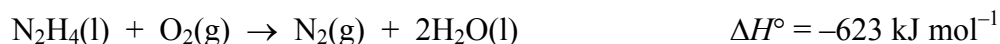


Marks
3

- The combustion of hydrazine, N_2H_4 , with oxygen is described by the following equation:



Given that ΔH°_f of $\text{H}_2\text{O}(\text{l})$ is -286 kJ mol^{-1} , find the standard enthalpy of formation of $\text{N}_2\text{H}_4(\text{l})$.

Using $\Delta_{\text{rxn}} H^\circ = \sum m \Delta_f H^\circ (\text{products}) - \sum n \Delta_f H^\circ (\text{reactants})$,

$$\Delta_{\text{rxn}} H^\circ = [\Delta_f H^\circ (\text{N}_2(\text{g})) + 2\Delta_f H^\circ (\text{H}_2\text{O}(\text{l}))] - [\Delta_f H^\circ (\text{N}_2\text{H}_4(\text{l})) + \Delta_f H^\circ (\text{O}_2(\text{g}))]$$

As $\Delta_f H^\circ = 0$ for an element in its standard state, this becomes:

$$\Delta_{\text{rxn}} H^\circ = [0 + (2 \times -286)] - [\Delta_f H^\circ (\text{N}_2\text{H}_4(\text{l})) + 0] = -623$$

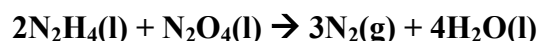
Hence,

$$\Delta_f H^\circ (\text{N}_2\text{H}_4(\text{l})) = +51 \text{ kJ mol}^{-1}$$

$$\Delta H^\circ_f = +51 \text{ kJ mol}^{-1}$$

The combustion of 1.00 mol of $\text{N}_2\text{H}_4(\text{l})$ can also be accomplished using $\text{N}_2\text{O}_4(\text{l})$ as the oxidant, whereupon 629 kJ of energy is released at standard temperature and pressure. What is the standard enthalpy of formation of $\text{N}_2\text{O}_4(\text{l})$?

The chemical equation for the combustion of $\text{N}_2\text{H}_4(\text{l})$ with $\text{N}_2\text{O}_4(\text{l})$ is:



As written, this reaction corresponds to burning two moles of $\text{N}_2\text{H}_4(\text{l})$ and hence $\Delta_{\text{rxn}} H^\circ = 2\Delta_{\text{comb}} H^\circ = 2 \times (-629 \text{ kJ mol}^{-1}) = -1258 \text{ kJ mol}^{-1}$. The negative sign indicates that energy is released during the reaction.

Using $\Delta_{\text{rxn}} H^\circ = \sum m \Delta_f H^\circ (\text{products}) - \sum n \Delta_f H^\circ (\text{reactants})$,

$$\begin{aligned} \Delta_{\text{rxn}} H^\circ &= [3\Delta_f H^\circ (\text{N}_2(\text{g})) + 4\Delta_f H^\circ (\text{H}_2\text{O}(\text{l}))] - [2\Delta_f H^\circ (\text{N}_2\text{H}_4(\text{l})) + \Delta_f H^\circ (\text{N}_2\text{O}_4(\text{l}))] \\ &= [(3 \times 0) + (4 \times -286)] - [(2 \times +51) + \Delta_f H^\circ (\text{N}_2\text{O}_4(\text{l}))] = -1258 \end{aligned}$$

Hence,

$$\Delta_f H^\circ (\text{N}_2\text{O}_4(\text{l})) = +12 \text{ kJ mol}^{-1}$$

$$\Delta H^\circ_f = +12 \text{ kJ mol}^{-1}$$