



CHEM 1035 – Lecture 19

Enthalpy – the Heat of Reaction

The energy changes that accompany chemical reactions are an important part of chemistry. Much of the Chemistry field is devoted to using chemical reactions to efficiently extract energy.



Enthalpy – Heat of Reaction

- Focus our attention on the heat flow during a Chemical process

$$\Delta H = \Delta E + P\Delta V$$

$$\Delta H = q_p$$

Where the reaction Enthalpy is symbolized by H

Measuring changes in the heat are relatively simple (e.g. monitoring the temperature), but monitoring the “work” of a chemical process is very difficult. We can focus our attention on the heat by limiting our attention to processes that occur at constant pressure. This is easy to do because we don't have to work very hard to maintain constant pressure – nature provides that for us, e.g. atmospheric pressure.

Given this definition for the change in Enthalpy during a chemical process, how does this isolate our attention onto heat flow? Consider that work done by the system on the surroundings is given by $-P\Delta V$, then $(\Delta)E = q_p + w = q_p - P(\Delta)V$

$$\text{And } q_p = (\Delta)E + P(\Delta)V$$

Enthalpy is a state function. Therefore, the change in enthalpy that accompanies a chemical reaction is simply equal to the enthalpy of the final state minus the enthalpy of the initial state.



Enthalpy is a state function

$$\Delta H_{\text{reaction}} = H_{\text{products}} - H_{\text{reactants}}$$

If: $\Delta H_{\text{reaction}} > 0$ the reaction is
Endothermic

$\Delta H_{\text{reaction}} < 0$ the reaction is
Exothermic

As is the case with all state functions, the value of the reaction enthalpy is independent of the path that the reaction takes – it only depends on the properties of the initial and final conditions of the chemical system.

If heat (q) flows into the system from the surroundings, then the chemical process is said to be Endothermic. If heat (q) flows out of the system into the surroundings, then the chemical process is said to be Exothermic



Origin of Reaction Enthalpy

Where does this heat come from?

Because the heat comes from changes in the bonding, we can consider the heat to be a net reactant or product

In chemical reactions we are rearranging the atoms from reactant molecules to product molecules. In the process, we are breaking chemical bonds, and forming new chemical bonds. It is the process of breaking and making bonds that results in the production (consumption of heat).

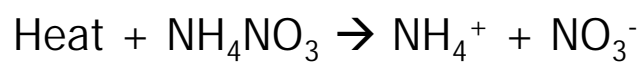
Chemical bonds have different strengths – some are very strong, and some are weak. It requires more energy to break a strong bond than it does to break a weak bond. Similarly, more energy is released when forming a strong bond than is released when forming a weak bond. The energy released/absorbed during a chemical reaction (in the form of heat) is determined by the relative strengths of the bonds being broken and formed.

Examples – combustion releases heat. What does this say about the bond strength?

NH_4NO_3 dissolution – gets colder. What does this say about the ionic interactions?



Examples



Draw enthalpy diagrams for these processes

These are also

1. Heat of formation
2. Heat of combustion
3. Heat of Dissolution
4. Heat of vaporization (heat of fusion is for melting)



Examples of Reactions and their Enthalpy change

- Combustion
- Formation reactions
- Melting/fusing
- Vaporization

Examples of these processes (both physical and chemical) and descriptions of the heat flow associated with each.



Measuring heat flow

Calorimetry – Laboratory method for measuring the Heat of Reaction.

$$\Delta H = q_p$$

Calorimetry is the name given to laboratory measurements that are used to determine the Enthalpy change that accompanies a chemical reaction. These measurements are dependent on the relationship between the temperature change, the heat (q) and Enthalpy for the determination.

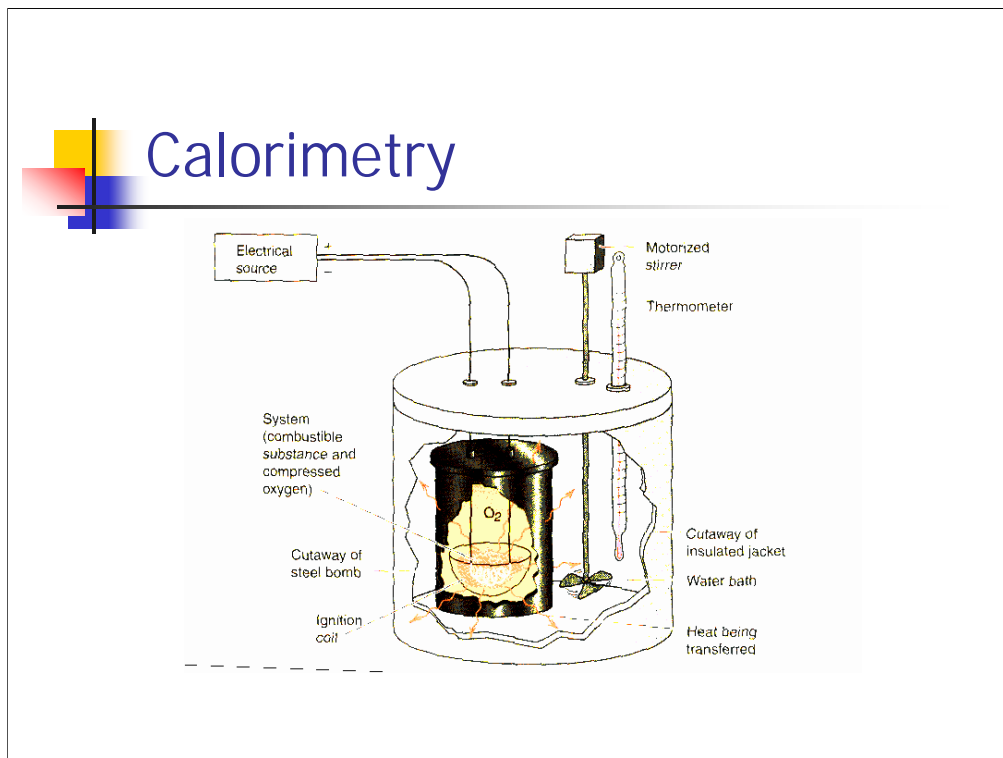


Figure from the text of a constant volume calorimeter. Basically the reaction is conducted in an enclosed container that is surrounded by an insulated water bath. The idea is that any heat generated (or consumed) by the reaction inside the system is absorbed by (or provided from) the surroundings (e.g. the water bath). By monitoring the temperature of the water bath, we get a measurement of the amount of heat transferred.

2 types of calorimetry – (1) constant volume (e.g. enclosed) and (2) constant pressure (e.g. open to atmosphere). Only the constant pressure measurement provides a direct measurement of $(\Delta)H$.

Question – do all materials conduct heat equivalently? Consider reaching in the hot oven to remove a pan that you've been cooking in. If you touch it with your fingers, they get hot almost immediately. If you were an oven mitt – your fingers are protected because the mitt does not conduct the heat very well. What other things conduct heat well? Not very well? (metals, fiberglass insulation, ceramics)

Calorimetry relies on the fact that the heat change of the system is equal to, but opposite of the heat change of the surroundings. In calorimetry, you are measuring the temperature change of the surroundings, and then relating that to the changes that are occurring in the system.



Heat Capacity

The heat capacity is broadly defined as the ability of a substance to absorb heat.

$$q \propto \Delta T$$

$$\frac{q}{\Delta T} = \textit{Heat Capacity}$$

When an object absorbs heat, then the temperature rises. The temperature rise is proportional to the amount of heat absorbed, and the proportionality factor is the Heat Capacity.

Specific Heat Capacity (lower case c) is defined as the quantity of heat required to change the temperature of 1 gram of a substance by 1K.

Molar heat capacity (C) is defined as the quantity of heat required to change the temperature of 1 mole of a substance by 1K.

This is a proportionality factor that tells us the relationship between the amount of heat generated in a reaction and the Temperature change.

Work some example problems



Example

What is q when 12.0gm of water is heated from 20° C to 100° C?



Thermochemistry and Stoichiometry

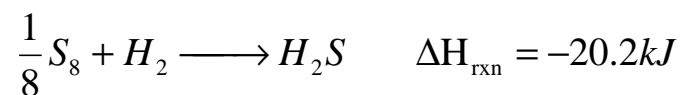
Have already indicated that we can think of “heat” as being a reactant (endothermic process) or a product (exothermic process) in a chemical reaction. This can be quantified by relating reaction stoichiometry to the “Heat of Reaction”

$$\Delta H_{\text{rxn}}$$

The heat of reaction (or the enthalpy of a balanced chemical reaction) provides a stoichiometric relationship between the moles of reactants/products and the Enthalpy change of the reaction.



Example



What is ΔH_{rxn} if 20.0gm S_8 reacts?

What does this reaction say? $1/8$ mole of S_8 reacts with 1 mole of H_2 to produce 1 mole of H_2S and produces 20.2kJ of heat. Is the reaction exothermic or endothermic? What is the enthalpy change if we change the stoichiometric coefficients to whole numbers?

What is the stoichiometric equivalence from this balanced Thermochemical reaction?