

4 For a sphere  $E = 3.0$

$$R = 0.005 \text{ m}$$

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

$$\Delta\theta_1 = (20 + -6.7)/2 - -36 = 42.6 \text{ K}$$

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

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

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

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

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

$$t_f = \frac{1}{3} \left( \frac{98.8 \times 10^6}{42.6} + \frac{238.6 \times 10^6}{29.3} \right) \left( \frac{0.005}{200} + \frac{0.005^2}{2 \times 1.63} \right)$$

$$\begin{aligned} &= \frac{1}{3} (10.46 \times 10^6) (3.24 \times 10^{-5}) \\ &= 113 \text{ sec} \end{aligned}$$

Hence residence time is too long

$$\rho \Delta h_f = \Delta H_{(-1 \rightarrow 20)} - \rho c_s (-1 - -20)$$

$$\begin{aligned} &= 238.6 \times 10^6 - 2.1 \times 10^6 \times 19 \\ &= 198.7 \times 10^6 \text{ J/m}^3 \end{aligned}$$

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

$$t = \frac{1}{3} \left( \frac{98.8 \times 10^6}{42.6} + \frac{222.4 \times 10^6}{29.3} \right) \left( \frac{0.005}{200} + \frac{0.005^2}{2 \times 1.63} \right)$$

$$= 108 \text{ s}$$

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