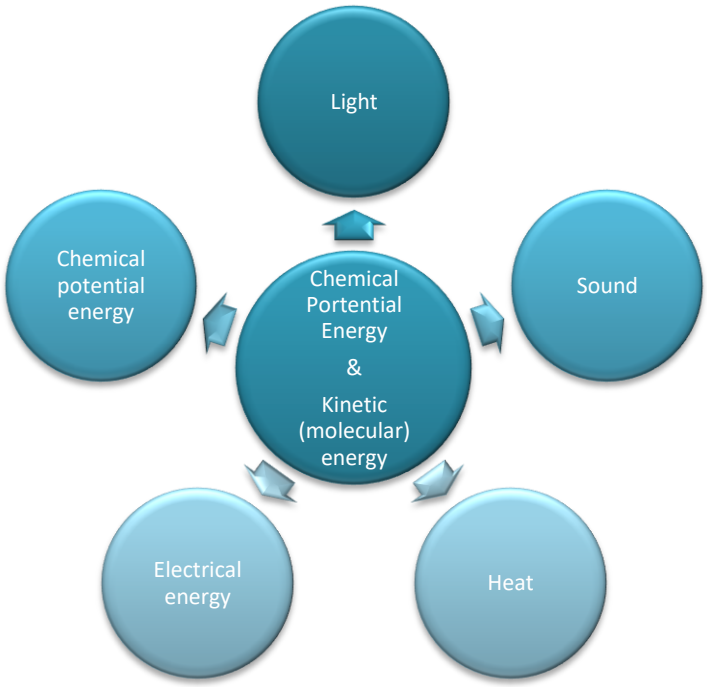
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# Bond Energy and the Types of Reactions Guided

Notes – Student Edition

Thermochemistry is the area of chemistry that focuses on the amount of heat _____ or _____ during chemical and physical changes.

All chemical reactions involve energy _____, changing from one form (chemical potential energy found in the bonds of the reactants or the kinetic energy of moving molecules) to another form such as _____ , _____ and _____. In some reactions, these energy changes can be observed by either an increase or a decrease in the overall energy of the system.




**Heat Energy**

Heat or thermal energy is _____energy which is related to the random movement of atoms and molecules. Temperature is a _____ measure of "hot" or "cold." When the atoms and molecules in an object are moving or vibrating quickly, they have a higher _____ _____ _____ (KE), and the object is "_____." When the atoms and molecules are moving slowly, they have _____ _____; the object is "_____". Increasing the amount of thermal energy of a substance will cause its temperature to increase and the substance will _____. Likewise, decreasing the amount of thermal energy in a substance will cause its temperature to decrease and the substance will _____.

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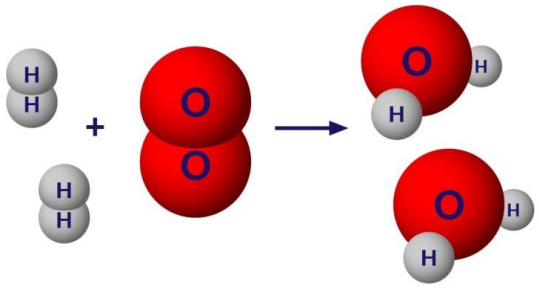
### What causes the energy changes in chemical reactions?

When substances participate in a chemical reaction they either release or absorb _____. During a reaction, the bonds in the reactants are _____ and new bonds are _____, creating the product(s). Energy is required to break bonds, which is then _____ when new bonds are formed. The amount of energy needed or released for a reaction depends on the _____ _____ _____ between that which is required to break the bonds and that which is released when the new bonds are formed.

**Example: Forming Water**

Hydrogen reacts with oxygen to form water, as is seen by the following equation:

$$2H_2 + O_2 \rightarrow 2H_2O$$




In this reaction, the _____ between the two hydrogen atoms in the $H_2$ molecule breaks, as will the bond between the oxygen atoms in the $O_2$ molecule. New bonds will form between two of the hydrogen atoms and a single oxygen atom in the water molecule (the _____).

When bonds break, energy is _____ from the surroundings, making this an _____ process. Energy is _____ when new bonds form, this is an _____ process.

### Making and Breaking Bonds

There are several factors which affect the ability of a bond to be broken.

**Bond Order:**

This is the _____ of electron pairs shared between two bonded _____.

- Bond order one – where two electrons are shared in a _____ bond between two atoms.

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- Bond order two – two electron pairs (i.e. four electrons in total) in a _____ bond.
- Bond order three – three electrons pairs (6 electrons in total) between two atoms in a _____ bond.

**Bond Length:**

This is the _____ between the nuclei of the atoms in a bond at the minimum point of energy. Bond lengths depend on the _____ of the atoms involved and the bond _____. Where there is a bond order of two or three, the levels of attraction between the nuclei are much _____ and the atoms are _____ _____ (i.e. there is a smaller bond length). Therefore, as the bond order _____, the bond length _____. The table below shows the bond length for some common carbon bonds.

| Bond | Bond length (picometers) |
|---|---|
| C—O | 143 |
| C = O | 122 |
| C—C | 154 |
| C = C | 134 |
| C ≡ O | 120 |

**Bond Energy:**

The energy required to break a bond is called the _____ _____or bond dissociation energy. Bond energies are measured in the units of kilojoules per mole ($kJ.mol^{-1}$).

**Practice Questions:**

1. What is thermochemistry?

2. Name the types of observable energy released in a chemical reaction.

3. Define temperature

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4. Why is energy required for a chemical reaction?

5. List the three factors which affect the strength of a chemical bond.

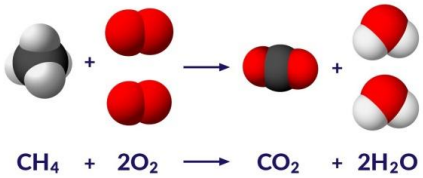
### Calculating Bond Energies

Since energy is always needed to break a bond (i.e. the process is _____), bond energy is always represented as a _____ number. The _____ _____of energy needed to break a bond is then released when that particular bond _____. The table below shows some of the common bonds seen in this course and their respective bond energies. The examples that follow show how this information can be used to calculate the change in energy (called _____ _____) during the course of a reaction.

| Bond | Bond Energy (kJ $mol^{-1}$) |
|---|---|
| C—H | 414 |
| C—O | 358 |
| C=O | 804 |
| H—O | 463 |
| N—H | 391 |
| H—H | 436 |
| C—C | 346 |
| C=C | 614 |

### Example Question

The combustion of methane forms carbon dioxide and water, as shown in the equation below:




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Calculate the enthalpy change for this reaction.

Drawing the diagrams as Lewis diagrams enables the bonds to be viewed:

*Step 1: Identify and total the bonds which are broken for each reactant:*

| **Reactant** | **Number of bonds** | **Enthalpy of bonds broken** | **Total enthalpy** |
|---|---|---|---|
| $CH_4$ | | | |
| $O_2$ | | | |

*Step 2: Total the energy for the bonds broken:*

1656 + 996 = _____

*Step 3: Identify and total the bonds which are made for each product:*

| **Product** | **Number of bonds** | **Enthalpy of bonds formed** | **Total enthalpy** |
|---|---|---|---|
| $CO_2$ | | | |
| $H_2O$ | | | |

*Step 4: Total the energy for the bonds made:*

1608 + 1852 = _____

*Step 5: Use the equation change in energy = energy required to break bonds – energy required to form bonds*

$\Delta H$ = 2652 – 3460 = _____

**Practice Question:**

Use the bond enthalpies in the table below to calculate the enthalpy change for formation of HCl.

The equation for this reaction is:

$$H_{2(g)} + Cl_{2(g)} \rightarrow 2HCl_{(g)}$$

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| Bond | Bond Enthalpy (kJ $mol^{-1}$) |
|---|---|
| H—H | 436 |
| Cl—Cl | 242 |
| H—Cl | 431 |

Answer:

Explanation:

**Endothermic Reactions**

The features of an endothermic reaction include:

- They _____heat energy from their surroundings in order to break the bonds in the _____.
- The energy required to break these bonds is _____ _____ the total energy released when the products are formed.
- As the reaction progresses, the products have _____ energy than the reactants.
- The enthalpy change will be _____
- This type of reaction can be represented by the following formula:

**Reactants + Energy → Product**

**Examples of Endothermic reactions**

- The thermal decomposition of limestone

  The breakdown of limestone into quicklime (calcium oxide) and _____ _____ is a very important process used in a variety of industries. Quicklime is used to make steel from iron and also to neutralize soils that are too acidic. The limestone must be heated in a kiln at a temperature of over 9000$^{o}$C before the thermal decomposition reaction, which breaks the bonds in the calcium carbonate will take place. The equation for the reaction is shown below:

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$$CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$$

- Ammonium nitrate dissolving in water

  When solid ammonium nitrate (_____) dissolves in a beaker of water, the water becomes _____ since the ammonium nitrate _____ energy from the water. The equation for this reaction is shown below:

$$NH_4NO_{3(s)} \xrightarrow{H_2O} NH_4^+{}_{(aq)} + NO_3^-{}_{(aq)}$$

The dissolved ammonium nitrate ($NH_4^+{}_{(aq)}$ and $NO_3^-{}_{(aq)}$ ions) contain _____ energy than the solid ammonium nitrate.

**Other Examples of Endothermic Reactions:**

- Photosynthesis
- Liquids evaporating
- Solids melting

**Exothermic Reactions**

The features of an exothermic reaction include:

- They _____ energy into their surroundings in the form of _____ and _____.
- The products have _____ energy than the _____ since energy is lost from the system
- The enthalpy change will be _____.
- We can represent an exothermic reaction using the following general formula:

**Reactants → Product + Energy**

**Examples of Exothermic reactions**

- Combustion Reactions

  When a fuel such as methane gas in burns oxygen it produces large amounts of _____ and _____. The burning of fuel is an example of a combustion reaction and is heavily

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relied on to produce the energy used in the production of electricity. Recall that the general equation for complete combustion is:

Fuel + Oxygen → Heat + Water + Carbon Dioxide

The following equation describes the combustion of a hydrocarbon such as methane ($CH_4$)

$$CH_4 + 2O_2 \rightarrow \text{Heat} + H_2O + CO_2$$

- Dissolving Sodium Hydroxide

  When solid sodium hydroxide pellets, NaOH (s) are dissolved in a beaker of water, the water becomes _____. This is an exothermic reaction since the heat energy that has been produced has been _____ to the surrounding water. The chemical equation for this reaction is:

$$NaOH_{(s)} \xrightarrow{H_2O} Na^+_{(aq)} + OH^-_{(aq)}$$

The dissolved sodium hydroxide ($Na^+_{(aq)}$ and $OH^-_{(aq)}$ ions) contains _____ energy than the solid sodium hydroxide.

**Other Examples of Exothermic Reactions:**

- Burning magnesium to form magnesium oxide
- Acid-Base (neutralization) reactions
- Explosions such as the Hindenburg disaster

**Practice Questions:**

Decide if the following reactions are endothermic or exothermic. Give a reason for your answer.

1. Magnesium metal is added to hydrochloric acid. The test tube becomes warm and the metal fizzes rapidly, releasing hydrogen gas. Water is vaporized to steam.

   Answer:

   Justification:

2. Ice melts

   Answer:

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Justification:

3. Two chlorine atoms combine to form a chlorine molecule.

   Answer:

   Justification:

4. Alcohol evaporates when placed on the skin

   Answer:

   Justification:

5. Plants use photosynthesis to generate the carbohydrate glucose.

   Answer:

   Justification:

**Dissolving and Energy**

The process of dissolving a solid such as those described in the examples above contains both endothermic and exothermic processes. When a solid dissolves two processes occur:

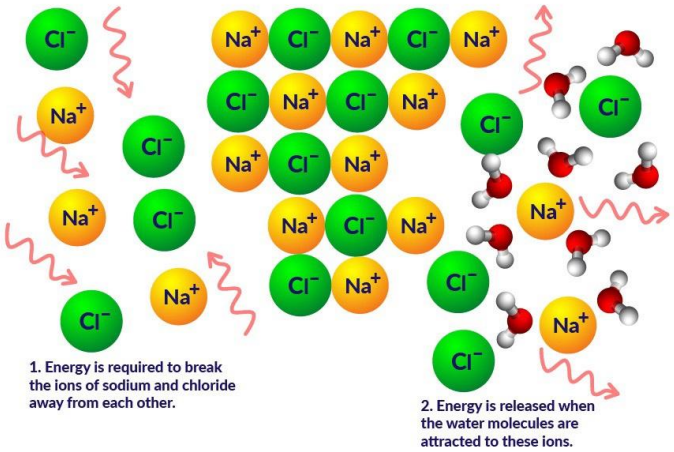
1. The solid particles _____. This process must overcome the _____ _____ which hold the solid particles together and therefore requires energy to be put into the system. This process is _____.
2. The solvent particles are attracted to and surround the separated solid particles. This process is _____ as it releases energy.

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Whether the overall dissolving process is endothermic or exothermic depends on the amount of _____ _____ by the first step in the process compared to the energy _____ in the second step.

- If _____ energy is needed for the first process, than is released in the second process, then the process will be _____. This will be observed by the test tube or beaker becoming hotter.
- If _____ energy is needed for the first step, than is released in the second step then the process is _____ and the test tube or beaker will _____ _____.

**Practice Question:**

Explain the 2 types of processes which occur in dissolving. Discuss which process is endothermic and which is exothermic.

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