ENERGY CHANGES IN CHEMICAL REACTIONS AND CHANGES

Enthalpy

Chapter Eight

Section 8.7

Enthalpy

- Suppose that we carry out some process (a reaction, boiling, freezing, melting, etc.) at constant pressure and that energy transfers only involve heat (that is, no work is done)
- Under these circumstances we will refer to the change in heat by its more formal name, the enthalpy change.
- The enthalpy change is symbolized as ΔH.
- There are many types of enthalpy changes which can be defined, although we will only consider one in this chapter

Enthalpy of Reaction

- An energy change is associated with every chemical reaction
  - As we have already seen, some reactions are exothermic, while others are endothermic – we will revisit these terms in a moment
- The enthalpy of reaction – symbolized by ΔH_{rxn} – tells us how much heat energy is absorbed or consumed by a given reaction

Enthalpy of Reaction

- An exothermic reaction is one which gives off more heat than it takes in.
  - For an exothermic reaction, $\Delta H_{rxn} < 0$.
  - For example, consider burning gasoline.
- An endothermic process is one which brings in more heat than it gives off.
  - For an endothermic reaction, $\Delta H_{rxn} > 0$.

Enthalpy of Reaction

- Consider the reaction of carbon with oxygen to form carbon monoxide:

$$C(s) + O_2(g) \longrightarrow CO_2(g) \quad \Delta H_{\mathrm{rxn}} = -394\ \mathrm{kJ}$$

- This tells us that 394 kJ of heat are given off when one mole of carbon reacts with one mole of oxygen
- If we were to react two moles of the reactants, we would produce twice as much energy

Enthalpy of Reaction

- Now, consider a more complicated case:

  $PCl_3(g) + ½O_2(g) \longrightarrow Cl_3PO(g)$ $\Delta H_{rxn} = - 285.7$ kJ

- In this case, the reactants do not react in a one-to-one ratio
- To determine the amount of heat evolved in this reaction, we must consider the equation as written
- This gives us the following ratios:

  1 mol PCl_3 : 0.5 mol O_2 : -285.7 kJ

Enthalpy of Reaction

Examples:

How much heat is evolved when 25.0 grams of carbon reacts with excess oxygen to produce CO_2 gas?

How much heat is given off or consumed in the reaction of 13.50 grams of oxygen with excess phosphorus trichloride? What mass of Cl_3PO is produced?

Specific Heat

Chapter Three

Sections 3.11-12

The Law of Conservation of Energy

- The Law of Conservation of Energy states that "Energy can neither be created nor destroyed in a process."

Specific Heat

- Some substances require more energy to raise their temperatures than others.
  - For example, it requires much less energy to raise the temperature of 50. g of aluminum by 10 °C than it would to raise 50. g of water by the same amount.
- This difference is represented by a constant called the specific heat, c.
- Its units are J/(g ·°C) or cal/(g ·°C) .

Transferring Heat

- The amount of heat (*q*) absorbed or given off by a substance when it changes temperature can be found using the following equation:

$$q = m \times \Delta T \times c$$

m is the mass of the substance

ΔT is the change in the temperature; it equals (final *T* – starting *T*)

c is the specific heat of the substance

- Note that heat always flows from an area of high temperature to one of lower temperature!

Example

How much heat is required to raised the temperature of 50.0 g of aluminum from 32 °C to 47 °C? The specific heat of aluminum is 0.903 J/(g ·°C).

Example

We can determine the specific heat of a substance by heating it to a fairly high temperature, then placing it in a cold substance (usually water) of known specific heat. We assume that any heat gained by the water must have come from the other substance.

A 23.55 g piece of metal is heated to 99.8 °C, then placed into 80.0 g of water at 5.5 °C. The system reaches a final temperature of 16.8 °C. What is the specific heat of the metal? The specific heat of water is 4.184 J/(g ·°C).

A More Difficult Example

A 50.0 g aluminum block is heated to 75 °C, then dropped into a sealed container containing 350. g of water at 15 °C. What will be the temperature of the block when it is finished cooling?

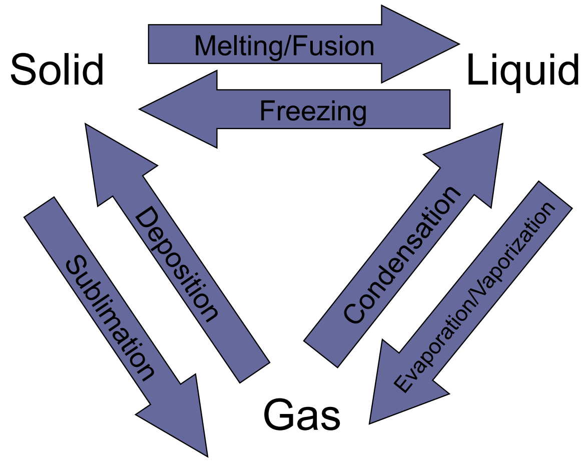
Energy Change during State Changes

Chapter Twelve:

Sections 12.4-5

Changes of State (Review)

- Special terms are associated when matter changes from one state to another.



Energy Changes Associated with Changes of State

- Energy must be added or removed from a substance for a change of state to occur
  - This is true assuming that the ambient pressure does *not* change.
- We know from everyday experience that we must add energy to melt ice and to boil water. Energy must be taken away in the reverse process.

Energy Changes Associated with Changes of State

- The *heat of fusion* (ΔH_{fus}) is the amount of energy required to convert one mole of a substance from its solid state to its liquid state *at the melting/freezing point*
- The *heat of vaporization* (ΔH_{vap}) is the amount of energy required to convert one mole of a substance from its liquid state to its gas state *at the boiling point*
- Both quantities are always positive
  - Why?
- The units of both quantities are typically reported in kJ/mol (although sometimes you will find them in kJ/gram)

Energy Changes Associated with Changes of State

- When energy is added to a pure *solid* at its *melting* point, the temperature of the solid should remain constant, with all energy directed towards overcoming the heat of *fusion*
- Similarly, when energy is added to a pure *liquid* at its *boiling* point, the temperature of the liquid should remain constant, with all energy directed towards overcoming the heat of *vaporization*
- The reverse is true when energy is taken away from a liquid or gas

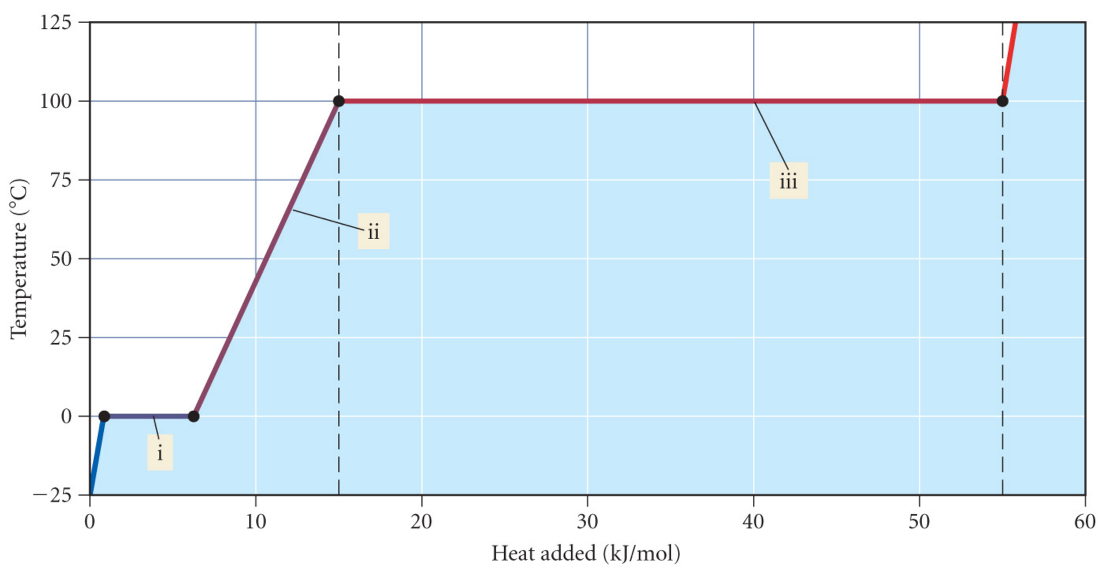
Energy Changes Associated with Changes of State

Suppose we wanted to carry out the following process:

"Take 5.00 grams of solid H_2O at -10 °C and convert it to steam at 120 °C."

(assume constant pressure)

Construct a *heating curve* to show the various stages involved in this process. Then, describe the necessary calculations you would need to carry out to calculate the total amount of heat required to accomplish this.



Examples

Always assume constant pressure for this type of problem unless told otherwise!

a. How much energy is required to convert 10.0 g of solid H_2O to liquid H_2O at 0 °C?
b. What is the change in energy when 10.0 g of liquid H_2O is changed to solid H_2O at 0 °C?
c. How much energy is required to convert 10.0 g of liquid H_2O to gaseous H_2O at 100. °C?

Example

How much energy is required to convert 5.00 grams of solid H_2O at -15.0 °C to liquid H_2O at 45.0 °C?