

**Thermodynamics:** The study of energy changes in physical and chemical processes.



• **System vs. Surroundings**

- **System:** includes the \_\_\_\_\_  
(here, the H<sub>2</sub> and O<sub>2</sub> molecules).
  - **Surroundings:** \_\_\_\_\_ (here, the cylinder and piston).
- **Energy**=the ability to \_\_\_\_\_

Types of Energy:

1. **Potential energy**=energy an object possesses by virtue of its \_\_\_\_\_
2. **Kinetic energy**= energy an object possesses by virtue of its \_\_\_\_\_

**\*Temperature**=measure of the \_\_\_\_\_ of a sample.

**\*Heat**=is measured as the \_\_\_\_\_ that is \_\_\_\_\_ from one object to another because of a \_\_\_\_\_. The direction of heat flow is always from the \_\_\_\_\_ object to the \_\_\_\_\_ object.

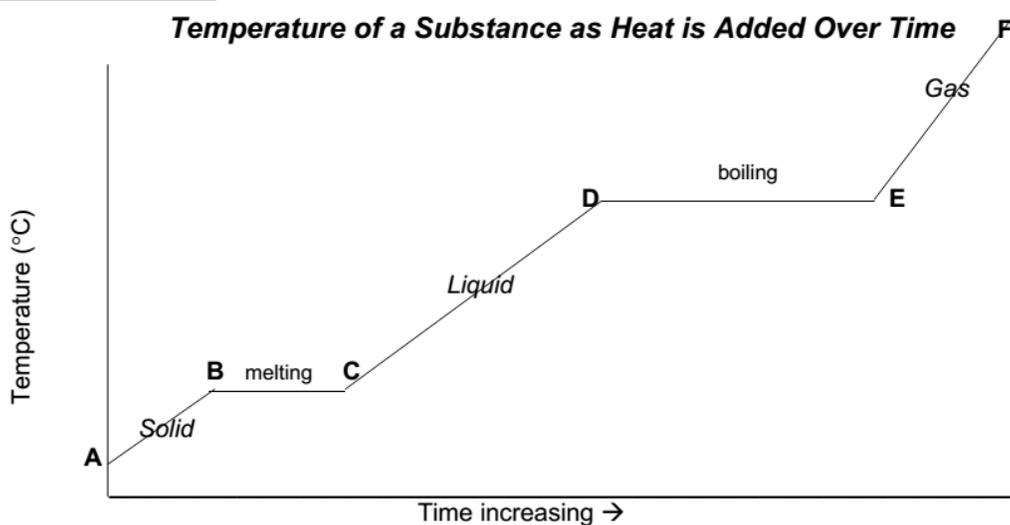
**\*Specific Heat Capacity:** The amount of \_\_\_\_\_ to \_\_\_\_\_ of \_\_\_\_\_ of a substance by \_\_\_\_\_

**Specific Heat Practice:** The specific heat capacities of several substances are listed in the following table.

Substance	Specific Heat Capacity
Water, H <sub>2</sub> O	4.18 J/g°C
Methanol, CH <sub>3</sub> OH	2.43 J/g°C
Air	1.00 J/g°C
Aluminum, Al	0.88 J/g°C
Brass (Cu+Zn mixture)	0.38 J/g°C

1. Imagine that you place an aluminum pot filled with water on the stove. After several minutes, the metal is too hot to touch, but the water is barely warm. Use specific heat capacity to explain why.
2. Why do you think adding water to a balloon prevents it from bursting when heated whereas a balloon filled with just air will burst when heated?

## Heating Curve



Use the graph above (known as a “heating curve”) to answer the questions that follow.

1. During which 3 line segments does the temperature of the substance increase?
2. During which 2 line segments does the temperature of the substance remain the same?
3. At which point do the molecules of the substance have the lowest average kinetic energy?  
The highest?
4. Which phases of matter are present during segment BC?
5. Which phases of matter are present during segment DE?
6. Even though heat is being added to the substance the entire time, why do you think there is no change in temperature during segments BC and DE? Where do you think the heat energy is going or being used for?
7. If there is no change in temperature during segments BC and DE, that means there is no change in \_\_\_\_\_ energy. However, since it is a phase change, there is a change in \_\_\_\_\_ energy (related to position).

## Heat Equations

**Heat** = Energy transferred due to a difference in temperatures. The amount of heat absorbed or released in a physical or chemical reaction can be calculated using the equation  $q = mC\Delta T$

$$q = mC\Delta T \quad \text{or, think of it as unit cancellation: } J = (g) \times \left(\frac{J}{g^{\circ}C}\right) \times (^{\circ}C)$$

q = heat (in Joules or J)

m = mass of sample (in grams)

C = specific heat capacity of sample

$\Delta T$  = change in temperature (Final Temp-Initial Temp)

**Example:** How much heat is required to raise the temperature of 5 grams of water from 20°C to 100°C? The specific heat of water is 4.18 J/g°C.

**Note:** For all the following problems, the specific heat of water is 4.18 J/°C.

1. You heat 1 gram of water from 25°C to 75°C. How many joules of energy are transferred to the water?
2. You cool 10 grams of water from 25°C to 0°C. How many joules of energy are transferred out of the water?
3. The temperature of a sample of water in the liquid phase is raised from 20°C to 50°C by the addition of 3762 Joules. What is the mass of water?

**\*\*Why can't we use the formula  $q = mC\Delta T$  when there is a phase change? Consider the problem "how many joules are required to melt 100 grams of ice at  $0^\circ\text{C}$ ?"**

**Heat of Fusion:** amount of \_\_\_\_\_ required to change a substance from a \_\_\_\_\_ to a \_\_\_\_\_. Heat energy to melt a substance:  $q = mH_f$

**Heat of Vaporization:** amount of \_\_\_\_\_ required to change a substance from a \_\_\_\_\_ to a \_\_\_\_\_; Heat energy to boil a substance:  $q = mH_v$

**$q = mH_f$  and  $q = mH_v$  Problems:**

1. How many joules are required to melt 100 grams of ice at  $0^\circ\text{C}$ ? The heat of fusion for water is 334 J/g.

$q =$

$m =$

$H =$

2. How many joules are absorbed by a 50 gram sample of  $\text{H}_2\text{O}$  that is boiling? The heat of vaporization of water is 2260 J/g.

$q =$

$m =$

$H =$

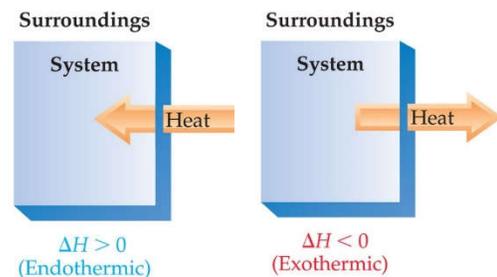
3. 10 joules of heat is required to melt a sample of ice. What is the mass of the ice if the heat of fusion of  $\text{H}_2\text{O}$  is 334 J/g?

4. What is the total number of joules required to completely boil 100 grams of water at  $100^\circ\text{C}$ ? The heat of vaporization of water is 2260 J/g.

5. 25.0 grams of a compound at its boiling point are converted to a gas by the addition of 34,400 Joules of heat. What is the heat of vaporization ( $H_v$ ) for this compound?

**Enthalpy**= A measurement for the \_\_\_\_\_ in a system

- $\Delta H > 0 =$  \_\_\_\_\_
- $\Delta H < 0 =$  \_\_\_\_\_



Ex: Determine the sign of the enthalpy change in each of the following scenarios:

a. An ice cube melts

b. 1g of butane is combusted in sufficient oxygen to give complete combustion to  $\text{CO}_2$  and  $\text{H}_2\text{O}$

• The **change in enthalpy,  $\Delta H$** , is also called the \_\_\_\_\_

• Enthalpy is an \_\_\_\_\_ property.

○ Ex.  $\text{CH}_4(\text{g}) + 2\text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l})$   $\Delta H = -890\text{kJ}$

The energy given off by reacting 1mol  $\text{CH}_4$  with 2mol  $\text{O}_2$  is \_\_\_\_\_

The energy given off by reacting 2mol  $\text{CH}_4$  with 4mol  $\text{O}_2$  is \_\_\_\_\_

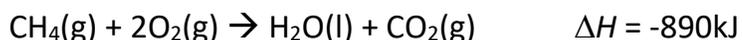
•  $\Delta H$  for a reaction in the forward direction is **equal in size, but opposite in sign**, to  $\Delta H$  for the reverse reaction.

○ Ex.  $\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$   $\Delta H = \underline{-890\text{kJ}}$

$\text{CO}_2 + 2\text{H}_2\text{O} \rightarrow \text{CH}_4 + 2\text{O}_2$   $\Delta H =$  \_\_\_\_\_

### Practice:

1. How much heat is released when 4.50g of methane gas is burned in a constant pressure system?

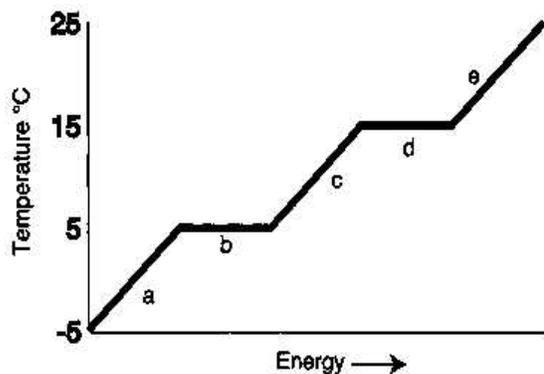


2. Consider the reaction:  $2\text{Mg}(\text{s}) + \text{O}_2(\text{g}) \rightarrow 2\text{MgO}(\text{s})$   $\Delta H = -1204\text{kJ}$

a. Is this an endothermic or exothermic reaction?

b. If 5.00g of  $\text{MgO}$  are produced, what is  $\Delta H$ ? Is energy being given off or absorbed in this reaction?

## Heat Homework:



**HEATING CURVES.** Use the heating curve below to answer the following questions.

1. What is the melting point of the substance? \_\_\_\_\_
2. What is the boiling point of the substance? \_\_\_\_\_
3. Which letter represents heating of the solid? \_\_\_\_\_
4. Which letter represents heating of the vapor? \_\_\_\_\_
5. Which letter represents melting of the solid? \_\_\_\_\_
6. Which letter represents boiling of the liquid? \_\_\_\_\_

### Heat Equations:

#### Properties of Benzene ( $C_6H_6$ )

Specific Heat Capacity:  $1.6 \text{ J/g}^\circ\text{C}$

Heat of Fusion:  $127 \text{ J/g}$

Heat of Vaporization:  $551 \text{ J/g}$

Using the above information about Benzene, answer the following questions. Assume the sample being heated is 50 grams of Benzene. Show your work!

Hint: Determine which heat equation you need to use, then plug in the values.

1. How much heat is required to raise the temperature of the sample from  $-14.5^\circ\text{C}$  to  $5.5^\circ\text{C}$ ?
2. How much heat is required to melt the sample at the melting point?
3. How much heat is required to raise the temperature of the sample of the liquid phase from  $5.5^\circ\text{C}$  to  $80^\circ\text{C}$ ?
4. How much heat is required to boil the sample at its boiling point?
5. How much heat is required to raise the temperature of the sample in the gas phase from the end of  $80^\circ\text{C}$  to  $100^\circ\text{C}$ ?