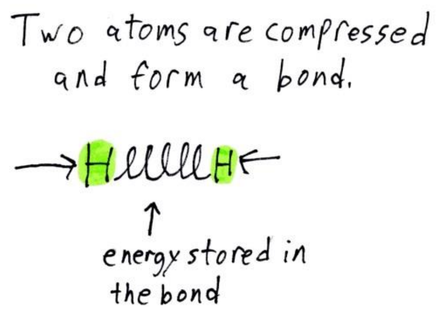
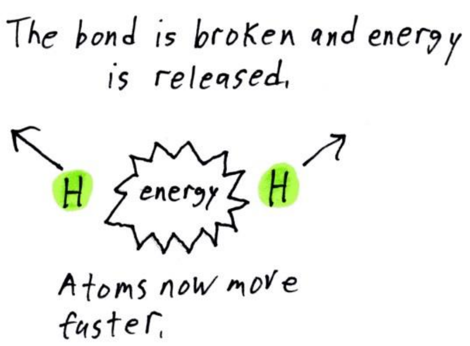
Chemistry Lecture #99: Change in Enthalpy

All substances are made of atoms, and atoms stick to each other and form bonds. The bonds between atoms contain energy. The bonds between atoms are like springs. If the spring is compressed, energy is stored in the spring. If the spring is broken, it uncoils and releases energy.

It takes energy to push atoms together to form bonds. In a sense, the bond/spring between two atoms is being compressed, and energy is stored in the bond/spring.



If the bond/spring between atoms is broken, energy is released from the bond/spring. The released energy pushes the atoms, which causes the atoms to move faster. The atoms now have more kinetic energy. Thus, the stored energy has been converted into kinetic energy.



In a chemical reaction between substances, old bonds break between atoms, which releases energy. New bonds are then formed, which stores energy.

If the energy released in a chemical reaction is greater than the energy that is absorbed, we have an *exothermic reaction*. We can detect an exothermic reaction if the substances involved in the reaction become warmer.

If the energy absorbed in a chemical reaction is greater than the energy that is released, we have an *endothermic reaction*. We can detect an endothermic reaction if the substances involved in the reaction become cooler.

One example of an exothermic reaction is the combustion of propane (C_3H_8) to form CO_2 and H_2O. This reaction releases 2219 kJ of energy per mole of C_3H_8 consumed.

$$C_3H_8\ (g) + 5O_2\ (g) \Rightarrow 3CO_2\ (g) + 4H_2O\ (g) + 2219\ kJ$$

Instead of writing "2219 kJ" as a product, we write $\Delta H = -2219$ kJ off to the right.

$$C_3H_8\ (g) + 5O_2\ (g) \Rightarrow 3CO_2\ (g) + 4H_2O\ (g) \quad \Delta H = -2219\ kJ$$

ΔH is the change in enthalpy. This is the energy absorbed or released in a chemical reaction. The negative sign in front of the 2219 kJ means that the reaction loses or releases energy, making it an exothermic reaction.

SiH_4 can be made from Si, H_2, and energy.

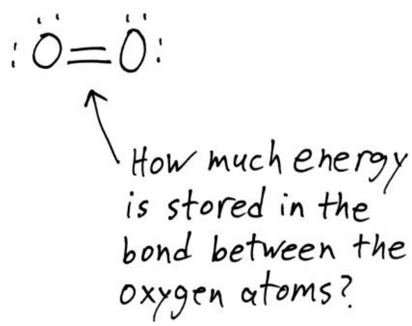
$Si_{(s)} + 2H_{2\,(g)} + 34\text{ kJ} \rightarrow SiH_{4\,(g)}$

Notice that 34kJ of energy was added or absorbed by Si and H_2, making this an endothermic reaction. Instead of adding 34 kJ to the left side of the equation, we write ΔH = 34 kJ off to the right of the equation.

$Si_{(s)} + 2H_{2\,(g)} \rightarrow SiH_{4\,(g)} \quad \Delta H = 34\text{ kJ}$

Since the value of ΔH (34 kJ) is a positive number, it means that the reaction absorbs energy. The enthalpy of the reaction is positive, meaning that the reaction is endothermic.

Can we ever know the absolute amount of energy that exists in a bond? Suppose we have an oxygen molecule, which consists of two oxygen atoms attached to each other with a double bond. How much energy is in this bond?



The answer is that we will never know the total amount of energy in the bond. We can measure the energy that goes into it, and the energy that comes out of it, but we'll never know the absolute amount of energy inside the bond.

This is true for all molecules. We just don't know how much total energy is stored in the bonds between atoms in a compound. The best we can do is measure the *change* in energy, ΔH, that occurs in a chemical reaction.

If a compound is formed from elements under the standard state (25 °C and 1 atm of pressure), ΔH is given a special name: heat or enthalpy of formation (ΔH^o_f). The "o" above the H means that the reaction is occurring at the standard state.

(Note: standard state and standard temperature and pressure are *not* the same. At STP, temperature is 0°C).

For example, when solid carbon reacts with oxygen under standard states to form CO_2, energy is released.

$$\underset{\text{element}}{C_{(s)}} + \underset{\text{element}}{O_{2\,(g)}} \rightarrow \underset{\text{compound}}{CO_{2\,(g)}} \qquad \Delta H^o_f = -394 \text{ kJ/mole}$$

Thus, when one mole of CO_2 is formed from elements, 394 kJ of energy is released.

What would be the heat of formation for an oxygen molecule? Chemist arbitrarily set the heat of formation for elements in the standard state as zero. Thus, when oxygen atoms form oxygen molecules, $\Delta H^o_f = 0$. Likewise, all other elements in molecular form, such as S_8, Cl_2, and H_2, have $\Delta H^o_f = 0$.