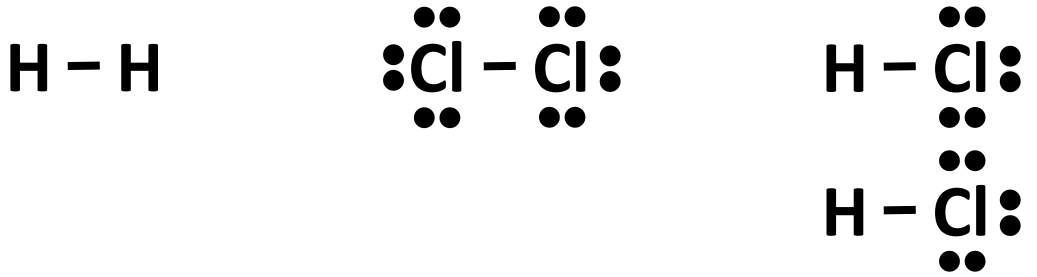
Energy Balance Problems:

Example 1:

Calculate the enthalpy change of the reaction by performing an energy balance. Indicate whether the reaction is endothermic or exothermic. Write out the chemical equation for this reaction with its energy. Finally, create an energy balance diagram.

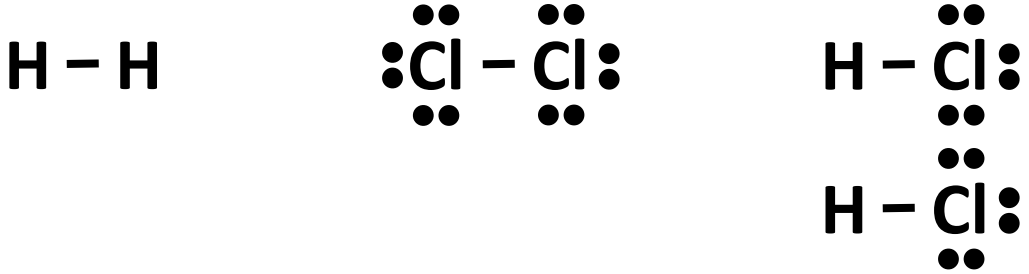
$$H_{2\ (g)} + Cl_{2\ (g)} \rightarrow 2HCl_{\ (g)}$$

Step 1: Determine Reactant and Product Bonds:



1molecule *1molecule* *2molecules*

There is **1** H-H bond in the 1 molecule of H_2 = **1 Bond**
There is **1** Cl-Cl bond in the 1 molecule of Cl_2 = **1 Bond**
There is **1** H-Cl bonds in the a single HCl x **2** molecules = **2 Bonds**



Step 2: List the corresponding Bond Energies from known table:

$E_{H\text{-}H}$: 436 kJ/mole
$E_{Cl\text{-}Cl}$: 243 kJ/mole
$E_{H\text{-}Cl}$: 432 kJ/mole

Step 3: Calculate the Enthalpy of the Bonds Broken (Reactants) and the Enthalpy of the Bonds Formed (Products):

Reactants: $\Delta H_{Bonds\ broken} = (1)E_{H\text{-}H} + (1)E_{Cl\text{-}Cl}$ = 436kJ + 243kJ = **679kJ**

Products: $\Delta H_{Bonds\ formed} = -(2)(E_{H\text{-}Cl})$ = -(2)(432kJ) = **-864kJ**

Step 4: Calculate Enthalpy using Energy Balance:

$$\Delta H = \Delta H_{Bonds\ broken} + \Delta H_{Bonds\ formed}$$

$$\Delta H = (679\ kJ) + (-864kJ)$$

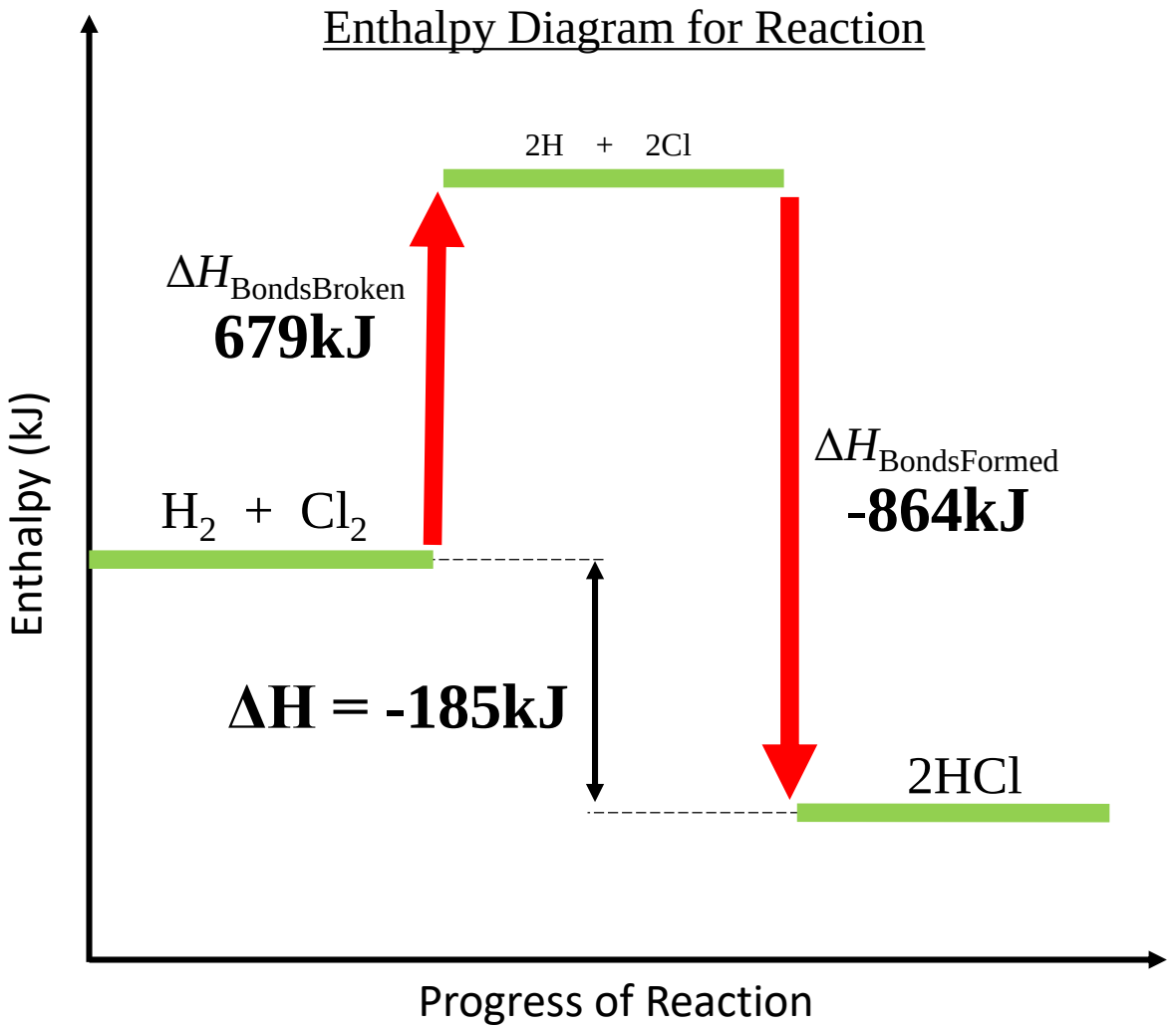
$$\mathbf{\Delta H = -185kJ}$$

Exothermic

Chemical Equation:

$$H_{2\ (g)} + Cl_{2\ (g)} \rightarrow 2HCl_{(g)} + 185kJ$$

Energy Balance Diagram:



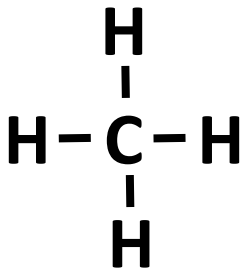
Example 2:

Calculate the enthalpy change of the reaction by performing an energy balance. Indicate whether the reaction is endothermic or exothermic. Write out the chemical equation for this reaction with its energy. Finally, create an energy balance diagram.

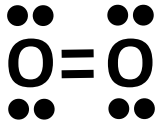
Combustion of Methane:

$$CH_4\ (g) + 2O_2\ (g) \rightarrow CO_2\ (g) + 2H_2O\ (g)$$

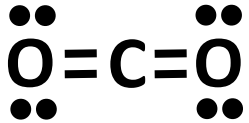
Step 1: Determine Reactant and Product Bonds:



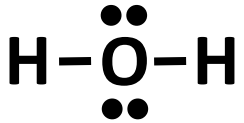
1molecule



2molecule



1molecules



2molecules

There are **4** C-H bonds	x	1 molecule	=	**4 Bonds**
There are **1** O=O bonds	x	2 molecules	=	**2 Bonds**
There are **2** C=O bonds	x	1 molecule	=	**2 Bonds**
There are **2** O-H bonds	x	2 molecules	=	**4 Bonds**

Step 2: List the corresponding Bond Energies from known table:

E_{C-H} : 413 kJ/mole
$E_{O=O}$: 498 kJ/mole
$E_{C=O}$: 745 kJ/mole
E_{O-H} : 460 kJ/mole

Step 3: Calculate the Enthalpy of the Bonds Broken (Reactants) and the Enthalpy of the Bonds Formed (Products):

Reactants: $\Delta H_{Bonds\ broken} = (4)(E_{C-H}) + (2)(E_{O=O}) = (4)(413) + (2)(498) =$ **2648kJ**

Products: $\Delta H_{Bonds\ formed} = -((2)(E_{C=O}) + (4)(E_{O-H})) = -((2)(745) + (4)(460)) =$ **-3330kJ**

Step 4: Calculate Enthalpy using Energy Balance:

$$\Delta H = \Delta H_{Bonds\ broken} + \Delta H_{Bonds\ formed}$$

$$\Delta H = (2648\ kJ) + (-3330kJ)$$

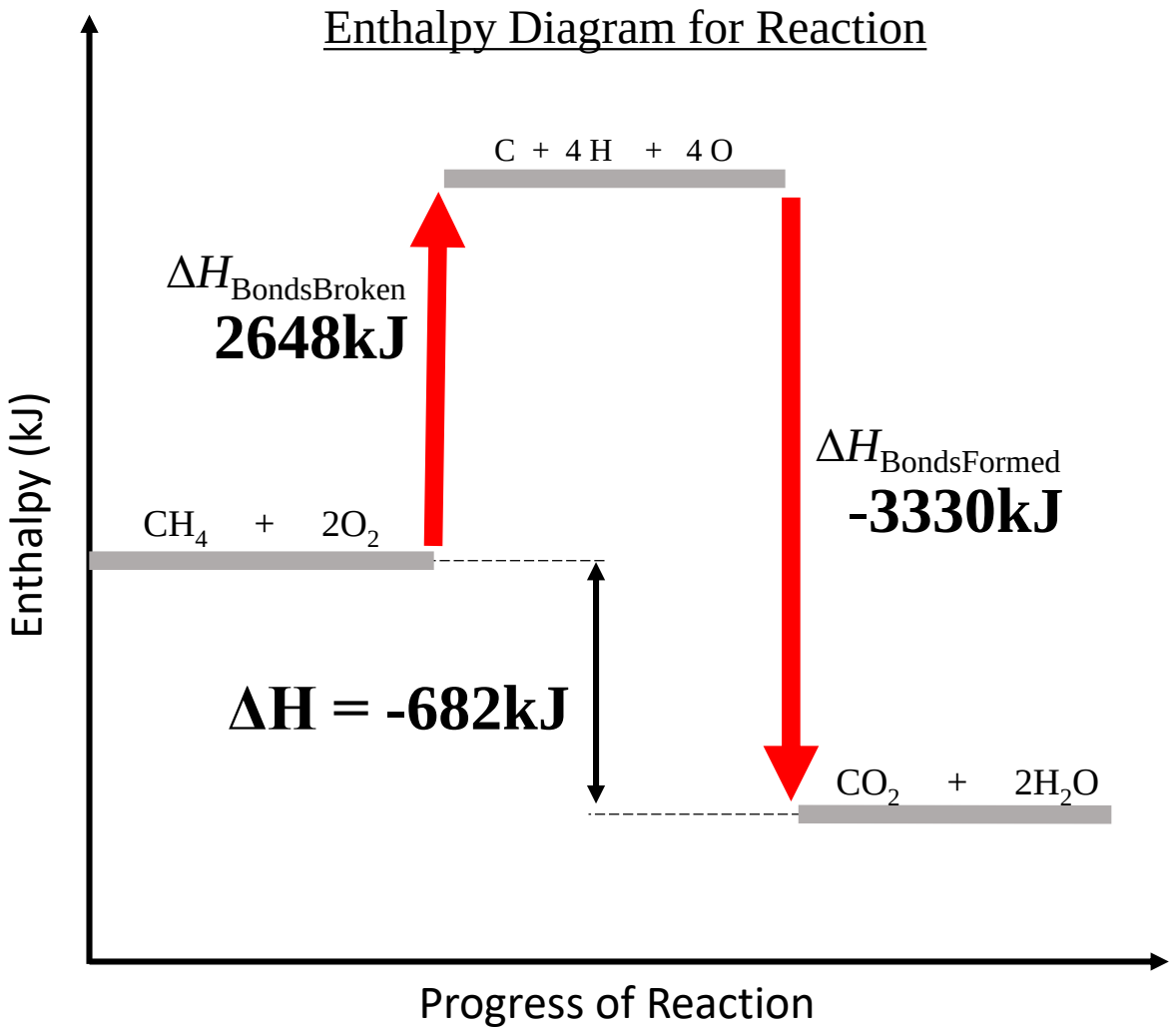
$$\mathbf{\Delta H = -682kJ}$$

Exothermic

Chemical Equation:

$$CH_4\ (g) + 2O_2\ (g) \rightarrow CO_2\ (g) + 2H_2O\ (g) + 682kJ$$

Energy Balance Diagram:



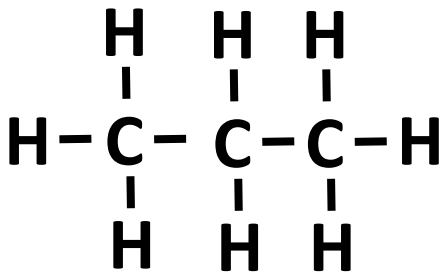
Example 3:

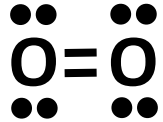
Calculate the enthalpy change of the reaction by performing an energy balance. Indicate whether the reaction is endothermic or exothermic. Write out the chemical equation for this reaction with its energy. Finally, create an energy balance diagram.

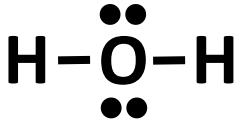
Combustion of Propane:

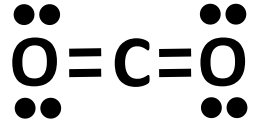
$$C_3H_8 + 5O_2 \rightarrow 4H_2O + 3CO_2$$

Step 1: Determine Reactant and Product Bonds:









1molecule *5molecules* *4molecules* *3molecules*

There are 2 C-C bonds x 1molecule → **2** bonds
There are 8 C-H bonds x 1molecule → **8** bonds
There are 1 O=O bonds x 5molecules → **5** bonds
There are 2 O-H bonds x 4molecules → **8** bonds
There are 2 C=O bonds x 3molecules → **6** bonds

Step 2: List the corresponding Bond Energies from known table:

E_{C-C} : 347 kJ/mole
E_{C-H} : 413 kJ/mole
$E_{O=O}$: 498 kJ/mole
E_{O-H} : 460 kJ/mole
$E_{C=O}$: 745 kJ/mole

Step 3: Calculate the Enthalpy of the Bonds Broken (Reactants) and the Enthalpy of the Bonds Formed (Products):

React: $\Delta H_{Bonds\ broken}$ = (2)(E_{C-C}) + (8)(E_{C-H}) + (5)($E_{O=O}$) = (2)(347) + (8)(413) + (5)(498) = **6488kJ**

Prod: $\Delta H_{Bonds\ formed}$ = - ((8)(E_{O-H}) + (6)($E_{C=O}$)) = -((8)(460) + (6)(745)) = **-8150kJ**

Step 4: Calculate Enthalpy using Energy Balance:

$$\Delta H = \Delta H_{Bonds\ broken} + \Delta H_{Bonds\ formed}$$

$$\Delta H = (6488\ kJ) + (-8150 kJ)$$

$$\mathbf{\Delta H = -1662 kJ}$$

Exothermic

Chemical Equation:

$$C_3H_8 + 5O_2 \rightarrow 4H_2O + 3CO_2 + 1662kJ$$

Energy Balance Diagram: