# Bond Enthalpy & Enthalpy of Reaction

**Unit:** Thermodynamics

### Skills:

* Utilize Latent Heat and Heat Capacity equations
* calculate ΔHrxn from bond enthalpies
* calculate ΔHrxn from  data

### Notes:

Last time, we determined a method for measuring the heat energy absorbed or given off by a system using calorimetry.

We were introduced to heat (q) equations to measure energy flow between the reaction and the water of the calorimeter:

1. **Latent Heat:**

q = m∆H

∆H can be:

∆Hf - heat of fusion (energy required to melt 1 g of ice)

=

∆Hv - heat of vaporization (energy required to boil 1 g of water)

=

1. **Heat Capacity:**

q = mCp∆T

C = the specific heat capacity of that substance

Cice =

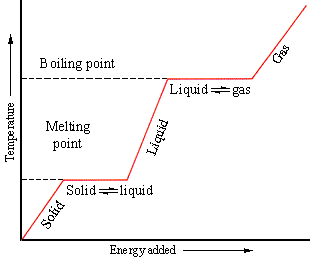
Cwater =

Csteam =



So, if you have to change the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ of a substance AND go through a \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, you would need to use the latent heat equation AND the heat capacity equation. In other words, each section of a heating/cooling curve has a “\_\_\_\_\_\_\_\_\_\_\_\_\_” equation to describe the energy needed to go through it.

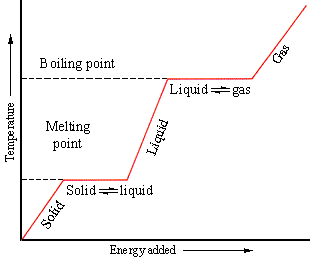
Ex: calculate the amount of energy required to increase the temperature of ice from -10°C to 35°C.



Notice the slopes on the heating cooling curve.

* What do they represent?
* How is the added thermal energy being used?
* Which equation describes this thermal energy flow?

Now investigate the plateaus on the heating cooling curve.

* What do they represent?
* How is the added thermal energy being used?
* Which equation describes this thermal energy flow?

We can also describe the energy released or absorbed during chemical reactions by describing the energy held within the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ of the molecules/compounds.

chemical bond: when two atoms are joined through the sharing of electrons. (We can say “\_\_\_\_\_\_\_\_\_\_\_\_” because no bond is 100% ionic—even CsF has a small amount of covalent character.)

Any chemical bond that actually forms is *always* more \_\_\_\_\_\_\_\_\_\_\_\_\_ than the corresponding unbonded atoms. If the bond were less stable than the unbonded atoms, the bond would fail to form.

* Where does this stability come from?

enthalpy:

state function: a function (variable) whose value depends only on the current state of the system, and whose value is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ of the pathway. Enthalpy is an example of a state function.

In thermodynamics, variables representing state functions are represented by capital letters. (G, H, S)

## Bond Dissociation Energies

“Bond energy” is the energy required to \_\_\_\_\_\_\_\_\_\_ a chemical bond. Generally, bond dissociation energies are for homolytic dissociation (*i.e.,* the electrons are \_\_\_\_\_\_\_\_\_\_\_ split between the two atoms). Heterolytic bond dissociation energies are always higher.



Here are some common heterolytic bond dissociation energies:

|  |  |
| --- | --- |
| Bond | Bond Dissociation Energy |
| C−C | 346 |
| C=C | 602 |
| C≡C | 835 |
| C−H | 411 |
| C−O | 358 |
| C=O | 799 |
| O=O | 494 |
| O−H | 459 |

You can use bond dissociation energies to determine the enthalpy change of a chemical reaction. For example, consider the combustion of methane:

CH4 +   O2 →

This actually means:

break \_\_ C−H bonds + \_\_ O=O bonds → form \_\_ C=O bonds + \_\_ O−H bonds

By convention, energy is positive if we put it in (\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_), and negative if it comes out (\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_). This means the enthalpy needed to break a bond is positive, and the enthalpy released by forming a bond is negative.

Adding the energies of all of the bonds broken and formed in the equation gives the following:

## Enthalpy of Formation

The enthalpy of formation () of a compound is the Δ*H*rxn for the formation of a compound from its elements in their natural state. For Δ*Hf* values measured/calculated at “standard state” (usually defined to be 1 atm and 25°C), we add a superscript °.

The enthalpy of formation of any pure element in its natural state is defined to be \_\_\_\_\_\_\_\_\_\_.

For example:

2 Al (s) + 3 O2 (g) → Al2O3 (s) 

Because  for Al (s) is \_\_\_\_, and  for O2 (g) is also \_\_\_\_\_, this means

 for Al2O3 (s) = 

## Calculating Δ*H*rxn from Enthalpy of Formation Data

Rather than calculate  values from bond energies, it is much more convenient to look them up in a table. Thus, for the reaction:

CH4 (g) + 2 O2 (g) → CO2 (g) + 2 H2O (g)

we could simply look up the  values for each of the compounds:

|  |  |
| --- | --- |
| Compound |  |
| CH4 (g) | −74.8 |
| O2 (g) | 0 |
| CO2 (g) | −393.5 |
| H2O (g) | −241.8 |

Then: