# The ΔH

Lesson 1a.- What to do with the ΔH of thermochemical equations.

When multiplying the equation by X then multiply the ΔH by X as well (sign stays the same).

For example take the equation below of the combustion of glucose.

$C_6H_{12}O_6(aq) + 6O_2(g) => 6CO_2(g) + 6H_2O(l)$ ΔH = -2803 kJ mol$^-$

½ X ($C_6H_{12}O_6(aq) + 6O_2(g) => 6CO_2(g) + 6H_2O(l)$ ΔH = -2803 kJ mol$^-$ )
=> ½ $C_6H_{12}O_6(aq) + 3O_2(g) => 3CO_2(g) + 3H_2O(l)$ ΔH = -1401.5 kJ mol$^-$

3 X ($C_6H_{12}O_6(aq) + 6O_2(g) => 6CO_2(g) + 6H_2O(l)$ ΔH = -2803 kJ mol$^-$ )
=> $3C_6H_{12}O_6(aq) + 18O_2(g) => 18CO_2(g) + 18H_2O(l)$ ΔH = -8409 kJ mol$^-$

When flipping the equation, change the sign of the ΔH.
For example.

$6CO_2(g) + 6H_2O(l)$ => $C_6H_{12}O_6(aq) + 6O_2(g)$ ΔH= +2803 kJ mol$^-$

$3CO_2(g) + 3H_2O(l)$ => ½ $C_6H_{12}O_6(aq) + 3O_2(g)$ ΔH= +1401.5 kJ mol$^-$

1. Consider the equation shown below of aluminium reacting with iron(III) oxide.
   2Al(s)+Fe2O3(s)⟶2Fe(s)+Al2O3(s) ΔH = -815.5kJmol$^-$
   Give the ΔH for the following thermochemical equations.
   a. $4Al(s) + 2Fe_2O_3(s) \longrightarrow 4Fe(s) + 2Al_2O_3(s)$ ΔH *= -1630.5kJ mol$^-$*
   b. $2Fe(s) + Al_2O_3(s) \longrightarrow 2Al(s) + Fe_2O_3(s)$ ΔH *= +815.5kJ mol$^-$*
   c. Fe(s) + ½ $Al_2O_3(s)$ ⟶ Al(s) + ½ $Fe_2O_3(s)$ ΔH = *+407.5 kJ mol$^-$*

2. Fill in the boxes to complete the thermochemical equation below.

| [6] Fe(s) + [3] $Al_2O_3(s)$ ⟶ [6] (Al(s) + [3] $Fe_2O_3(s)$ ΔH = +2445kJ/mol |
|---|

3. Consider the equation below showing the complete combustion of methane in oxygen gas.
   $CH_4(g)+2O_2(g) \rightarrow CO_2(g)+2H_2O(l)$ ΔH= –890kJ mol$^-$

   Transform this equation to obtain balanced thermochemical equations that produce the following ΔH values.
   *a. $CO_2(g)+2H_2O(l) \rightarrow CH_4(g)+2O_2(g)$ ΔH= +890kJ mol$^-$ $^-$*

   *b. ½ $CH_4(g) + O_2(g) \rightarrow$ ½ $CO_2(g) + H_2O(l)$ $^-$ ΔH= –445kJ mol$^-$*

   c. *¼ $CO_2(g)$ + ½ $H_2O(l) \rightarrow$ ¼ $CH_4(g)$ + ½ $O_2(g)$ ΔH= +222.5kJ mol$^-$*

4. Methane burns in oxygen according to the equation below.

$CH_4(g)+2O_2(g) \rightarrow CO_2(g)+2H_2O(l)$ $\Delta H = -890kJ\ mol^{-}$

a. What amount, in mol, of carbon dioxide gas is produced when 1780kJ of energy is released during the complete combustion of methane .

$$\frac{\text{Energy(from the equation)}}{\text{Mol (from the equation)}} = \frac{\text{Energy( Asked for or given in the question )}}{\text{Mol ( Asked for or given in the question )}}$$

*Use the ratio shown on the right.*
*We are dealing with $CO_2$. So:*
*- Energy from the equation = 890*
*- Mol of $CO_2$ from the question = 1*
*- Energy given in the question = 1780 kJ*
*- Mol of $CO_2$ =?*

*Putting the information in the ratio gives us the expression on the right.*

$$\frac{890\text{ kJ}}{1} = \frac{1780}{\text{Mol}_{CO_2}}$$

*Transpose to make mol of $CO_2$ the subject.*
*Mol of $CO_2$ = 2.00*

$$\text{Mol}_{CO_2} = \frac{1780 \times 1}{890\text{ kJ}}$$

b. What amount, in mol, of oxygen gas is used to produce 455 kJ of energy when methane is burnt in oxygen

$$\frac{\text{Energy(from the equation)}}{\text{Mol (from the equation)}} = \frac{\text{Energy( Asked for or given in the question )}}{\text{Mol ( Asked for or given in the question )}}$$

*Use the ratio shown on the right.*
*We are dealing with $O_2$. So:*
*- Energy from the equation = 890*
*- Mol of $O_2$ from the question = 2*
*- Energy given in the question = 455 kJ*
*- Mol of $O_2$ =?*

*Putting the information in the ratio gives us the expression on the right.*

$$\frac{890\text{ kJ}}{2} = \frac{455}{\text{mol of } O_2}$$

*Transpose to make mol of $O_2$ the subject.*
*Mol of $O_2$ = 1.02*

$$\text{Mol}_{O_2} = \frac{455 \times 2}{890\text{ kJ}}$$

c. What mass, in grams, of methane is needed to produce 1780 kJ of energy?

*Use the ratio shown on the right.*

*We are dealing with $CH_4$. So:*

*- Energy from the equation = 890*

*- Mol of $CH_4$ from the question = 2*

*- Energy given in the question = 1780 kJ*

*- Mol of $CH_4$ =?*

$$\frac{\text{Energy(from the equation)}}{\text{Mol (from the equation)}} = \frac{\text{Energy(Asked for or given in the question)}}{\text{Mol (Asked for or given in the question)}}$$

*Putting the information in the ratio gives us the expression on the right.*

$$\frac{890\ \text{kJ}}{1} = \frac{1780}{\text{mol of } CH_4}$$

*Transpose to make mol of $CH_4$ the subject.*

*Mol of $CH_4$ = 2.00*

$$\text{Mol}\ CH_4 = \frac{1780 \times 1}{890\ \text{kJ}}$$

*Mass of $CH_4$ = 2.00 X 16.0 = 32.0 grams.*

5. Consider the combustion of octane in atmospheric oxygen at SLC.

a. Write the thermochemical equations for the complete combustion, at SLC, of octane in atmospheric oxygen ($O_2$). Include states.

*$2C_8H_{18}(l) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(l)$ $\Delta H$ = -10920 kJ mol$^{-}$*

*The molar heat of combustion for octane is obtained from the data booklet.*

*It is given as 5460 kJ mol$^{-}$. Since there are two moles of octane shown in the equation the $\Delta H$ is given as -10920 kJ mol$^{-}$*

b. What volume, in litres, of $CO_2$ gas is produced if 80.0 megajoules of heat energy is delivered by the combustion octane in atmospheric oxygen? Express your answer to the right number of significant figures.

*Use the ratio shown on the right to find the mol of $CO_2$ produced..*

*We are dealing with $CO_2$. So:*

*- Energy from the equation = 10920 kj mol$^{-}$*

*- Mol of $CO_2$ from the question = 16*

*- Energy given in the question = 80000 kJ*

*- Mol of $CO_2$ =?*

$$\frac{\text{Energy(from the equation)}}{\text{Mol (from the equation)}} = \frac{\text{Energy(Asked for or given in the question)}}{\text{Mol (Asked for or given in the question)}}$$

*Putting the information in the ratio gives us the expression on the right.*

$$\frac{10920\ \text{kJ}}{16} = \frac{80000\ \text{kJ}}{\text{mol of } CO_2}$$

*Transpose to make mol of $CO_2$ the subject.*

*Mol of $CO_2$ = 117.2*

$$\text{Mol}_{CO_2} = \frac{80000\ \text{kJ} \times 16}{10920\ \text{kJ}}$$

*Since the gas is at SLC ($25^0$C and 100.0 KPa)*

*we can go straight to the data book and obtain the molar volume of an ideal gas as 24.8 L mol$^{-}$*

*=> total volume of gas is 24.8 X 117.2 = 2.91 X $10^3$L*

*If you used the ideal gas equation you can also successfully obtain the answer albeit the longer way.*

*PV=nRT*

*=> V = 117.2 X 8.31 X 298 °K / 100.0 kPa = 2.90 X $10^3$L*

*The two values should be the same , however, since the molar volume of a gas at SLC is rounded up to 24.8 there may be a small discrepancy.*