

## Practice Questions Section 3.3

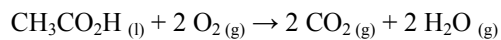
## Gibbs Free Energy

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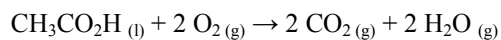
1. Calculate  $\Delta G$  at  $25^\circ\text{C}$  for the following reaction, by first calculating  $\Delta H$  and  $\Delta S$ . Once you've found  $\Delta H$  and  $\Delta S$ , solve for  $\Delta G$  using the formula:

$$\Delta G = \Delta H - T \Delta S$$

Also - will this reaction be spontaneous at this temperature?



2. Again find  $\Delta G$  at  $25^\circ\text{C}$  for the reaction



This time using the Table of Thermochemical Data and the formula:  $\Delta G = \sum \Delta G^\circ_{\text{products}} - \sum \Delta G^\circ_{\text{reactants}}$

3. For the reaction  $\text{Fe}_2\text{O}_{3(s)} + 3 \text{CO}_{(g)} \rightarrow 2 \text{Fe}_{(s)} + 3 \text{CO}_{2(s)}$

$\Delta G^\circ = -31.3 \text{ kJ}$ . Calculate the standard free energy of formation of the ferric oxide,  $\text{Fe}_2\text{O}_3$ ,

if  $\Delta G^\circ_f$  of  $\text{CO} = -137 \text{ kJ/mol}$  and  $\Delta G^\circ_f$  of  $\text{CO}_2 = -394 \text{ kJ/mol}$ .

## Practice Questions Section 3.3

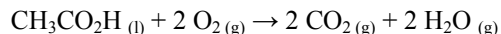
## Gibbs Free Energy

## Answers

1. Calculate  $\Delta G$  at  $25^\circ\text{C}$  for the following reaction, by first calculating  $\Delta H$  and  $\Delta S$ . Once you've found  $\Delta H$  and  $\Delta S$ , solve for  $\Delta G$  using the formula:

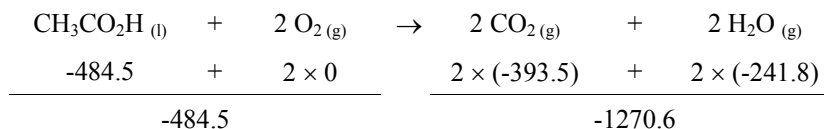
$$\Delta G = \Delta H - T \Delta S$$

Also - will this reaction be spontaneous at this temperature?



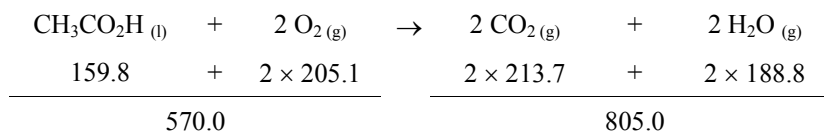
**Solution:**

**Step 1 - Calculate  $\Delta H$**



$$\begin{aligned} \Delta H &= \Sigma \Delta H^\circ_{\text{products}} - \Sigma \Delta H^\circ_{\text{reactants}} \\ &= -1270.6 - (-484.5) \\ &= -786.1 \text{ kJ} \quad \textbf{Answer} \end{aligned}$$

**Step 2- Calculate  $\Delta S$**



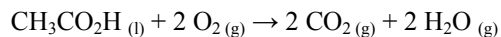
$$\begin{aligned} \Delta S &= \Sigma \Delta S^\circ_{\text{products}} - \Sigma \Delta S^\circ_{\text{reactants}} \\ &= 805.0 - (570.0) \\ &= \mathbf{235.0 \text{ J/K} = 0.235 \text{ kJ/K}} \quad \textbf{Convert to kJ / K for calculating } \Delta G \end{aligned}$$

**Step 3 - Calculate  $\Delta G$  Be sure to convert  $25^\circ\text{C}$  into K and  $\Delta S$  into kJ/K**

$$\begin{aligned} \text{K} &= \text{C} + 273 \\ &= 25 + 273 \\ &= 298 \text{ K} \\ \Delta G &= \Delta H - T \Delta S \\ &= -786.1 - (298.0 \times 0.235) \\ &= -856.1 \text{ kJ} \quad \textbf{answer} \end{aligned}$$

**Because  $\Delta G$  is negative, the reaction is spontaneous at this temperature.**

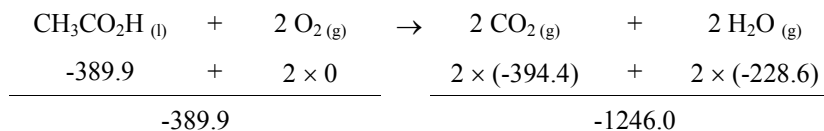
2. Again find  $\Delta G$  at 25°C for the reaction



This time using the Table of Thermochemical Data and the formula:  $\Delta G = \Sigma \Delta G^\circ_{\text{products}} - \Sigma \Delta G^\circ_{\text{reactants}}$

**Solution:**

Look up  $\Delta G$  values for all reaction participants. Multiply by coefficients from the balanced equation. Find totals for the reactant and product sides of the equation:



$$\Delta G = \Sigma \Delta G^\circ_{\text{products}} - \Sigma \Delta G^\circ_{\text{reactants}}$$

$$= -1246.0 - (-389.9)$$

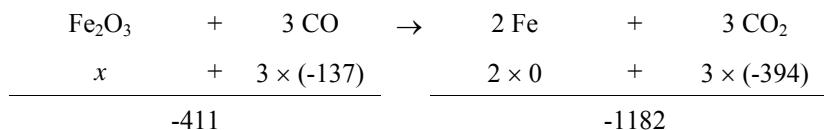
$$\Delta G = -856.1 \text{ kJ} \quad \text{answer}$$

3. For the reaction  $\text{Fe}_2\text{O}_{3(s)} + 3 \text{CO}_{(g)} \rightarrow 2 \text{Fe}_{(s)} + 3 \text{CO}_{2(s)}$

$\Delta G^\circ = -31.3 \text{ kJ}$ . Calculate the standard free energy of formation of the ferric oxide,  $\text{Fe}_2\text{O}_3$ , if  $\Delta G^\circ_f$  of  $\text{CO} = -137 \text{ kJ/mol}$  and  $\Delta G^\circ_f$  of  $\text{CO}_2 = -394 \text{ kJ/mol}$ .

**Solution:**

This time we are given the value  $\Delta G^\circ$  for the entire reaction, and need to find  $\Delta G^\circ_f$  for one of the reaction participants,  $\text{Fe}_2\text{O}_3$ . Let's let that unknown equal  $x$ : (Yes, you could look up the answer in the Table of Thermochemical Data, but let's use that to check our answer at the end)



Next, set up our formula for  $\Delta G^\circ$  and substitute in the values we know, then solve for  $x$ :

$$\Delta G = \Sigma \Delta G^\circ_{\text{products}} - \Sigma \Delta G^\circ_{\text{reactants}}$$

$$-31.3 = (-1182) - (x - 411)$$

$$-31.3 = -1182 - x + 411$$

$$-31.3 = -771 - x$$

$$x = -771 + 31.3 = -740$$

$$\text{Answer} - \Delta G^\circ_f \text{ for } \text{Fe}_2\text{O}_3 = -740 \text{ kJ/mol}$$