Practice Questions Section 3.3

Gibbs Free Energy

1. Calculate ΔG at 25°C for the following reaction, by first calculating ΔH and ΔS. Once you've found ΔH and ΔS, solve for ΔG using the formula:

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

   Also - will this reaction be spontaneous at this temperature?

   $CH_3CO_2H_{(l)} + 2\ O_{2\,(g)} \rightarrow 2\ CO_{2\,(g)} + 2\ H_2O_{(g)}$

2. Again find ΔG at 25°C for the reaction

   $CH_3CO_2H_{(l)} + 2\ O_{2\,(g)} \rightarrow 2\ CO_{2\,(g)} + 2\ H_2O_{(g)}$

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

3. For the reaction $Fe_2O_{3\,(s)} + 3\ CO_{(g)} \rightarrow 2\ Fe_{(s)} + 3\ CO_{2\,(s)}$

   $\Delta G^\circ = -31.3$ kJ. Calculate the standard free energy of formation of the ferric oxide, Fe_2O_3, if ΔG°_f of CO = -137 kJ/mol and ΔG°_f of CO_2 = -394 kJ/mol.

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Gibbs Free Energy Answers

1. Calculate ΔG at 25°C for the following reaction, by first calculating ΔH and ΔS. Once you've found ΔH and ΔS, solve for ΔG using the formula:

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

   Also - will this reaction be spontaneous at this temperature?

   $CH_3CO_2H_{(l)} + 2\,O_{2\,(g)} \rightarrow 2\,CO_{2\,(g)} + 2\,H_2O_{(g)}$

   Solution:

   Step 1 - Calculate ΔH

$CH_3CO_2H_{(l)}$	+	$2\,O_{2\,(g)}$	→	$2\,CO_{2\,(g)}$	+	$2\,H_2O_{(g)}$
-484.5	+	2×0		$2 \times (-393.5)$	+	$2 \times (-241.8)$
-484.5				-1270.6		

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

   $= -1270.6 - (-484.5)$

   $= -786.1$ kJ **Answer**

   Step 2- Calculate ΔS

$CH_3CO_2H_{(l)}$	+	$2\,O_{2\,(g)}$	→	$2\,CO_{2\,(g)}$	+	$2\,H_2O_{(g)}$
159.8	+	2×205.1		2×213.7	+	2×188.8
570.0				805.0		

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

   $= 805.0 - (570.0)$

   $=$ **235.0 J/K = 0.235 kJ/K** **Convert to kJ / K for calculating ΔG**

   Step 3 - Calculate ΔG Be sure to convert 25°C into K and ΔS into kJ/K

   $K = C + 273$
   $= 25 + 273$
   $= 298$ K

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

   $= -786.1 - (298.0 \times 0.235)$

   $= -856.1$ kJ **answer**

   Because ΔG is negative, the reaction is spontaneous at this temperature.

2. Again find ΔG at 25°C for the reaction

$CH_3CO_2H_{(l)} + 2\ O_{2\,(g)} \rightarrow 2\ CO_{2\,(g)} + 2\ H_2O_{(g)}$

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

Solution:

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

$CH_3CO_2H_{(l)}$	+	$2\ O_{2\,(g)}$	→	$2\ CO_{2\,(g)}$	+	$2\ H_2O_{(g)}$
-389.9	+	2×0		$2 \times (-394.4)$	+	$2 \times (-228.6)$
-389.9				-1246.0		

$\Delta G = \Sigma\Delta G°_{\text{products}} - \Sigma\Delta G°_{\text{reactants}}$

$= -1246.0 - (-389.9)$

$\Delta G = -856.1$ kJ **answer**

3. For the reaction $Fe_2O_{3\,(s)} + 3\ CO_{(g)} \rightarrow 2\ Fe_{(s)} + 3\ CO_{2\,(s)}$

$\Delta G° = -31.3$ kJ. Calculate the standard free energy of formation of the ferric oxide, Fe_2O_3, if $\Delta G°_f$ of CO = -137 kJ/mol and $\Delta G°_f$ of CO_2 = -394 kJ/mol.

Solution:

This time we are given the value ΔG°for the entire reaction, and need to find $\Delta G°_f$ for one of the reaction participants, Fe_2O_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)

Fe_2O_3	+	3 CO	→	2 Fe	+	$3\ CO_2$
x	+	$3 \times (-137)$		2×0	+	$3 \times (-394)$
-411				-1182		

Next, set up our formula for ΔG° and substitute in the values we know, then solve for x:

$\Delta G = \Sigma\Delta G°_{\text{products}} - \Sigma\Delta G°_{\text{reactants}}$

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

$-31.3 = -1182 - x + 411$

$-31.3 = -771 - x$

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

Answer - $\Delta G°_f$ for Fe_2O_3 = -740 kJ/mol