**HEAT TRANSFER AND CALORIMETRY: GUIDED PROBLEMS**

**Problem A** A copper penny has a mass of 0.00302 kg and a temperature of 20°C. It has a melting point of 1083°C and a latent heat of fusion of 2.07 \times 10^5 J/kg. How much heat must be added to the penny to melt it and raise the liquid penny to 40°C?

\[ Q = \Delta H \times m \]
\[ = 2.07 \times 10^5 \times 0.00302 \]
\[ = 626.387 \text{ J} \]

**Problem B** A copper penny has a mass of 0.00302 kg and a temperature of 20°C. It has a melting point of 1083°C and a latent heat of fusion of 2.07 \times 10^5 J/kg. How much heat must be added to the penny to melt it and raise the liquid penny to 40°C?

\[ Q = mc \Delta T \]
\[ = (0.00302)(0.385)(1083 - 20) \]
\[ = 124 \text{ J} \]

**Problem C** The latent heat of sublimation (\(\Delta H_{\text{sublimation}}\)) of dry ice (solid carbon dioxide) is 570 J/g. Determine the amount of heat required to turn a 5.0-pound bag of dry ice into gaseous carbon dioxide. (Given: 1.00 kg = 2.20 lb)

\[ Q = mL = (22.72 \text{ g})(570 \text{ J/g}) \]
\[ = 1295040 \text{ J} \]

\[ 5.0 \text{ lb} \times 453.6 \text{ g/lb} \]
\[ = 2272 \text{ g} \]

\[ 2.20 \text{ lb} \times 453.6 \text{ g/lb} \]
\[ = 1000 \text{ g} \]
HEAT TRANSFER AND CALORIMETRY PARTNER PRACTICE

1. The temperature last night was 38° F. Convert this to the Celsius and to the Kelvin temperature scales. Be sure to label which temperature is which.

2. The melting point of lead is 327.3° C. Convert this measurement to Fahrenheit.

3. Oxygen changes from a gas to a liquid at -183° C. Convert this to Kelvin.

4. The specific heat of silver is 235 J/kg°C. How much heat must be added to a 0.25 kg piece of silver to raise its temperature from 25° C to 600° C?

\[ Q = (0.25)(235)(600 - 25) \]
\[ = 33781.25 J \quad 330000 J \]

5. How much heat energy must be added to a 0.65 kg sample of water at 30° C to turn it into steam at 125° C? (The specific heat of steam is 2100 J/kg°C and the specific heat of water is 4186 J/kg°C. The boiling point of water is 100° C. The latent heat of vaporization for water is 2.26 \times 10^6 J/kg.)

\[ Q_1 = (0.65)(4186)(70 - 30) = 190463 J \]
\[ Q_2 = (0.65)(2100)(100 - 30) = 1469000 J \]
\[ Q_3 = (0.65)(4186)(125 - 60) = 34125 J \]
\[ Q_{total} = 1693888 J \]

6. How much heat must be added to a 0.45 kg piece of lead with an initial temperature of 20° C to change it to molten (melted) lead? The specific heat of lead is 128 J/kg°C, the latent heat of fusion for lead is 2.32 \times 10^6 J/kg, and lead melts at 327° C.

\[ Q_1 = (0.45)(128)(327 - 20) = 17683.2 J \]
\[ Q_2 = mL = (0.45)(2.32 \times 10^6) = 10440 J \]
\[ Q_{total} = 28123.2 J \]

7. A 1.2 kg sample of water has a temperature of 22° C. A 0.6 kg piece of copper at a temperature of 325° C is added to the sample. What is the final temperature of the water and copper? (The specific heat of copper is 385 J/kg °C and the specific heat of water is 4186 J/kg°C)

\[ Q_{H_2O} = - Q_{copper} \]
\[ mc_\Delta T = - mc_\Delta T \]
\[ \Delta T = \frac{(1.2)(4186)(T_f - 22) = -(0.6)(385)(T_f - 325)}{50.232(T_f - 22) = -231(T_f - 325)} \]
\[ 5023.2T_f - 110510 = -231T_f + 75075 \]
\[ 5254.2T_f = 185585 \]
\[ T_f = 35°C \]
8. A 0.50 kg block of ice has a temperature of -20°C. How much heat must be added to this ice to change it to water at 70°C?

\[ L_{\text{fusion}} = 3.34 \times 10^5 \text{ J/kg} \]
\[ c_{\text{ice}} = 2108 \text{ J/kg°C} \]
\[ c_{\text{water}} = 4186 \text{ J/kg°C} \]

\[ \begin{align*}
\text{Q}_1 &= (0.5)(3.34 \times 10^5) = \frac{167000}{1} \\
\text{Q}_2 &= (1.5)(3.34 \times 10^5) = \frac{444000}{2} \\
\text{Q}_3 &= (1.5)(4186)(70) = \frac{146570}{3} \\
\text{Q} &= \frac{334590}{3} + \frac{300000}{3} \\
\end{align*} \]

9. A copper penny has a mass of 0.003 kg and a temperature of 20°C. It has a melting point of 1083°C and a latent heat of fusion of 2.07 \times 10^5 \text{ J/kg}. How much heat must be added to the penny to melt it?

\[ c_{\text{copper}} = 385 \text{ J/kg°C} \]

\[ \begin{align*}
\text{Q}_1 &= (0.003)(385)(1083-20) = 1227.765 \text{ J} \\
\text{Q}_2 &= (0.003)(8.07 \times 10^5) = 1848.765 \text{ J} \\
\text{Q} &= 2000 \text{ J} \\
\end{align*} \]

10. A 0.30 kg piece of steel \((c_{\text{steel}} = 452 \text{ J/kg°C})\) at a temperature of 350°C is added to 10 kg of water at 20°C. Assuming no heat is lost to the surroundings and no water escapes, what is the final temperature of the water and steel?

\[ c_{\text{water}} = 4186 \text{ J/kg°C} \]

\[ Q_{\text{water}} = -Q_{\text{steel}} \]
\[ mc(T_f-T_i) = -mc(T_f-T_i) \]
\[ (10)(4186)(T_f-20) = -(0.30)(452)(T_f-350) \]
\[ 41840T_f -836800 = -135.6+47460 \]
\[ 41975T_f = 884260 \]
\[ T_f = 21.1°C \]

11. A 0.38 kg glass container has 1 kg of water in it. The water and the container have an initial temperature of 25°C. One kg of water at 90°C is added to the container. What is the final temperature of the 2 kg of water and the container?

\[ \begin{align*}
\text{Q}_{\text{water}} &= -Q_{\text{hot water}} \\
mc(T_f-T_i) &= -mc(T_f-T_i) \\
(1)(4186)(T_f-25) &= -(1)(4186)(T_f-90) \\
T_f-25 &= -T_f + 90 \\
\end{align*} \]

\[ \Delta T_f = 115 \]
\[ T_f = 57.5°C \]
FREZING AND BOILING POINT GRAPH

Answer the following questions using the chart above.

1. What is the freezing point of the substance? \( 5^\circ C \)
2. What is the boiling point of the substance? \( 15^\circ C \)
3. What is the melting point of the substance? \( 5^\circ C \)
4. What letter represents the range where the solid is being warmed? \( a \)
5. What letter represents the range where the liquid is being warmed? \( c \)
6. What letter represents the range where the vapor is being warmed? \( e \)
7. What letter represents the melting of the solid? \( b \)
8. What letter represents the vaporization of the liquid? \( d \)
9. What letter(s) shows a change in potential energy? \( b, d \)
10. What letter(s) shows a change in kinetic energy? \( a, c, e \)
11. What letter represents condensation? \( d \)
12. What letter represents crystallization? \( b \)
Solve the following problems.

1. How many joules of heat are given off when 5.0 g of water cool from 75°C to 25°C? (Specific heat of water = 4.18 J/g°C)
   \[ Q = (5)(4.18)(-50) = -1045 J \]

2. How many calories are given off by the water in Problem 1? (Specific heat of water = 1.0 cal/g°C)
   \[ -250 \text{cal} \]

3. How many joules does it take to melt 35 g of ice at 0°C? (heat of fusion = 333 J/g)
   \[ Q = (35)(333) = 11655 J \]

4. How many calories are given off when 85 g of steam condense to liquid water? (heat of vaporization = 539.4 cal/g)
   \[ Q = (85)(539.4) = 45849 \text{cal} \]

5. How many joules of heat are necessary to raise the temperature of 25 g of water from 10°C to 60°C?
   \[ Q = (25)(4.18)(50) = 5225 J \]

6. How many calories are given off when 50 g of water at 0°C freezes? (heat of fusion = 79.72 cal/g)
   \[ Q = (50)(79.72) = 3986 \text{cal} \]