

4 For a sphere  $E = 3.0$   $R = 0.005 \text{ m}$

$$\theta_{fm} = 1.8 + 0.263(-18) + 0.105(-36) = -6.7^\circ\text{C}$$

$$\Delta\theta_1 = (20 + -6.7)/2 = 11.65 \text{ K}$$

$$\Delta\theta_2 = -6.7 - -36 = 29.3 \text{ K}$$

$$\Delta H_1 = 3.7 \times 10^6 (20 - -6.7) = 98.8 \times 10^6 \text{ J/m}^3$$

To find  $\Delta H_2$  we need  $\rho \Delta h_f$

$$\begin{aligned}\rho \Delta h_f &= \frac{\Delta H_{-1/-12}}{11 \text{ PCS}} \\ &= \frac{238 \times 10^6}{11 \times 2.1 \times 10^6} \\ &= 214.9 \times 10^6 \text{ J/m}^3\end{aligned}$$

$$\begin{aligned}\Delta H_2 &= 2.1 \times 10^6 (-6.7 - -18) + 214.9 \times 10^6 \\ &= 238.6 \times 10^6 \text{ J/m}^3\end{aligned}$$

$$\begin{aligned}t_f &= \frac{1}{3} \left( \frac{98.8 \times 10^6}{42.6} + \frac{238.6 \times 10^6}{29.3} \right) \left( \frac{0.005}{200} + \frac{0.005^2}{2 \times 1.63} \right) \\ &= \frac{1}{3} \left( 10.46 \times 10^6 \right) \left( 3.24 \times 10^{-5} \right) \\ &= 113 \text{ sec}\end{aligned}$$

Hence residence time is too long

$$\begin{aligned}\rho \Delta h_f &= \Delta H_{(-1--20)} - \text{PCS}(-1--20) \\ &= 238.6 \times 10^6 - 2.1 \times 10^6 \times 19 \\ &= 198.7 \times 10^6 \text{ J/m}^3.\end{aligned}$$

$$\begin{aligned}\Delta H_2 &= 2.1 \times 10^6 (-6.7 - -18) + 198.7 \times 10^6 \\ &= 222.4 \times 10^6 \text{ J/m}^3.\end{aligned}$$

$$\begin{aligned}t &= \frac{1}{3} \left( \frac{98.8 \times 10^6}{42.6} + \frac{222.4 \times 10^6}{29.3} \right) \left( \frac{0.005}{200} + \frac{0.005^2}{2 \times 1.63} \right) \\ &= 108 \text{ s}\end{aligned}$$

Hence residence time is too long and could be reduced, or the air temperature could be increased.