Chemistry 192
Recitation Session Questions
March 19, 2018
Solutions

1. The standard enthalpy of combustion of solid naphthalene at 298K ($C_{10}H_8$) is $\Delta_{r,m}H^\circ = -5156.1$ kJ mol^{-1}. Given $\Delta_{f,m}H^\circ(H_2O_{(\ell)}) = -285.8$ kJ mol^{-1} and $\Delta_{f,m}H^\circ(CO_{2(g)}) = -393.5$ kJ mol^{-1}, calculate the standard enthalpy of formation of solid naphthalene.
Answer:

$$C_{10}H_{8(s)} + 12O_{2(g)} \longrightarrow 10CO_{2(g)} + 4H_2O_{(\ell)}$$

$$\Delta_{r,m}H^\circ = 10\Delta_{f,m}H^\circ(CO_{2(g)}) + 4\Delta_{f,m}H^\circ(H_2O_{(\ell)}) - \Delta_{f,m}H^\circ(C_{10}H_{8(s)}) - 12\Delta_{f,m}H^\circ(O_{2(g)})$$

$$-5156.1 \text{ kJ mol}^{-1} = 10(-393.5 \text{ kJ mol}^{-1}) + 4(-285.8 \text{ kJ mol}^{-1}) - 12(0) - \Delta_{f,m}H^\circ(C_{10}H_{8(s)})$$

$$\Delta_{f,m}H^\circ(C_{10}H_{8(s)}) = 77.9 \text{ kJ mol}^{-1}$$

2. The standard Gibbs free energy of combustion of solid naphthalene at 298K ($C_{10}H_8$) is $\Delta_{r,m}G^\circ = -5094.1$ kJ mol^{-1}. Given $\Delta_{f,m}G^\circ(H_2O_{(\ell)}) = -237.1$ kJ mol^{-1} and $\Delta_{f,m}G^\circ(CO_{2(g)}) = -394.4$ kJ mol^{-1}, calculate the standard Gibbs free energy of formation of solid naphthalene.
Answer:

$$\Delta_{r,m}G^\circ = 10\Delta_{f,m}G^\circ(CO_{2(g)}) + 4\Delta_{f,m}G^\circ(H_2O_{(\ell)}) - \Delta_{f,m}G^\circ(C_{10}H_{8(s)}) - 12\Delta_{f,m}G^\circ(O_{2(g)})$$

$$-5094.1 \text{ kJ mol}^{-1} = 10(-394.4 \text{ kJ mol}^{-1}) + 4(-237.1 \text{ kJ mol}^{-1}) - 12(0) - \Delta_{f,m}G^\circ(C_{10}H_{8(s)})$$

$$\Delta_{f,m}G^\circ(C_{10}H_{8(s)}) = 201.7 \text{ kJ mol}^{-1}$$

3. Given the standard, molar entropies at 298K $S^\circ(CO_{2(g)}) = 213.7$ J mol^{-1}K^{-1}, $S^\circ(H_2O_{(\ell)}) = 69.91$ J mol^{-1}K^{-1}, and S°(naphthalene) $= 167.5$ J mol^{-1}K^{-1}, calculate the standard third-law entropy of oxygen gas.
Answer:
Let the subscript c represent combustion. Then

$$\Delta_{c,m}G^\circ = \Delta_{c,m}H^\circ - T\Delta_{c,m}S^\circ$$

$$-5094.1 \times 10^3 \text{ J mol}^{-1} = -5156.1 \times 10^3 \text{ J mol}^{-1} - (298.\text{ K})\Delta_{c,m}S^\circ$$

$$
\begin{aligned}
\Delta_{c,m}S^\circ &= -208.\ \mathrm{J\ mol^{-1}K^{-1}} \\
&= 10S_m^\circ(\mathrm{CO}_{2(g)}) + 4S_m^\circ(\mathrm{H_2O}_{(\ell)}) - S_m^\circ(\mathrm{C_{10}H}_{8(s)}) - 12S_m^\circ(\mathrm{O}_{2(g)}) \\
&= 10(213.7\ \mathrm{J\ mol^{-1}K^{-1}}) + 4(69.91\ \mathrm{J\ mol^{-1}K^{-1}}) - 167.5\ \mathrm{J\ mol^{-1}K^{-1}} - 12S_m^\circ(\mathrm{O}_{2(g)}) \\
S_m^\circ &= 205.\ \mathrm{J\ mol^{-1}K^{-1}}
\end{aligned}
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