Answer on Question # 59866 – Chemistry – General Chemistry

Use the mean bond enthalpies given below (in kJ/mol) to calculate the enthalpy change of each reaction.

$$N_2(g) + 3H_2(g) \Rightarrow 2NH_3(g)$$

$$H_2(g) + I_2(g) \Rightarrow 2HI(g)$$

$$H_2(g) + \frac{1}{2}O_2(g) \Rightarrow H_2O(g)$$

$N \equiv N$: 944, H-H: 436, N-H: 388, I-I: 151, H-I: 299, O-H: 463 and O=O: 496.

Explain it in the way that is simple.

Solution:

Each bond between the atoms in a molecule has its own energy – the enthalpy (H). The enthalpy change of a chemical reaction is the difference between the total energy of the bonds of the product and the total energy of the bonds of the agents.

1) $N_2(g) + 3H_2(g) \Rightarrow 2NH_3(g)$

A nitrogen molecule consists of two nitrogen atoms, which are bound with a triple bond:

$:\dot{N}\vdots\dot{N}:$ or $:N \equiv N:$

Therefore, the bond enthalpy of a nitrogen molecule is:

$$H_{N_2} = H_{N \equiv N} = 944\left[\text{kJ/mol}\right].$$

A hydrogen molecule consists of two hydrogen atoms, which are bound with an ordinary bond:

$H\dot{:}H$ or $H - H$

Therefore, the bond enthalpy of a hydrogen molecule is:

$$H_{H_2} = H_{H\text{-}H} = 436\left[\text{kJ/mol}\right].$$

An ammonia molecule consists of one nitrogen atom and three hydrogen atoms. Each hydrogen atom is ordinary-bound with the nitrogen atom:

$$\begin{matrix} H & & H \\ \ddot{} & & | \\ :\dot{N}\dot{:}H \text{ or } & & :N - H \\ \ddot{} & & | \\ H & & H \end{matrix}$$

Therefore, the bond enthalpy of a hydrogen molecule is:

$$H_{NH_3} = 3H_{N\text{-}H} = 3 \cdot 388 = 1164\left[\text{kJ/mol}\right].$$

This reaction involves one mole of nitrogen, three moles of hydrogen and two moles of ammonia, as can be seen from its equation. The enthalpy change of this reaction is calculated taking to account the number of moles of each agent and product:

$$\Delta H_{NH_3} = 2H_{NH_3} - H_{N_2} - 3H_{H_2} = 2 \cdot 1164 - 944 - 3 \cdot 436 = 76\left[\text{kJ}\right].$$

2) $H_2(g) + I_2(g) \Rightarrow 2HI(g)$

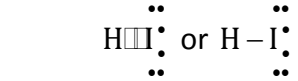
An iodine molecule consists of two iodine atoms, which are bound with an ordinary bond:

$:\ddot{I}\dot{:}\ddot{I}:$ or $:\ddot{I} - \ddot{I}:$

Therefore, the bond enthalpy of an iodine molecule is:

$$H_{I_2} = H_{I\text{-}I} = 151\left[\text{kJ/mol}\right].$$

A molecule of hydroiodic acid consists of a hydrogen atom and an iodine atom, which are ordinary-bound with each other:

 or $H-\ddot{I}:$

Therefore, the bond enthalpy of a hydroiodic acid molecule is:

$$H_{HI} = H_{H\text{-}I} = 299\left[\text{kJ/mol}\right].$$

This reaction involves one mole of hydrogen, one mole of iodine and two moles of hydroiodic acid. The enthalpy change of this reaction:

$$\Delta H_{HI} = 2H_{HI} - H_{H_2} - H_{I_2} = 2\cdot 299 - 436 - 151 = 11\left[\text{kJ}\right].$$

3) $H_2(g) + \frac{1}{2}O_2(g) \Rightarrow H_2O(g)$

An oxygen molecule consists of two oxygen atoms, which are double-bound with each other:

$\ddot{O}:\ddot{O}$ or $\ddot{O}=\ddot{O}$

Therefore, the bond enthalpy of an oxygen molecule is:

$$H_{O_2} = H_{O=O} = 496\left[\text{kJ/mol}\right].$$

A water molecule consists of two hydrogen atoms and one oxygen atom. Each hydrogen atom is ordinary-bound with the oxygen atom:

$H:\ddot{O}:H$ or $H-\ddot{O}-H$

Therefore, the bond enthalpy of a water molecule is:

$$H_{H_2O} = 2\cdot H_{O-H} = 2\cdot 463 = 926\left[\text{kJ/mol}\right].$$

This reaction involves one mole of hydrogen, half mole of oxygen and one mole of water. The enthalpy change of this reaction:

$$\Delta H_{H_2O} = H_{H_2O} - H_{H_2} - \frac{1}{2}H_{O_2} = 926 - 436 - \frac{1}{2}\cdot 496 = 242\left[\text{kJ}\right].$$

Answer: $\Delta H_{NH_3} = 76\left[\text{kJ}\right];\ \Delta H_{HI} = 11\left[\text{kJ}\right];\ \Delta H_{H_2O} = 242\left[\text{kJ}\right].$