

Quite a bit of thermochemistry revolves around keeping track of energy in the form of heat.  
Get that? Heat, just like work, is a form of energy.

You need to understand the sign convention for the flow of heat

Heat,  $q$ , is **positive** when it comes **into a system** from the surroundings.

Heat,  $q$ , is **negative** when it goes **out of a system** and into the surroundings.

This makes sense for chemical reactions, right?

**Exothermic reactions** give off energy,  $\Delta H_{\text{rxn}}$  is negative.

**Endothermic reactions** take in energy,  $\Delta H_{\text{rxn}}$  is positive.

You need to understand the definitions that go along with thermodynamic systems.

- An **open system** allows for the transfer of both matter and energy between the system and surroundings. An example of this is a cup of coffee. Evaporation transfers matter and the coffee cools down because the barrier is not completely insulating.
- A **closed system** allows for the transfer of energy but not matter. An example of this is a bag of ice. As long as there isn't a hole in it, all that gets transferred across the boundary is heat energy.
- An **isolated system** allows neither the transfer of matter or energy. It is insulated (the thermodynamic word for that is adiabatic) and has a boundary that doesn't allow for matter to go in or out of the system. A perfect thermos is an example of this types of system.

There are two types of processes that occur when you are heating up or cooling down a material.

- Heating up or cooling down a substance while it's all one phase (solid, liquid or vapor) is called a **sensible heat process**.
- Phase changes are called **latent heat processes**. Latent heat processes require a lot more energy than sensible heat processes, and they occur at constant temperature. There are standard amounts of energy required to change a mole of a substance from one phase to another.

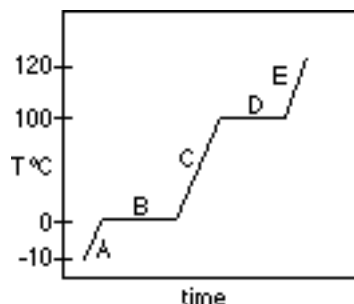
$\Delta H_{\text{fus}}$  is the heat (enthalpy) of fusion. That is the energy associated with a transition between the solid and liquid phase of a substance.

$\Delta H_{\text{vap}}$  is the heat (enthalpy) of vaporization. That's the energy associated with a transition between the liquid and vapor phase of a substance.

$\Delta H_{\text{sub}}$  is the heat (enthalpy) of sublimation. That's the energy associated with a transition between the solid and vapor phase of a substance.

These processes allow you to keep track of the transfer of energy for each step in a heating cycle.

- sensible heat process,  $q = mS\Delta T$  where  $m$  is mass,  $S$  is specific heat and  $\Delta T$  is temp change.
- latent heat process,  $q = n\Delta H$  where  $n$  is moles and  $\Delta H$  is the energy of the phase change.



Take a look at this basic heating cycle. It is the heating of water from  $-10^{\circ}\text{C}$  to  $120^{\circ}\text{C}$

A: Sensible Heat Process. The ice is heated up to its melting point.  $q_A = mS_{\text{ice}} \Delta T$

B: Latent heat process. Melt all the ice at constant temperature.  $q_B = n\Delta H_{\text{fus}}$

C: Sensible Heat Process. The water is heated up to its boiling point.  $q_C = mS_{\text{water}}\Delta T$

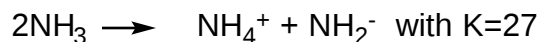
D: Latent heat process. Evaporate all the water at constant T.  $q_D = m\Delta H_{\text{vap}}$

E: Sensible Heat Process. The steam is heated up.  $q_E = mS_{\text{steam}}\Delta T$

For the entire process:  $q_{\text{total}} = q_A + q_B + q_C + q_D + q_E$

**Student Packet: 7.1: Thermochemistry: AssessMe questions**

- 1) Consider the autoionization of liquid ammonia:



What is the concentration of  $[\text{NH}_4^+]$  in a neutral solution of liquid ammonia?

- A) 13.5 M    B)  $3.2 \times 10^{-14}$  M    C)  $1.0 \times 10^{-27}$  M    D)  $1.0 \times 10^{-7}$  M    E) I'm clueless
- 2) At 35°C the water dissociation constant,  $K_w$ , is  $2.089 \times 10^{-14}$ . (This temperature is close to the normal temperature of the human body.) This means that the concentration of protons in a pure water sample at 35°C is:
- A)  $1.00 \times 10^{-7}$     B)  $1.45 \times 10^{-7}$     C)  $1.00 \times 10^{-6}$     D)  $1.45 \times 10^{-6}$     E) I'm clueless
- 3) If a reaction vessel is observed to cool off, the reaction is said to be:
- A) isothermal    B) endothermic    C) exothermic    D) adiabatic    E) I'm clueless
- 4) The following reaction is observed to occur:  
 $\text{heat} + \text{Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O} + 2\text{NH}_4\text{NO}_3 \longrightarrow 2\text{NH}_3 + 10\text{H}_2\text{O} + \text{Ba}(\text{NO}_3)_2$   
This reaction is:
- A) isothermal    B) endothermic    C) exothermic    D) adiabatic    E) I'm clueless
- 5) Le Chatelier's Principle holds
- A) for all reactions.  
B) only for reactions far from equilibrium.  
C) only when the concentrations of reactants and products are equal.  
D) only for reactions near or at equilibrium.  
E) I'm clueless
- 6) Heating an endothermic reaction which is at equilibrium will
- A) decrease the reaction rate.  
B) have no effect on the reaction.  
C) increase the amount of products.  
D) increase the amount of reactants.  
E) I'm clueless

**Student Packet: 7.1: Thermochemistry: ShowMe questions**

- 1) Categorize the following as open systems, closed systems, or isolated systems:
  - A) soup in a thermos
  - B) air filled balloon
  - C) a mouse
  - D) glass of water
  
- 2) Consider the processes of vaporization, freezing, and sublimation. Are each of these processes endothermic or exothermic?
  
  
  
  
  
  
  
  
  
- 3) A sample of 36 g of water is to be heated from the solid state to the gaseous state at 1 atm. The sample begins at a temperature of  $-40^{\circ}\text{C}$  and ends at  $120^{\circ}\text{C}$ . Calculate the heat energy absorbed by the water sample. Use the following information:  
  
$$\begin{aligned} \text{MP} &= 0^{\circ}\text{C}, \text{BP} = 100^{\circ}\text{C}, S_{(s)} = 1.88 \text{ J/g}\cdot^{\circ}\text{C}, S_{(l)} = 4.18 \text{ J/g}\cdot^{\circ}\text{C}, \\ S_{(g)} &= 2.01 \text{ J/g}\cdot^{\circ}\text{C}, \text{DH}_{\text{fus}} = 6 \text{ kJ}\cdot\text{mol}^{-1}, \text{DH}_{\text{vap}} = 40.7 \text{ kJ}\cdot\text{mol}^{-1} \end{aligned}$$
  
  
  
  
  
  
  
  
  
- 4) The combustion of 1 mole of glucose,  $\text{C}_6\text{H}_{12}\text{O}_6$ , gives off  $2.38 \times 10^3 \text{ kJ}$  of heat energy. What is the specific heat of an unknown liquid if 2 kg of the liquid absorbs all the heat energy released by the combustion of 18 g of glucose and undergoes a temperature rise of  $60^{\circ}\text{C}$ ?

**Student Packet: 7.1: Thermochemistry: TestMe questions**

1) Which of the following is not a state function?

- A) Enthalpy    B) Work    C) Entropy    D) Internal energy    E) Pressure

2) Which of the following reactions produces a decrease in entropy?

- 1)  $\text{Fe}_{(s)} + \text{HCl}_{(aq)} \rightarrow \text{HFeCl}_{4(aq)} + \text{H}_{2(g)}$   
2)  $\text{HCl}_{(g)} + \text{NH}_{3(g)} \rightarrow \text{NH}_4\text{Cl}_{(s)}$   
3)  $4\text{NH}_{3(g)} + 5\text{O}_{2(g)} \rightarrow 4\text{NO}_{(g)} + 6\text{H}_2\text{O}_{(g)}$   
4)  $3\text{Al}_{(s)} + 3\text{NH}_4\text{ClO}_{4(s)} \rightarrow \text{Al}_2\text{O}_{3(s)} + \text{AlCl}_{3(s)} + 3\text{NO}_{(g)} + 6\text{H}_2\text{O}_{(g)}$   
5)  $2\text{Na}_{(s)} + \text{Cl}_{2(g)} \rightarrow 2\text{NaCl}_{(s)}$

- A) 1 and 3    B) 1, 3, and 4    C) 2    D) 2 and 5    E) 2, 3, and 5

3) If 120.5 J of heat raised the temperature of gold from 11.2°C to 24.5°C, what is the mass of the sample? The specific heat of Au is 0.132 J/g•°C

- A) 0.352 moles Au  
B) 124.7 moles Au  
C) 72.5 moles Au  
D) 68.6 moles Au  
E) 34.3 moles Au

4) Which of the following processes are exothermic?

- 1) Ice melting  
2) Liquid gold solidifies  
3) A wooden splint burning  
4) Acetone evaporating  
5) A metal block cools from 100°C to 80°C

- A) 1 and 2    B) 2 and 4    C) 1, 3, and 5    D) 2, 3, and 5    E) 1 and 4

5) An expanding gas absorbs 2.17 kJ of heat. Its internal energy increases by 1.64 kJ. What of the following statements is correct?

- A) The surroundings do 0.53 kJ of work on the gas.  
B) The gas does 0.53 kJ of work on the surroundings.  
C) The surroundings do 3.81 kJ of work on the gas.  
D) The gas does 3.81 kJ of work on the surroundings.  
E) None of the above.