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CHE 119S: Thermodynamics

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QUIZ 4 – MARCH 27, 2007

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You have 45 min to solve BOTH of the following problems. Clarity and brevity will be rewarded. Use this sheet only. Put your final answers in the appropriate boxes THIS IS A CLOSED BOOK QUIZ

1. A heat pump operates in the summer as an air conditioner (COP = 3.5) and in the winter as a heater (COP = 6.0). The device maintains the indoor temperature at 25.0°C throughout the year. The heat exchanged with the outside environment is proportional to 0.55 kW per degree of temperature difference between the room and the outside atmosphere. If the heat pump draws a power input of 1.65 kW, what is the (a) maximum and (b) minimum outside temperature for which this device can be used? [2 + 2 = 4 marks]

2. A piece of gold is immersed in boiling water until its temperature is 100.0°C. Then it quickly is removed, dried off, and transferred to an insulated flask containing 20.0 g of water at an initial temperature of T_i. After temperature equilibrium has been attained, the change in the entropy of the contents of the flask (i.e., the gold + the water) is + 0.087481 J K^{-1} and the water has increased in temperature by ΔT_W = +2.5209 K. When the experiment is repeated with the flask initially containing only 10.0 g of water at T_i, the temperature of the water increases by +4.8934 K. Assuming none of the water vaporizes, what is the mass of the piece of gold? The heat capacities of water and gold are 4.19 J g^{-1} K^{-1} and 0.131 J g^{-1} K^{-1}, respectively. [6 marks]

1. $COP = \frac{q_{hi}}{W}$ (heating)

Minimum outside temperature T_{lo} at COP = 6.0, T_{hi} = 25.0°C

$\dot{q}_{loss} = (0.55\ kW/°C)(25°C - T_{lo})$

$6.0 = \frac{(0.55)(25 - T_{lo})}{1.65}$

$9.9 = 13.75 - 0.55 T_{lo}$

$T_{lo} = 7°C$

$COP = \frac{q_{lo}}{W}$ (cooling)

Maximum outside temp. T_{hi} at COP = 3.5, T_{lo} = 25.0°C

$\dot{q}_{loss} = (0.55\ kW/°C)(T_{hi} - 25°C)$

$3.5 = \frac{(0.55)(T_{hi} - 25)}{1.65}$

$5.775 = 0.55 T_{hi} - 13.75$

$T_{hi} = 35.5°C$

∴ a) T_{max} = 35.5°C ✓
b) T_{min} = 7°C ✓

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2. T_{igold} = 100.0°C = 373.15 K

T_i = ?

m_{gold} = ?

m_{water} = 20.0 g m_{water}' = 10.0 g

~~$\Delta S = m c_p \ln\left(\frac{T_f}{T_i}\right)$ for gold & water~~

~~$0.087481 = m_{gold}(0.131)\ln\left(\frac{T_i + 2.5209}{373.15}\right) + (20.0)(4.19)\ln\left(\frac{T_i + 2.5209}{T_i}\right)$~~

~~$m_{gold} = \frac{0.087481 - (20.0)(4.19)\ln\left(\frac{T_i+2.5209}{T_i}\right)}{(0.131)\ln\left(\frac{T_i+2.5209}{373.15}\right)}$~~

Heat released by gold to water (insulated)

$m_{gold} C_{p\,gold} \Delta T_{gold} = m_{water} C_{p\,water} \Delta T_{water}$

① $m_{gold}(0.131)(373.15 - (T_i + 2.5209)) = (20.0)(4.19)(2.5209)$

$m_{gold} = \frac{(20.0)(4.19)(2.5209)}{(0.131)(373.15 - T_i - 2.5209)}$

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② $m_{gold}(0.131)(373.15 - (T_i + 4.8934)) = (10.0)(4.19)(4.8934)$

$m_{gold} = \frac{(10.0)(4.19)(4.8934)}{(0.131)(373.15 - T_i - 4.8934)}$

$\frac{(20.0)(4.19)(2.5209)}{(0.131)(373.15 - T_i - 2.5209)} = \frac{(10.0)(4.19)(4.8934)}{(0.131)(373.15 - T_i - 4.8934)}$

$27.67(368.2566 - T_i) = 26.859(370.63 - T_i)$

$10189.66 - 27.67 T_i = 9954.75 - 26.859 T_i$

$0.811 T_i = 234.91$

③ $T_i = 289.65\ K$ ✓ sub ③ into ①

$m_{gold} = \frac{(20.0)(4.19)(4.8934)}{(0.131)(370.63 - 289.65)} = 19.9\ g$

∴ m_{gold} = 19.9 g