Chemistry 2720 Fall 2003 Quiz 1 Solution

We first have to decide what is going to happen. The number of moles of eicosane is

$$n_{C_{20}H_{42}} = \frac{150\,\text{g}}{282.56\,\text{g/mol}} = 0.531\,\text{mol}.$$

Cooling the liquid eicosane from 55°C (328.15 K) to its freezing point would release

$$\begin{aligned} q_{328\to310} &= n_{C_{20}H_{42}}\bar{C}_P\Delta T \\ &= (0.531\,\text{mol})\left(664\,\text{J K}^{-1}\text{mol}^{-1}\right)(310-328.15\,\text{K}) \\ &= -6398\,\text{J}. \end{aligned}$$

Can the water absorb this much heat in going from 20°C (293.15 K) to the freezing point of eicosane (310 K)? If not, the final temperature will be above 310 K and the eicosane will remain in the liquid state.

$$\begin{aligned} q_{293\to310} &= m_{H_2O}\tilde{C}_P\Delta T \\ &= (400\,\text{g})\left(4.184\,\text{J K}^{-1}\text{g}^{-1}\right)(310-293.15\,\text{K}) \\ &= 28\,200\,\text{J}. \end{aligned}$$

We conclude that the liquid eicosane will reach its freezing point.

The next question we face is whether the eicosane will freeze completely. Suppose that it does. This would release

$$q_{\text{freeze}} = n_{C_{20}H_{42}}\Delta\bar{H}_{\text{freeze}} = (0.531\,\text{mol})\,(-69.1\,\text{kJ/mol}) = -36\,682\,\text{J}.$$

Note that $|q_{328\to310} + q_{\text{freeze}}| > q_{293\to310}$. Thus, the water is not cold enough to freeze all of the eicosane. We now know, qualitatively, what the final state of the system will be like: There will be a layer of liquid eicosane separated from the water by a layer of solid eicosane, the whole system being at the melting point of eicosane. The heat balance is

$$\begin{aligned} q = 0 &= \left\{\begin{array}{c}\text{Cool eicosane}\\ \text{from 328}\\ \text{to 310 K}\end{array}\right\} + \left\{\begin{array}{c}\text{Freeze}\\ \text{eicosane}\end{array}\right\} + \left\{\begin{array}{c}\text{Warm water}\\ \text{from 293}\\ \text{to 310 K}\end{array}\right\} \\ &= -6398 + n_{\text{frozen}}\,(-69\,100\,\text{J/mol}) + 28\,200\,\text{J}. \\ \therefore n_{\text{frozen}} &= 0.316\,\text{mol}. \\ \therefore n_{\text{liquid}} &= 0.531 - 0.316\,\text{mol} = 0.215\,\text{mol}. \end{aligned}$$

We will therefore have 0.215 mol (60.8 g) of liquid eicosane and 0.316 mol (89.2 g) of solid eicosane. Both the water and the eicosane will be at the freezing point of the latter compound, namely 310 K.