CHAPTER 18 | Absorption of Heat

1 | How much water remains unfrozen after 77.2 \(kJ\) is transferred as heat from 260 \(g\) of liquid water initially at 25\(^\circ\)C?  
\(Ans:\ 0.11 \text{ kg}\)

2 | A small electric immersion heater is used to heat 100 \(g\) of water for a cup of instant coffee. The heater is labeled “200 \text{ watts}” (it converts electrical energy to thermal energy at this rate). Calculate the time required to bring all this water from 23.0\(^\circ\)C to 100\(^\circ\)C, ignoring any heat losses.  
\(Ans:\ 160 \text{ s}\)

3 | What mass of steam at 100\(^\circ\)C must be mixed with 150 \(g\) of ice at its melting point, in a thermally insulated container, to produce liquid water at 60\(^\circ\)C?  
\(Ans:\ 0.036 \text{ kg}\)

4 | Ethyl alcohol has a boiling point of 78.0\(^\circ\)C, a freezing point of −114\(^\circ\)C, a heat of vaporization of 879 \(kJ/kg\), a heat of fusion of 109 \(kJ/kg\), and a specific heat of 2.43 \(kJ/kg \cdot K\). How much energy must be removed from 0.510 \(kg\) of ethyl alcohol that is initially a gas at 78.0\(^\circ\)C so that it becomes a solid at −114\(^\circ\)C?  
\(Ans:\ 742 \text{ kJ}\)

5 | An insulated Thermos contains 130 \(cm^3\) of hot coffee at 80.0\(^\circ\)C. You put in a 12.0 \(g\) ice cube at its melting point to cool the coffee. By how many degrees has your coffee cooled once the ice has melted and equilibrium is reached? Treat the coffee as though it were pure water and neglect energy exchanges with the environment.  
\(Ans:\ 13.5\text{\degree C}\)

The specific heat of water: \(c_w = 4186 \text{ J/(kg} \cdot \text{K)}\)
The specific heat of ice: \(c_i = 2060 \text{ J/(kg} \cdot \text{K)}\)
The specific heat of copper: \(c_c = 386 \text{ J/(kg} \cdot \text{K)}\)
The heat of fusion for water: \(L_f = 333 \text{ kJ/kg}\)
The heat of vaporization for water: \(L_v = 2256 \text{ kJ/kg}\)
6 | A 150 g copper bowl contains 220 g of water, both at 20.0°C. A very hot 300 g copper cylinder is dropped into the water, causing the water to boil, with 5.00 g being converted to steam. The final temperature of the system is 100°C. Neglect energy transfers with the environment.
(a) How much energy is transferred to the water as heat? (Ans: 84935.2 J)
(b) How much to the bowl? (Ans: 4644.2 J)
(c) What is the original temperature of the cylinder? (Ans: 873°C)

7 | A person makes a quantity of iced tea by mixing 500 g of hot tea (essentially water) with an equal mass of ice at its melting point. Assume the mixture has negligible energy exchanges with its environment. If the tea’s initial temperature is \( T_i = 90°C \), when thermal equilibrium is reached what are
(a) the mixture’s temperature \( T_f \) (Ans: 5.3°C), and
(b) the remaining mass \( m_f \) of ice? (Ans: 0.0 g)
If \( T_i = 70°C \), when thermal equilibrium is reached what are
(c) \( T_f \) (Ans: 0.0°C), and
(d) \( m_f \)? (Ans: 60.0 g)

8 | (a) Two 50 g ice cubes are dropped into 200 g of water in a thermally insulated container. If the water is initially at 25°C, and the ice comes directly from a freezer at −15°C, what is the final temperature at thermal equilibrium? (Ans: 0°C)
(b) What is the final temperature if only one ice cube is used? (Ans: 2.5°C)

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1 | Figure below shows the cross-section of a wall made of three layers. The layer thicknesses are \( L_1, L_2 = 0.700L_1 \), and \( L_3 = 0.350L_1 \). the thermal conductivities are \( k_1, k_2 = 0.900k_1 \), and \( k_3 = 0.800k_1 \). the temperatures at the left side and right side of the wall are \( T_H = 30.0^\circ C \) and \( T_C = -15.0^\circ C \), respectively. Thermal conduction is steady.

a) What is the temperature difference \( \Delta T_2 \) across layer 2 (between the left and right sides of the layer)? \( (\text{Ans: } 15.8^\circ C) \)

b) If \( k_2 \) were, instead, equal to \( 1.1k_1 \), would the rate at which energy is conducted through the wall be greater than, less than, or the same as previously? \( (\text{Ans: greater}) \)

c) What would be the value of \( \Delta T_2 \)? \( (\text{Ans: } 13.8^\circ C) \)

2 | in figure (a) two identical rectangular rods of metal are welded end to end, with a temperature of \( T_1 = 0^\circ C \) on the left side and a temperature of \( T_2 = 100^\circ C \) on the right side. In \( 2.0 \text{ min} \), \( 10 \text{ J} \) is conducted at a constant rate from the right side to the left side. How much time would be required to conduct \( 10 \text{ J} \) if the rods were welded side to side as in figure (b)? \( (\text{Ans: } 30 \text{ s}) \)

3 | (a) What is the rate of energy loss in watts per square meter through a glass window 3.0 mm thick if the outside temperature is \(-27^\circ C\) and the inside temperature is \(24^\circ C\)? \( (k_{\text{Glass}} = 1.0 \text{ W/m.K}) \) \( (\text{Ans: } 17 \text{ kW/m}^2) \)

(b) A storm window having the same thickness of glass is installed parallel to the first window, with an air gap of 7.5 cm between the two windows. What now is the rate of energy loss if conduction is the only important energy-loss mechanism? \( (k_{\text{Air}} = 0.026 \text{ W/m.K}) \) \( (\text{Ans: } 18 \text{ W/m}^2) \)
CHAPTER 18 | The First Law of Thermodynamics

1 | In figure head-on, a gas sample expands from $V_0$ to $4.0V_0$ while its pressure decreases from $p_0$ to $p_0/4.0$. If $V_0 = 1.0 \text{ m}^3$ and $p_0 = 40 \text{ Pa}$, how much work is done by the gas if its pressure changes with volume via
   a) path A, (Ans: 120 J)
   b) path B, (Ans: 75 J) and
   c) path C? (Ans: 30 J)

4 | As a gas is held within a closed chamber, it passes through the cycle shown in the figure. Determine the energy transferred by the system as heat during constant-pressure process $CA$ if the energy added as heat $Q_{AB}$ during constant-volume process $AB$ is 20.0 J, no energy is transferred as heat during adiabatic process $BC$, and the net work done during the cycle is 15.0 J. (Ans: 18 cal)

2 | When a system is taken from state $i$ to state $f$ along path $iaf$ in figure in front, $Q = 50 \text{ cal}$ and $W = 20 \text{ cal}$. Along path $ibf$, $Q = 36 \text{ cal}$.
   a) What is $W$ along path $ibf$? (Ans: 6 cal)
   b) If $W = -13 \text{ cal}$ for the return path $fi$, what is $Q$ for this path? (Ans: -43 cal)
   c) If $E_{int,i} = 10 \text{ cal}$, what is $E_{int,f}$? (Ans: 40 cal)
   d) If $E_{int,b} = 22 \text{ cal}$, what is $Q$ for path $ib$, (Ans: 18 cal) and
   e) path $bf$? (Ans: 18 cal)