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Stream 11-1

Chemistry Notes: Energetics

Energy is a measure of the ability to do work (move object against opposing force)

Forms of Energy: Heat, Light, Sound, Electricity, and Chemical Energy

Heat is energy transferred as a result of temperature difference. It increases disorder in particle behavior (entropy). Heat increases the average kinetic energy in disordered fashion.

A joule is a measure of heat. 1 Joule of work occurs when 1 Newton of force is enacted over 1 meter.

5.1: Exothermic and Endothermic Reactions

5.1.1 Define the terms exothermic reaction, endothermic reaction, standard enthalpy change of endothermic reaction

Exothermic reactions are reactions that release energy. (5.1.2 :All Combustion and Neutralization reactions are exothermic)

- They are the transfer of heat from the system to the surroundings.
    - An open system can exchange energy and matter with surroundings.
    - An open system can exchange only energy with surroundings.
- Products have less energy or heat content (enthalpy) than reactants.
- ΔH is negative.
- Examples:

$$CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O(l)\ \Delta H = -890\ kJ\ mol^{-1}\ (releases\ 890\ kJ\ of\ heat)$$

$$2Al_{(s)} + Fe_2O_{3(s)} \rightarrow Al_2O_{3(s)} + 2Fe_{(s)} \Delta H = -841\ kJ\ mol^{-1}\ (releases\ 841\ kJ\ of\ heat)$$

Endothermic Reactions absorb heat.

- They are the transfer of heat from the surroundings to the system.
- Products have more energy and enthalpy than reactants.
- ΔH is positive

- Example: Photosynthesis Reaction:

$$6CO_{2(g)} + 6H_2O_{(l)} \rightarrow C_6H_{12}O_{6(aq)} + 6O_{2(g)} \Delta H = +2802.5\ kJ\ mol^{-1}\ (absorbs\ 2802.5\ kJ\ of\ heat)$$

State Symbols are important because enthalpy/energy depends on the state of reactants and products.

$$Ba(OH)_2.8H_2O_{(s)} + 2NH_4SCN_{(s)} \rightarrow Ba(SCN)_{2(aq)} + 2NH_{3(g)} + 10H_2O_{(l)}\ \Delta H\ is\ positive$$

The standard enthalpy change of a reaction is the difference in enthalpy between the reactants and the products.

Standard Conditions for enthalpy changes:

- Temperature of 298 Kelvin or 25 degrees centigrade.
- Pressure of 101.3 kPa (1 atm)
- For Solutions: 1 mol dm^{-3}
- All substances in standard state

5.1.3: Apply the relationship between temperature change, enthalpy change, and the classification of reactions as exothermic and endothermic (the latter is completed in 5.1.2)

-Temperature is a measure of the average kinetic energy of particles.

- If the **same amount of heat** is added to two substances the temperature change **will not be the same**

- The substance with **smaller number of particles** experiences a **greater temperature change**.

  - Increase in temperature when object is heated depends on:
    - Mass of Object (not molar mass, the mass given in a problem ex: 10 grams of water)
    - Amount of Heat Added
    - The Nature of Substance

Different substances need a different amount of heat to increase their temperatures by 1 K (these amounts are due to an elements **specific heat capacity**)

Formula for all heat changes:

$$\Delta H = mass(m)\ x\ specific\ heat\ capacity(c) x\ temperature\ change\ (\Delta T)$$

Remember that when heat is given off, the temperature goes down. So if ΔT is from 85 to 25 degrees centigrade, the heat change will be negative because this is an exothermic reaction.

On the contrary, if the temperature goes from 25 to 85 degrees, the heat change will be positive because this is an endothermic reaction.

5.1.4: Deduce from the enthalpy level diagram, the relative stabilities of reactants and products and the sign of the enthalpy change from the reaction

Chemicals are changing in a way that reduces their enthalpy.

In an exothermic reaction, the reactants are **more stable than the products** because they have a lower enthalpy than the products.

Hydrogen peroxide is stable relative to hydrogen and oxygen (alone as gases).

Hydrogen peroxide is unstable relative to its decomposition in water.

Order in decreasing stability:

$$H_2O_{(l)} + \frac{1}{2}O_{2\,(g)} > H_2O_{2(l)} > H_{2(g)} + O_{2(g)}$$

It is important to note that the enthalpy difference between decomposed hydrogen peroxide and hydrogen peroxide is greater than the enthalpy difference between hydrogen peroxide and hydrogen and oxygen gas.

Endothermic reactions are generally less common and occur when disorder increase in a system.

5.2: Calculations in enthalpy changes

5.2.1 & 5.2.2: Calculate the heat energy change when the temperature of a pure substance is changed

Enthalpy Change Combustion: The heat produced when one mole of a substance is burned in excess oxygen.

Ethanol can be combusted then the heat given off can be determined by the temperature change of a sample of water heated by the flame.

As the temperature of the water in the apparatus increase, the enthalpy of the substance (in this case ethanol decreases).

As the **mass** of the burner and its contents **decreases**, the **reading** of the thermometer **increases**.

The heat produced by the reaction can be calculated based on the temperature change in water assuming that the water has absorbed all the heat given off by the reaction.

$$Heat\ change\ of\ the\ reaction = -(heat\ change\ of\ water)$$

The above principle hold true. For example, in the exothermic combustion of ethanol, the heat change is negative, because it **gives off** heat to the water. Consequently, the water would have a positive heat change.

Thus we can assume that if the enthalpy change in water is negative, the reaction is endothermic.

To calculate enthalpy of combustion given the mass of water, the temperature increase of water, and the mass of ethanol burned:

1.) Find the number of moles of ethanol (divide mass burned by molar mass).
2.) Set up the equation for heat change of reaction. (heat change rxn = -(heat change of water)) remember that in this case delta H = the heat change of reaction for one mole of ethanol.
3.) Divide the temperature change of water by the "mass of ethanol burned-to-molar mass of ethanol" ratio. Basically:

$$\frac{\Delta T \ of \ Water}{mass \ of \ substance \ (ethanol) \ burned \ in \ moles}$$

4.) Do the calculations. Remember that the final heat change is limited in terms of sig figs by the mass of the substance burned. In this case, the answer is limited to two sig figs.

Two concepts that make the heat calculated different from heat change in IB booklet:

- Not all heat produced is transferred to water (some heats the calorimeter, some passes to surroundings)
- The combustion of ethanol is not complete due to limited amount of oxygen available.

5.2.3 & 5.2.4: Enthalpy changes of reaction in solution

Solution reactions most commonly take place in a polystyrene cup because it traps heat and keeps if from going to surroundings due to its low heat capacity.

In these reactions, heat is lost from the system as soon as the temperature of the water rises above the temperature of its surroundings.

The following equations hold true for reactions in solutions:

$$\Delta H_{system} = 0 \ (assuming \ no \ heat \ is \ lost \ to \ surroundings)$$

$$\Delta H_{system} = \Delta H_{water} + \Delta H_{reaction}$$

To calculate the molar heat change of the reaction, you need to determine the number of moles of limiting reagent that went through with the reaction.

$$Molar \ heat \ change \ reaction = -m_{H_2O} \ x \ c_{H_2O} \ x \ \frac{\Delta T \ of \ H_2O}{(moles \ of \ limiting \ reagent)}$$

In order to determine the number of moles of the limiting reagent recall the formula:

$$number \ of \ moles \ (n) = [limiting \ reagant] \ x \ \frac{volume(cm^3)(V)}{1000}$$

If the solution is dilute, we can assume that volume of water is equal to the volume of the limiting reagent (Because the solvent spreads throughout)

We also assume that the density of water is 1.00 gm cm^{-3} therefore the volume of water and the mass of water are the same (you can prove this using d = m/v) if d = 1, then m must equal v

You can thus manipulate the following equation:

$$molar\ heat\ change = -m_{H_2O}\ x\ c_{H_2O}\ x\ \frac{\Delta T\ of\ H_2O}{([limiting\ reagant]\ x\ Volume\ of\ Limiting\ reagant)/\ 1000}$$

Assuming volume of limiting reagent = volume of water and volume of water = mass of water

$$molar\ heat\ change = -c_{H_2O}\ x\ \frac{\Delta T\ of\ H_2O}{([limiting\ reagant])/\ 1000} kJ$$

Remember to calculate percent error: (Accepted value – Experimental)/(Accepted Value) x 100

(You are always comparing with the IB booklet)