

# Enthalpy changes and bond enthalpies

Answer all the questions below then check your answers

1. What is an exothermic reaction?
2. Is bond breaking an exothermic or endothermic process? What about bond formation? Is that exothermic or endothermic?
3. What is bond enthalpy or bond energy?
4. In an energy profile diagram, what does the difference in height between reactants and products represent?
5. State the equation for calculating the enthalpy change of a reaction using bond enthalpies.
6. Methane ( $\text{CH}_4$ ) combusts in air to form carbon dioxide and water. Calculate the enthalpy change (amount of heat energy released) for this reaction. It may help you to draw up a table to show the bonds broken and bonds formed to help you get the correct answer. Equations for this reaction are shown below:

bond enthalpies:  $\text{C-H} = 412 \text{ kJ/mol}$ ,  $\text{O=O} = 498 \text{ kJ/mol}$ ,  
 $\text{C=O} = 743 \text{ kJ/mol}$ ,  $\text{O-H} = 463 \text{ kJ/mol}$ .

Methane + oxygen  $\longrightarrow$  carbon dioxide + hydrogen oxide

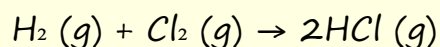


7. Calculate the enthalpy change for the combustion of ethane ( $\text{C}_2\text{H}_6$ ) using bond enthalpies:

$\text{C}-\text{C} = 348 \text{ kJ/mol}$ ,  $\text{C}-\text{H} = 412 \text{ kJ/mol}$ ,  $\text{O}=\text{O} = 498 \text{ kJ/mol}$ ,  $\text{C}=\text{O} = 743 \text{ kJ/mol}$ ,  $\text{O}-\text{H} = 463 \text{ kJ/mol}$ .

The reaction is:  $2\text{C}_2\text{H}_6 + 7\text{O}_2 \rightarrow 4\text{CO}_2 + 6\text{H}_2\text{O}$ .

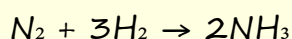
8. Hydrogen and chlorine gases react to form hydrogen chloride gas according to the equation below:



Calculate the enthalpy change for the following reaction using the bond enthalpy data provided:

Bond Enthalpies (kJ/mol):  $\text{H}-\text{H} = 436$   $\text{Cl}-\text{Cl} = 242$   $\text{H}-\text{Cl} = 431$

9. Explain why bond enthalpies are always positive values.
10. The reaction between methane ( $\text{CH}_4$ ) and oxygen ( $\text{O}_2$ ) is exothermic. Explain this in terms of bond breaking and bond forming, using the concept of bond enthalpies.
11. Calculate and explain the enthalpy change for the reaction of nitrogen and hydrogen gases to form ammonia:

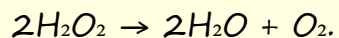


Use the following bond enthalpies:  $\text{N}\equiv\text{N} = 945 \text{ kJ/mol}$ ,  $\text{H}-\text{H} = 436 \text{ kJ/mol}$ ,  $\text{N}-\text{H} = 391 \text{ kJ/mol}$ .

12. Explain the steps and calculate the enthalpy change for the decomposition of hydrogen peroxide (HO-OH) into water and oxygen gas using bond enthalpies:

O-H = 463 kJ/mol, O-O = 146 kJ/mol, O=O = 498 kJ/mol.

An equation for the reaction is:



## Answers

1. What is an exothermic reaction?

*A reaction that releases heat energy to the surroundings. The temperature of the surrounding will increase during an exothermic reaction.*

2. Is bond breaking an exothermic or endothermic process? What about bond formation? Is that exothermic or endothermic?

*Bond breaking is endothermic, bond formation is exothermic*

3. What is bond enthalpy or bond energy?

*Bond enthalpy is the energy required to break one mole of a specific bond in a gaseous molecule.*

4. In an energy profile diagram, what does the difference in height between reactants and products represent?

*The difference represents the overall energy change (enthalpy change) of the reaction.*

5. State the equation for calculating the enthalpy change of a reaction using bond enthalpies.

$$\Delta H = \Sigma(\text{bond enthalpies of reactants}) - \Sigma(\text{bond enthalpies of products})$$

6. Methane ( $\text{CH}_4$ ) combusts in air to form carbon dioxide and water. Calculate the enthalpy change (amount of heat energy released) for this reaction. It may help you to draw up a table to show the bonds broken and bonds formed to help you get the correct answer. Equations for this reaction are shown below:

bond enthalpies: C-H = 412 kJ/mol, O=O = 498 kJ/mol,  
 C=O = 743 kJ/mol, O-H = 463 kJ/mol.

Methane + oxygen  $\longrightarrow$  carbon dioxide + hydrogen oxide



Answer:

Bonds broken: 4 C-H (4 × 412 kJ) + 2 O=O (2 × 498 kJ) = 1648 kJ + 996 kJ = 2644 kJ

Bonds formed: 2 C=O (2 × 743 kJ) + 4 O-H (4 × 463 kJ) = 1486 kJ + 1852 kJ = 3338 kJ

$\Delta H = \Sigma(\text{bond enthalpies of reactants}) - \Sigma(\text{bond enthalpies of products})$

Or simply

Enthalpy change ( $\Delta H$ ) = Bonds broken - Bonds formed = 2644 kJ - 3338 kJ = -694 kJ

7. Calculate the enthalpy change for the combustion of ethane (C<sub>2</sub>H<sub>6</sub>) using bond enthalpies:

C-C = 348 kJ/mol, C-H = 412 kJ/mol, O=O = 498 kJ/mol, C=O = 743 kJ/mol, O-H = 463 kJ/mol.

The reaction is:  $2\text{C}_2\text{H}_6 + 7\text{O}_2 \rightarrow 4\text{CO}_2 + 6\text{H}_2\text{O}$ .

Bonds broken:  $2 \text{ C-C } (2 \times 348 \text{ kJ}) + 12 \text{ C-H } (12 \times 412 \text{ kJ}) + 7 \text{ O=O } (7 \times 498 \text{ kJ}) = 696 \text{ kJ} + 4944 \text{ kJ} + 3486 \text{ kJ} = 9126 \text{ kJ}$

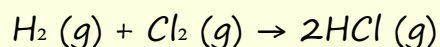
Bonds formed:  $8 \text{ C=O } (8 \times 743 \text{ kJ}) + 12 \text{ O-H } (12 \times 463 \text{ kJ}) = 5944 \text{ kJ} + 5556 \text{ kJ} = 11500 \text{ kJ}$

$\Delta H = \Sigma(\text{bond enthalpies of reactants}) - \Sigma(\text{bond enthalpies of products})$

Or simply

Enthalpy change ( $\Delta H$ ) = Bonds broken - Bonds formed =  $9126 \text{ kJ} - 11500 \text{ kJ} = -2374 \text{ kJ}$

8. Hydrogen and chlorine gases react to form hydrogen chloride gas according to the equation below:



Calculate the enthalpy change for the following reaction using the bond enthalpy data provided:

Bond Enthalpies (kJ/mol):  $\text{H-H} = 436 \text{ Cl-Cl} = 242 \text{ H-Cl} = 431$

$\Delta H = \Sigma(\text{bond enthalpies of reactants}) - \Sigma(\text{bond enthalpies of products})$

$\Delta H = (1 * 436 + 1 * 242) - (2 * 431) = -184 \text{ kJ/mol}$

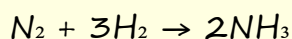
9. Explain why bond enthalpies are always positive values.

Bond enthalpies represent the energy required to break bonds, which is always an endothermic process, hence requiring an input of energy.

10. The reaction between methane ( $\text{CH}_4$ ) and oxygen ( $\text{O}_2$ ) is exothermic. Explain this in terms of bond breaking and bond forming, using the concept of bond enthalpies.

In this reaction, the relatively strong C-H and O=O bonds are broken, which requires energy. However, stronger C=O and O-H bonds are formed in the products (carbon dioxide and water), releasing more energy than was required to break the initial bonds. The overall energy release results in an exothermic reaction.

11. Calculate and explain the enthalpy change for the reaction of nitrogen and hydrogen gases to form ammonia:



Use the following bond enthalpies:  $\text{N}\equiv\text{N} = 945 \text{ kJ/mol}$ ,  $\text{H}-\text{H} = 436 \text{ kJ/mol}$ ,  $\text{N}-\text{H} = 391 \text{ kJ/mol}$ .

Bonds broken: 1  $\text{N}\equiv\text{N}$  (945 kJ) + 3  $\text{H}-\text{H}$  ( $3 \times 436 \text{ kJ}$ ) = 945 kJ + 1308 kJ = 2253 kJ

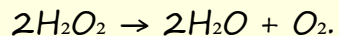
Bonds formed: 6  $\text{N}-\text{H}$  ( $6 \times 391 \text{ kJ}$ ) = 2346 kJ

Enthalpy change ( $\Delta H$ ) = Bonds broken - Bonds formed = 2253 kJ - 2346 kJ = -93 kJ

12. Explain the steps and calculate the enthalpy change for the decomposition of hydrogen peroxide ( $\text{HO}-\text{OH}$ ) into water and oxygen gas using bond enthalpies:

$\text{O}-\text{H} = 463 \text{ kJ/mol}$ ,  $\text{O}-\text{O} = 146 \text{ kJ/mol}$ ,  $\text{O}=\text{O} = 498 \text{ kJ/mol}$ .

An equation for the reaction is:



Answer:

Bonds broken:  $4 \text{ O-H} (4 \times 463 \text{ kJ}) + 2 \text{ O-O} (2 \times 146 \text{ kJ}) = 1852 \text{ kJ} + 292 \text{ kJ} = 2144 \text{ kJ}$

Bonds formed:  $4 \text{ O-H} (4 \times 463 \text{ kJ}) + 1 \text{ O=O} (498 \text{ kJ}) = 1852 \text{ kJ} + 498 \text{ kJ} = 2350 \text{ kJ}$

Enthalpy change ( $\Delta H$ ) = Bonds broken - Bonds formed =  $2144 \text{ kJ} - 2350 \text{ kJ} = -206 \text{ kJ}$