Chapter 3.2

1 Specific heat capacity is the thermal energy required to change the temperature of a unit mass by one degree.

One kg of aluminum and 1 kg of copper contain very different numbers of molecules. Thus if the same amount of thermal energy is supplied to 1 kg of each metal, the energy per molecule will be very different. This means that the change in temperature will be different and so the specific heat capacities will be different.

2 From the definition, $Q = mc\Delta\theta \Rightarrow c = \dfrac{Q}{m\Delta\theta} = \dfrac{385}{0.150\times 5.00} = 513\ \text{J kg}^{-1}\ \text{K}^{-1}$.

3 (a) $C = m_1c_1 + m_2c_2 = 45.0\times 470 + 23.0\times 4200 = 1.18\times 10^5\ \text{J K}^{-1}$. (b) $\Delta Q = C\Delta\theta \Rightarrow \dfrac{\Delta Q}{\Delta t} = C\dfrac{\Delta\theta}{\Delta t}$. Hence $450 = 1.18\times 10^5 \times \dfrac{\Delta\theta}{\Delta t} \Rightarrow \dfrac{\Delta\theta}{\Delta t} = 3.8\times 10^{-3}\ \text{K s}^{-1}$. For a change of temperature of 20.0 K we then require a time of $\dfrac{20}{3.8\times 10^{-3}} = 5.3\times 10^3\ \text{s} = 88\ \text{min}$.

4 The loss of potential energy is $mgh = 1360\times 10\times 86 = 1.17\times 10^6\ \text{J}$. Then, $C\Delta\theta = 1.17\times 10^6 \Rightarrow \Delta\theta = \dfrac{1.17\times 10^6}{16\times 10^3} = 73\ \text{K}$.

5 The mass of ice is $m = 12.3\times 10^{-3}\times 929 = 11.43\ \text{kg}$ and so the heat capacity of the ice-pipe system is $C = 11.43\times 2200 + 7.1\times 10^3 = 3.22\times 10^4\ \text{J K}^{-1}$. The ice will melt after a time given by $4.99\times 10^3\times t = C\Delta\theta + mL$, i.e.
$t = \dfrac{3.22\times 10^4\times 4.8 + 11.4\times 334\times 10^3}{4.99\times 10^3} = 794\ \text{s} = 13\ \text{min}$.

6 The thermal energy transferred from the water and the aluminum container is $Q = 0.300\times 4200\times 10 + 0.150\times 910 = 12736\ \text{J}$. This is used to (a) raise the temperature of ice to he melting point of $0\ ^\circ\text{C}$, (b) melt the ice at $0\ ^\circ\text{C}$ and (c) raise the temperature of the melted ice (which is now water) to the final temperature of $0\ ^\circ\text{C}$. Thus $12736 = m\times 2200\times 10 + m\times 334\times 10^3 + m\times 4200\times 10$. Hence $m = 0.032\ \text{kg}$.

7 The mass of ice is $m = 20\times 0.06\times 900 = 1080\ \text{kg}$. So we need $\text{Q} = 1080\times 2200\times 5 + 1080\times 334\times 10^3 = 3.7\times 10^8\ \text{J}$.

8 The volume of ice is $V = 50.0\times 0.15 = 7.5\ \text{m}^3$ and so its mass is $m = 7.5\times 900 = 6750\ \text{kg}$. In 6.0 hrs the energy supplied is

$342\times 50.0\times 6\times 60\times 60 = 3.69\times 10^8$ J and so the mass that will melt is

$mL = Q \Rightarrow m = \dfrac{Q}{L} = \dfrac{3.69\times 10^8}{334\times 10^3} = 1105$ kg. The fraction is then $\dfrac{1105}{6750} = 0.16$.

9 Let the surface area (in square meters) of the pond be A. Then in time t the energy falling on the surface will be $Q = 600\times A\times t$. The volume of ice is $V = A\times 0.01$ and so its mass is $m = (A\times 0.01)\times 900$. Then $600\times A\times t = (A\times 0.01)\times 900\times 334\times 10^3$. We see that the unknown surface of area cancels out and is not required. Then,

$t = \dfrac{0.01\times 900\times 334\times 10^3}{600} = 5010\text{ s} = 54\text{ min}$. This assumes that none of the incident radiation is reflected from the ice and that all the ice is uniformly heated.

10 (a) $Q_1 = 1.0\times 2200\times 10 = 2.2\times 10^4$ J. (b) $Q_2 = 1.0\times 334\times 10^3 = 3.34\times 10^5$ J. (c) $Q_3 = 1.0\times 4200\times 10 = 4.2\times 10^4$ J.

11 The water will lose an amount of thermal energy $1.00\times 4200\times 10 = 42000$ J. This energy is used to (a) melt the ice and then raise the temperature of the melted ice to $10\ ^\circ\text{C}$. Thus $m\times 334\times 10^3 + m\times 4200\times 10 = 42000 \Rightarrow m = 0.112$ kg.

12 Since the specific latent heat of vaporization of water is so much larger than the specific latent heat of fusion we expect that the final temperature will be greater than the initial $30\ ^\circ\text{C}$ of the water. Then:

$$0.150\times 4200\times (T-30) + 0.100\times 334\times 10^3 + 0.100\times 4200\times T = 0.050\times 2257\times 10^3$$
$$+\,0.050\times 4200\times (100-T)$$

This long equation can be solved for T (preferably using the Solver of your calculator) to give $T = 95\ ^\circ\text{C}$.

13 The energy provided is $20\times 3.0\times 60 = 3600$ J. Hence

$0.090\times 400\times 4.0 + 0.300\times c\times 4.0 = 3600 \Rightarrow c = 2.88\times 10^3\ \text{J kg}^{-1}\,\text{K}^{-1}$.

14 The energy provided is $40\times 4.0\times 60 = 9600$ J. Hence

$25\times 15.8 + 0.140\times c\times 15.8 = 9600 \Rightarrow c = 4.2\times 10^3\ \text{J kg}^{-1}\,\text{K}^{-1}$. The obvious assumptions are that the liquid and the calorimeter are heated uniformly and that none of the energy supplied gets lost to the surroundings.

15 (a) The air is heated at a rate given by $\frac{\Delta Q}{\Delta t}=\frac{\Delta m}{\Delta t}c\Delta\theta$ and so

$\frac{\Delta m}{\Delta t}=\frac{\frac{\Delta Q}{\Delta t}}{c\Delta\theta}=\frac{600}{990\times 40}=0.015\text{ kg s}^{-1}$. (b) This corresponds to a volume of air per second of $\frac{\Delta V}{\Delta t}=\frac{0.015}{1.25}=0.012\text{ m}^3\text{ s}^{-1}$.

16 (a) The volume of the auditorium is $V=40\times 20\times 8.0=6400\text{ m}^3$ and hence the mass of air in it is $m=\rho V=1.25\times 6400=8000\text{ kg}$. This corresponds to

$\frac{8000\times 10^3}{29}=2.76\times 10^5\text{ mol}$. (b) From $\frac{\Delta Q}{\Delta t}=nc\frac{\Delta\theta}{\Delta t}$ we find

$\frac{\Delta\theta}{\Delta t}=\frac{\frac{\Delta Q}{\Delta t}}{nc}=\frac{600\times 80}{2.76\times 10^5\times 29}=6.0\times 10^{-3}\text{ K s}^{-1}$.

17 (a) The main factors are: the temperature of the liquid, the surface area of the liquid and the flow of air over the liquid. (b) Evaporation involves the fastest molecules on the surface of the liquid that leave the surface. The molecules that are left behind therefore have a lower average kinetic energy and so a lower temperature since temperature is proportional to the average random kinetic energy of the molecules. (c) A container of water that is surrounded by a wet felt cover is kept slightly cooler since the water in the wet felt evaporates.

18 The average kinetic energy in the two containers is the same and hence so is the temperature.

19 Since both gases are at the same temperature, $\frac{1}{2}mv^2\Big|_{Oxygen}=\frac{1}{2}mv^2\Big|_{Nitrogen}$. Hence

$\frac{v^2\big|_{Oxygen}}{v^2\big|_{Nitrogen}}=\frac{m\big|_{Nitrogen}}{m\big|_{Oxygen}}=\frac{28}{32}$. Hence $\frac{v\big|_{Oxygen}}{v\big|_{Nitrogen}}=\sqrt{\frac{28}{32}}=0.94$

20 Since $E_K=\frac{1}{2}mv^2\propto T$, increasing the temperature by a factor of 4 increases the average kinetic energy by a factor of 4. Therefore the rms speed increases by 2.