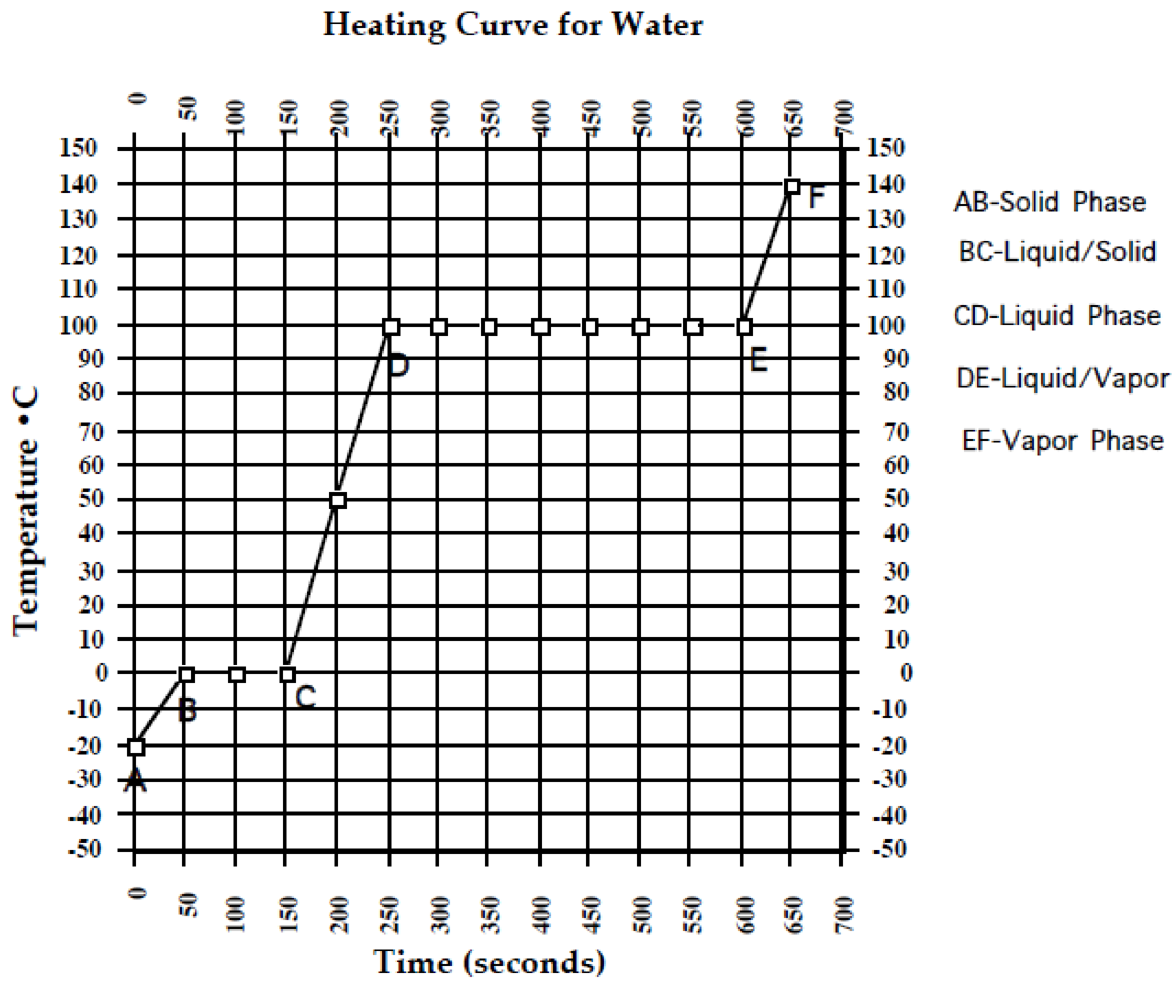
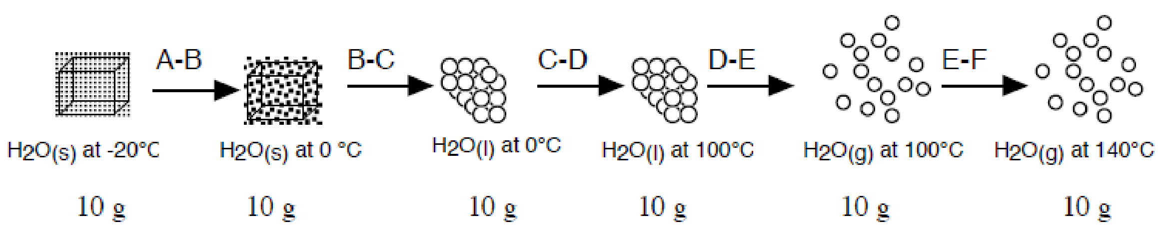
Heating Curve Worksheet



If this curve is read from right to left, it is a <u>Cooling Curve</u>.

The diagram below illustrates the steps involved to convert 10g of solid ice at -20°C to 10g of gaseous steam at 140°C.



A. Solid Phase

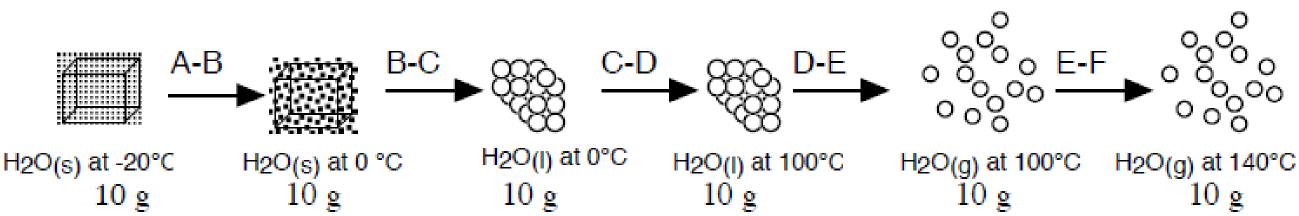
Solids are easily recognized by their ability to retain a fixed shape and definitely volume. Particles making up a solid are held together in a rigid form. They are not free to move about or slide past one another and the solid does not have the ability to flow. (Although the particles of a solid do not move position to position, they do have motion in that they are constantly vibrating.)

To change the temperature of a solid, heat energy must be added. The amount of heat energy that changes the temperature of 1.0g of a solid by 1.0°C is called its specific heat (c). Each substance has its own specific heat. The specific heat of ice is 2.03 J/g°C. In other words, we must supply 1.0 gram of ice with 2.03 Joules of heat energy to raise its temperature by 1.0°C.

The general equation for calculating heat energy to change the temperature of a solid is:

Heat = Mass x Specific Heat $_{(solid)}$ x Temperature Change

$$Q = m\,c\,\Delta T$$



1. Calculate the heat necessary to change 10g of ice(s) at -20°C to 10g of ice(s) at 0°C. (A-B)

$Q = mc\,\Delta T$ **q =10(2.03) (0- -20) = 406 JOULES**

If you continue to add heat energy once the temperature of the ice reaches 0°C, the heat absorbed per mole is called the molar heat of fusion (ΔH_{fus}). This heat is used to cause a change of phase (from a solid to a liquid). This heat is increasing the potential energy of the molecules of the solid. No temperature change takes place. Each substance has its own heat of fusion. The molar heat of fusion for ice is 6.01 kJ/mol. The same amount of heat is given up when water is changed to ice. This is called the heat of solidification ($-\Delta H_{solid}$).

The general equation for calculating heat energy to change a solid to a liquid is set up much like a stoichiometry conversion:

Heat = Mass of substance x (1 mol/molar mass) x Molar Heat of Fusion

$Q = m \times \text{molar mass} \times \Delta H_{fus}$

2. Calculate the heat necessary to change 10g of ice(s) at 0°C to 10g of water(l) at 0°C. (B-C)

Heat = (10g) 1/18 (6.01 kj/mole) = 3.33 KJ

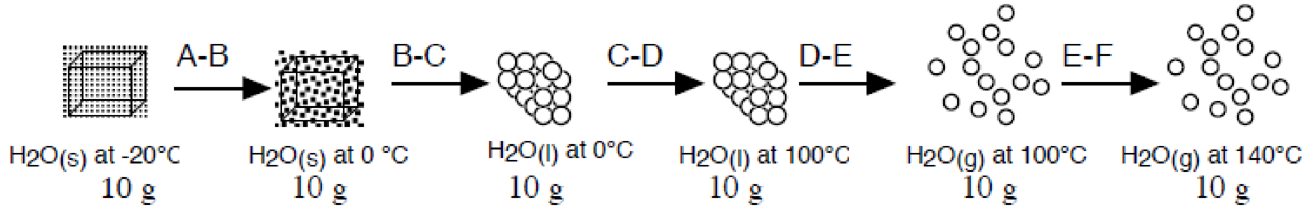
B. Liquid Phase

Liquids have a definite volume, but assume the shape of their container. If a drop of colored dye is placed into a beaker of liquid, the dye will slowly spread throughout the liquid (without being stirred) until it is equally dispersed. The movement of the dye indicates that the particles of the liquid are in constant motion and, through collisions, push the dye throughout the liquid in the beaker. The particles of a liquid are not held together as tightly as the particles of a solid. To change the temperature of a liquid, heat energy must be added. The amount of heat energy that changes the temperature of 1.0g of a liquid by 1.0°C is called its **specific heat (c)**. Each liquid has its own specific heat. The specific heat of water(l) is 4.184J/g°C. In other words, we must supply 1.0 gram of water with 4.184 Joules of energy to raise its temperature by 1.0°C.

The general equation for calculating heat energy to change the temperature of a liquid is:

Heat = Mass x Specific Heat $_{(liquid)}$ x Temperature Change

$Q = m\,c\,\Delta T$



3. Calculate the heat necessary to change 10g of water(l) at 0°C to 10g of water(l) at 100°C. (C-D)

Q = 10 (4.184) (100 -0) = 4184 Joules

If you continue to add heat energy once the temperature of the water reaches 100°C, the boiling temperature, the heat absorbed is called the molar heat of vaporization (ΔH_{vap}). This heat is used to cause a change of phase (from a liquid to a vapor). This heat is increasing the potential energy of the molecules of the liquid. No temperature change takes place. Each substance has its own molar heat of vaporization. The molar heat of vaporization for water is 40.7kJ/mol. The same amount of heat is given up when 1.0g of water vapor is changed to liquid water. This is called the heat of condensation ($-\Delta H_{cond}$). The general equation for calculating heat energy to change a solid to a liquid is set up much like a stoichiometry conversion:

Heat = Mass of substance x (1 mol/molar mass) x Molar Heat of Vaporization

$Q = m \times \text{molar mass} \times \Delta H_{vap}$

4. Calculate the heat necessary to change 10g of water(l) at 100°C to 10g of water(g) at 100°C. (D-E)

$\Delta H = 10\ (1/18)\ 40.7 = 22.6$ KJ

C. Gas Phase

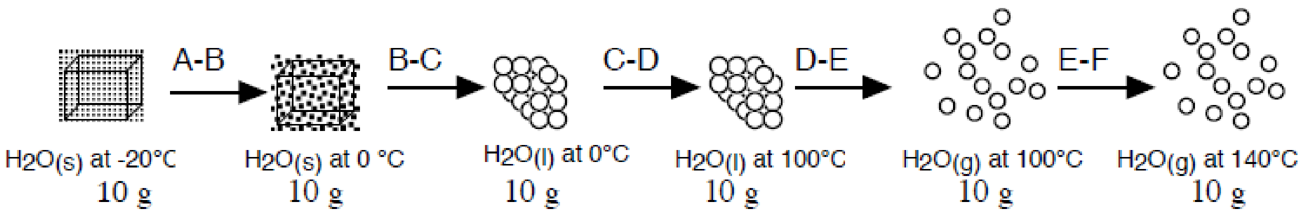
Unlike a solid or a liquid, a gas completely fills its container and its volume is drastically changed by temperature and pressure changes. On the average, gaseous molecules are many times farther apart from each other than the molecules of solids and liquids.

To change the temperature of a gas, heat energy must be added. The amount of heat energy that changes the temperature of 1.0g of a gas by 1.0°C is called its **specific heat (c)**. Each substance has its own specific heat. The specific heat of steam is 2.02 J/g°C. In other words, we must supply 1.0g of steam with 2.02 J of energy to raise its temperature by 1.0°C.

The general equation for calculating heat energy to change the temperature of a liquid is:

Heat = Mass x Specific Heat $_{(vapor)}$ x Temperature Change

$Q = m\ c\ \Delta T$



5. Calculate the heat necessary to change 10g of water(g) at 100°C to 10g of water(g) at 140°C. (E-F)

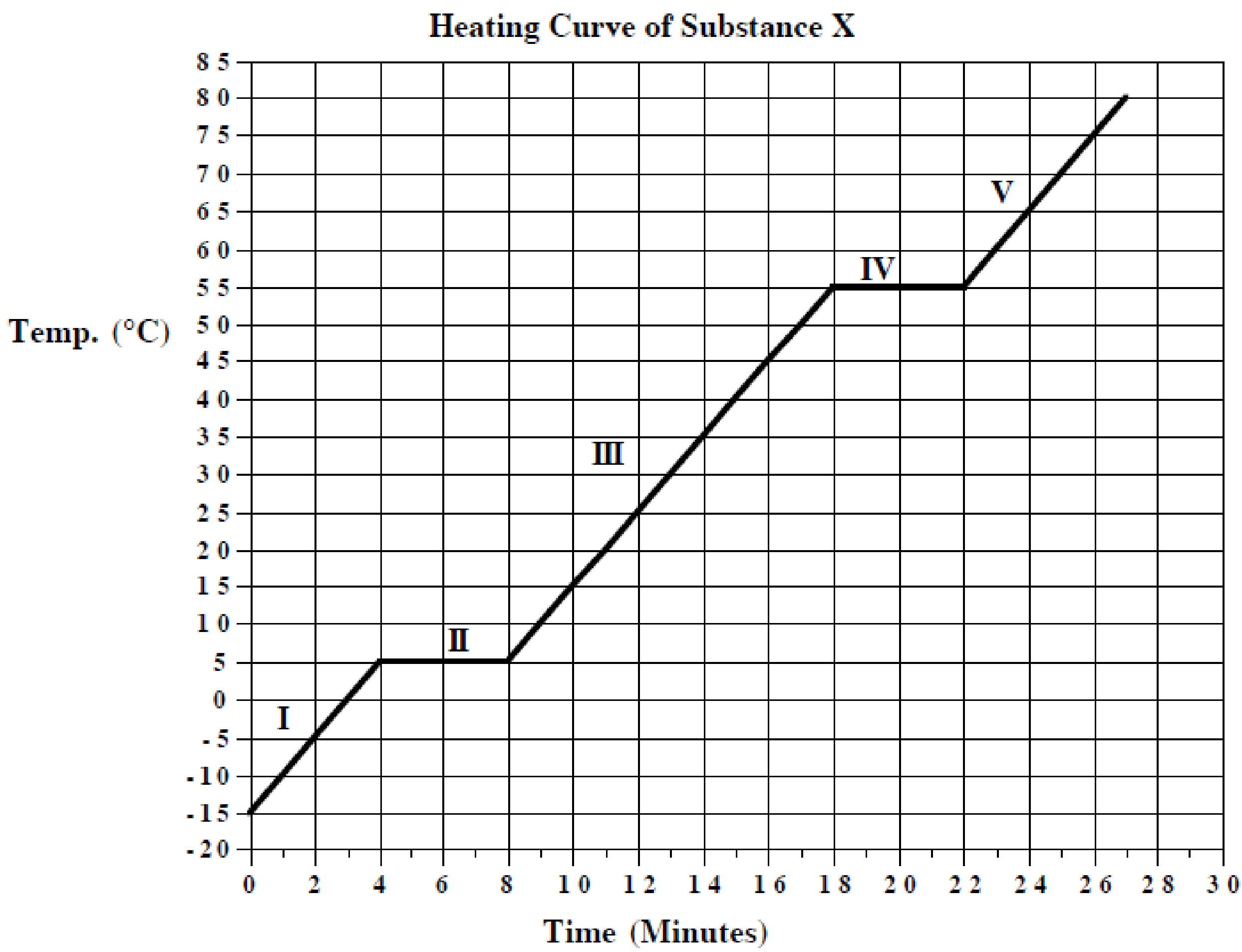
Q = 10 (2.02) (140-100) = 808 JOULES

The total heat for converting 10g of solid ice at -20°C to 10g of gaseous steam at 140°C is the sum of all steps. **Be sure your units match when you complete this step!!!**

6. Calculate the total heat required (in Joules) to convert 10g of solid ice at -20°C to 10g of gaseous steam at 140°C. (A-F)

406 J + 3.33 kJ + 4184 J + 22.6 kJ + 808 J = 31,328 Joules
(3330 J) 22600 J

Chemistry **Heating Curve Worksheet**



_________ 1. In what part of the curve would substance X have a definite shape and definite volume?

_________ 2. In what part of the curve would substance X have a definite volume but no definite shape?

_________ 3. In what part of the curve would substance X have no definite shape or volume?

_________ 4. What part of the curve represents a mixed solid/liquid phase of substance X?

_________ 5. What part of the curve represents a mixed liquid/vapor phase of substance X?

_________ 6. What is the melting temperature of substance X?

_________ 7. What is the boiling temperature of substance X?

_________ 8. In what part(s) of the curve would increasing kinetic energy be displayed?

_________ 9. In what part(s) of the curve would increasing potential energy be displayed?

_________ 10. In what part of the curve would the molecules of substance X be farthest apart?

_________ 11. In what part of the curve would the molecules of substance X have the lowest kinetic energy?

_________ 12. In what part of the curve would the molecules of substance X have the greatest kinetic energy?

Given the following information for substance X:

Specific heat (c) of solid phase:	**2.0 J/g°C**
Molar heat of fusion (ΔH_{fus}):	**50 kJ/mol**
Specific heat (c) of liquid phase:	**5.0 J/g°C**
Molar heat of vaporization (ΔH_{vap}):	**500 kJ/mol**
Specific heat (c) of vapor phase:	**1.0 J/g°C**
Molar mass of substance X:	**65.7 g/mol**

Heat Equations:

$Q = m\ c\ \Delta T$ **$Q = m$ x molar mass x ΔH_{fus}** **$Q = m$ x molar mass x ΔH_{vap}**

13. Calculate the total heat energy (in Joules) needed to convert 20g of substance X from -10°C to 70°C.

solid	s→l	liquid	l→g	gas	TOTAL
600 J	15221 J	5000 J	152210 J	300 J	173,331 J

*see separate page for work