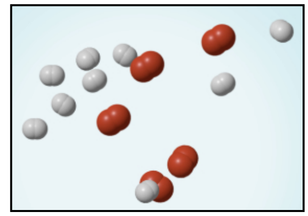
Student Exploration: Reaction Energy

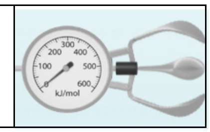


Gizmo Warm-up
Just like magnets, atoms of different elements are attracted together to form **chemical bonds**. Breaking these bonds requires energy. When a new bond forms, energy is released and temperatures rise.

To begin, check that **Reaction 1** and **Forward** are selected. In this reaction, hydrogen (H_2) and oxygen (O_2) react to form water (H_2O). The reaction takes place inside a device called a **calorimeter**. Inside the calorimeter, a small chamber holds the reactants. The rest of the calorimeter is filled with water.

1. Click **Play** (▶). What happens? ____

2. How does the temperature change? Why? ____

Activity A: **Energy of chemical bonds**	Get the Gizmo ready: • Check that **Reaction 1** and **Forward** are selected. • Select the INVESTIGATION tab.	

Introduction: The heat energy stored in a chemical system is called the **enthalpy** (*H*) of the system. When atoms are joined by a chemical bond, energy must be added to pull them apart. This increases the enthalpy of the system. When a chemical bond forms, energy is released as shared electrons move into lower-energy orbitals. This causes the enthalpy to decrease.

Question: How can you predict how much energy is released in a chemical reaction?

1. Observe: In the Gizmo, the energy required to break a chemical bond is modeled by placing a molecule into a set of mechanical claws. Place one of the hydrogen (H_2) molecules between the claws, and press **Break bond**.

   A. Look under the **Energy absorbed** column of the table. How much energy was required to break this bond? _____________

   Note: The energy is given here in units of kilojoules per mole (kJ/mol). This is the energy, in kilojoules, required to break all of the H–H bonds in one mole of H_2 gas.

   B. Remove the hydrogen atoms from the claws and then break apart the other H–H molecule. What is the total energy absorbed so far? ______________________________

2. Measure: Notice that the oxygen atoms are connected by a double covalent bond. This is because the oxygen atoms share two pairs of electrons. Place the oxygen molecule in the claws and press **Break bond**.

   A. How much energy is required to break the first O–O bond? ___________

   B. Press **Break bond**. How much energy is needed to break both bonds? ___________

   C. What is the total energy required to break up two moles of H_2 molecules and one mole of O_2 molecules? ____

3. Create: Remove the two oxygen atoms from the claws. Now the claws disappear and you see a template for creating a water molecule. Drag an oxygen and a hydrogen atom into the template.
   A. Click **Create bond**. What happens? ____

   B. The "jiggling" animation you see represents the release of kinetic energy that occurs when a bond is formed. How much energy was released? ________________________

   C. Drag another hydrogen molecule into the template and click **Create bond** to make a water molecule. What is the total energy released so far? ________________

   D. Drag the first water molecule away from the template, then use the Gizmo to create a second water molecule. What is the total energy released now? _________________

4. Calculate: Compare the energy absorbed in breaking up the molecules to the energy released when new bonds are formed.

   A. In this reaction, was more energy absorbed or released? ________________________

   B. How does this relate to the change in temperature observed for this reaction?

   ____

   C. The change in enthalpy (ΔH) of the system is equal to the total energy absorbed minus the total energy released. What is the ΔH value for this reaction? ____________

   Compare this value to the **Theoretical ΔH** listed on the right side.

5. Draw conclusions: The experimental ΔH value was determined by measuring how much heat the reaction produced inside the calorimeter. This is calculated based on the temperature change of the reaction, the amount of water inside the calorimeter, and the specific heat of the calorimeter. Compare the theoretical change in enthalpy to the experimental value.

   Are these values close? ____

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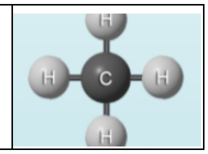
Activity B: **Bond enthalpy**	Get the Gizmo ready: • Select **Reaction 3** and **Reverse**. • Select the INVESTIGATION tab.	

Introduction: Each chemical bond has a "bond enthalpy" that describes how much energy is absorbed to break a bond and how much energy is released when the bond is formed. (These values are the same.) A chart of bond enthalpies for some common bonds is shown below.

Bond	Enthalpy (kJ/mol)	Bond	Enthalpy (kJ/mol)	Bond	Enthalpy (kJ/mol)
C–H	413	O–H	463	H–H	436
C–C	348	O=O	495	N–H	391
C=C	614	O–S	265	N≡N	941
C=O	799	O=S	523	S–S	266

Question: How can you use bond enthalpy to predict the total enthalpy change of a chemical reaction?

1. Calculate: Consider the reaction $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$.

   A. In the reactants, how many C–H bonds are there? __________

   B. Using the chart above, what is the total bond enthalpy of these bonds? ___________

   C. How many O=O bonds are there? ___________

   D. What is the total enthalpy of these bonds? __________

   E. What is the total bond enthalpy of the reactants? ___________

   F. Do the same calculation for the products of the reaction, $CO_2 + 2H_2O$. Carefully count how many of each bond there is, and consider whether bonds are single or double bonds.

      Total bond enthalpy of products: _____________________

   G. Based on the enthalpy of the reactants and products, what is the ΔH value for this reaction? (Recall that ΔH = energy absorbed – energy released.) ____________

   H. Use the Gizmo to check your results, and correct any errors if necessary.

2. Analyze: In all of the reactions you investigated today, did it make any difference in which order you broke bonds or formed bonds? ____________________________________

   Explain your answer. ____