A temperature change occurs when temperature is increased or decreased by the flow of heat. This shifts chemical equilibria toward the products or reactants, which can be determined by studying the reaction and deciding whether it is endothermic or exothermic.

Introduction

Le Chatelier's principle states that a change in temperature, pressure, or concentration of reactants in an equilibrated system will stimulate a response that partially off-sets the change to establish a new equilibrium. In the case of changing temperature, adding or removing of heat shifts the equilibrium. Typically chemical reactions are written to not explicitly address the flow of heat in the reaction. For example, the below chemical equation describing the oxidation of carbon to make carbon monoxide contains all the information regarding matter and bonding:

\[
\ce{2C (s) + O_2 (g) -> 2CO (g)}
\]

However, reactions invariably involve changes in enthalpy, with energy (typically in the form of thermal energy via heat) either being absorbed or released during the reaction. The more complete reaction would be written as

\[
\ce{2C (s) + O2 (g) -> 2CO(g) + heat}
\]

Heat of Reaction

The Heat of Reaction is the change in the enthalpy of a chemical reaction. In endothermic reactions, \((\Delta H>0)\) thermal energy is absorbed via the reaction. Another way to view endothermic reactions is that more (thermal) energy is needed to overcome the forces of attraction between molecules and to separate them from one another (the activation energy) than (thermal) released when new bonds are formed.

\[
\ce{heat + 6CO2(g) + 6H2O(l) <=> C6H12O6(aq) + 6O2(g)}
\]

In exothermic reactions, \((\Delta H<0)\) thermal energy is general with reaction. When new bonds are generated, more thermal energy is released that needed to break bonds in the reactants. In this chemical reaction

\[
\ce{CaO (s) + H2O(l) <=> Ca(OH)2(s) + heat}
\]

the forward reaction is exothermic because energy is released when \(\ce{CaO(s)}\) and \(\ce{H2O(l)}\) combine to form \(\ce{Ca(OH)2(s)}\). The energy to break the bonds in \(\ce{CaO(s)}\) and \(\ce{H2O(l)}\) on the left side of the equation is less than the energy released from forming the \(\ce{Ca(OH)2(s)}\) on the right side of the equation; the net difference is observed as heat on the right side of the equation.

Example \(\PageIndex{1}\)

In the oxidation reaction

\[
\ce{CaO(s) + H2O(l) <=> Ca(OH)2(s) + heat}
\]
Raising the temperature favors the reverse reaction (endothermic) and similarly Lowering the temperature favors the forward reaction (exothermic)

Example \(\PageIndex{2}\)

In the reaction

\[
2\text{C(s)} + \text{O}_2 (\text{g}) \rightleftharpoons 2\text{CO(g)} + \text{heat}
\]

Le Chatelier’s principle explains that the reaction will proceed in such a way as to counteract the temperature change. The exothermic reaction will favor the reverse reaction, opposite the side heat is (the opposite is true in endothermic reactions; the reaction will proceed in the forward reaction)

Although it is not technically correct to do so, if heat is treated as product in the above reaction, then it becomes clear that if the temperature is increased the equilibrium will shift to the left (using Le Chatelier’s principle). If temperature is decreased, the reaction will proceed forward to produce more heat (which is lacking). The effect of temperature on equilibrium will also change the value of the equilibrium constant.

Problems

1. If heat is added to a phase change equation at equilibrium from solid to liquid, which way will the reaction proceed?
2. Which side is heat on in this reaction (photosynthesis): \[6\text{CO}_2(\text{g}) + 6\text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{C}_6\text{H}_{12}\text{O}_6(\text{aq}) + 6\text{O}_2(\text{g})\]
3. In a combustion reaction is heat absorbed or released?
4. In this reaction: \[\text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{H}_2\text{O}(\text{g})\], how could conditions be manipulated to create more \(\text{H}_2\text{O}(\text{l})\)?
5. Explain how to determine if a reaction is exothermic or endothermic.

Solutions

1. The reaction will proceed towards the liquid phase.
2. Heat is on the reactant side of the equation.
3. Heat is released in a combustion reaction.
4. Lowering temperature will shift equilibrium left, creating more liquid water.
5. A reaction that is exothermic releases heat, while an endothermic reaction absorbs heat.

References

Contributors and Attributions

- Karissa Pulido (UCD), Carlynn Chappell (UCD), Aileen McDuff (UCD)