1. Exactly one mole of neon (\(C_{p,m} = (5/2)R\)) is heated from 300 K to 400 K at a constant pressure of 1.0 atm.

   a. (4 points) Calculate \(\Delta S\) for the system.
   \[
   \Delta S = nC_p \ln \left( \frac{V_2}{V_1} \right) = (1.00) \frac{5}{2} (8.314) \ln \left( \frac{400}{300} \right) = 5.98 \text{ J/K}
   \]

   b. (4 points) If the surroundings are held at 400 K throughout the heating process, calculate \(\Delta S\) for the surroundings, and for the universe.
   \[
   \Delta S_{\text{sur}} = -\frac{q}{T} = C_p \Delta T = \frac{5}{2} R (400 - 300) = 20.78 \text{ J/K}
   \]
   \[
   \Delta S_{\text{surf}} = \frac{-20.78 \text{ J}}{400 \text{ K}} = -5.20 \text{ J/K}
   \]
   \[
   \Delta S_{\text{univ}} = 5.98 - 5.20 = 0.78 \text{ J/K}
   \]

2. (6 points) Evaluate \((\partial S/\partial V)_T\) in terms of the expansion coefficient \(\alpha = (1/V)(\partial V/\partial T)_p\) and the isothermal compressibility \(\kappa_T = -(1/V)(\partial V/\partial p)_T\).
   \[
   \left( \frac{\partial S}{\partial V} \right)_T = \left( \frac{\partial P}{\partial T} \right)_V \quad \text{(MAXWELL)}
   \]
   \[
   = -\frac{\left( \frac{\partial V}{\partial T} \right)_p}{\left( \frac{\partial V}{\partial P} \right)_T} \quad \text{(EULER)}
   \]
   \[
   = -\frac{V \kappa_T}{-V \kappa_T} = \frac{\alpha}{\kappa_T}
   \]

3. (6 points) Suppose that 0.54 mol of \(\text{Ar}(g)\) occupies 8.5 dm\(^3\) at 285 K and expands isothermally to 15.0 dm\(^3\). Calculate \(\Delta G\) for this process, assuming that argon behaves as a perfect gas.

   \[
   \Delta S = \int_{P_1}^{P_2} \left( \frac{nRT}{P} \right) dP = nRT \ln \left( \frac{P_2}{P_1} \right) = nRT \ln \left( \frac{V_2}{V_1} \right)
   \]
   \[
   = (0.54)(8.314 \text{ J/K})(285 \text{ K}) \ln \left( \frac{8.5}{15.0} \right)
   \]
   \[
   = -727 \text{ J}
   \]
4. (6 points) The vapor pressure of chlorobenzene is 11.1 torr at 80°C and 417 torr at 110°C. What is the enthalpy of vaporization of chlorobenzene?

\[
\ln \left( \frac{P_2}{P_1} \right) = \frac{-\Delta_{\text{vap}} H}{R} \left( \frac{1}{T_2} - \frac{1}{T_1} \right)
\]

\[
\ln \left( \frac{417}{11.1} \right) = \frac{-\Delta_{\text{vap}} H}{R} \left( \frac{1}{383} - \frac{1}{353} \right)
\]

\[
\Delta_{\text{vap}} H = \left( \frac{8.314}{383} \right) \ln \left( \frac{417}{11.1} \right) = 135.865 \text{ J/mol} = 135.9 \text{ kJ/mol}
\]

5. (6 points) When solid mercury melts at −38.83°C and 1 bar, its density changes from 14.18 g/cm³ to 13.69 g/cm³. The enthalpy of fusion is 2.29 kJ/mol. Estimate the melting point of mercury at 200 MPa.

\[
\frac{\Delta P}{\Delta T} = \frac{\Delta H}{T \Delta V}
\]

\[
\Delta T = \frac{T \Delta P \Delta V}{\Delta H}
\]

\[
\Delta T = \frac{(273.15 - 38.83)(200 \times 10^5 Pa)(2.29 \times 10^{-3})}{14.65 \text{ cm}^3/\text{mol}} = 10,23 \text{ K}
\]

\[
T_{\text{ fus}} = -38.83 + 10.23 = -28.60 \text{ °C}
\]

\[
= 244.55 \text{ K}
\]

6. (6 points) At 20°C, the density of a 20 per cent by mass ethanol/water solution is 968.7 kg/m³. Given that the partial molar volume of ethanol in the solution is 52.2 cm³/mol, calculate the partial molar volume of the water. (The molar mass of ethanol is 46.07 g/mol. The molar mass of water is 18.02 g/mol.)

\[V = n_4 V_A + n_8 V_B\]

**LET A = ETHANOL, B = WATER**

**ASSUME 1.00 kg of solution = 200 g A, 800 g B**

\[
V = \frac{1 \text{ kg}}{968.7 \text{ kg/m}^3} = 1.001032 \text{ m}^3 = 1.032 \text{ L} = 1032 \text{ cm}^3
\]

\[
n_A = \frac{200 \text{ g}}{46.07 \text{ g/mol}} = 4.34 \text{ mol}
\]

\[
n_B = \frac{800 \text{ g}}{18.02 \text{ g/mol}} = 44.40 \text{ mol}
\]

\[
1032 = (4.34)(52.2) + (44.40)V_B \Rightarrow V_B = 18.14 \text{ cm}^3/\text{mol}
\]
7. (6 points) The osmotic pressure of an aqueous solution at 288 K is 92.0 kPa. Estimate the freezing point of the solution.

\[ \frac{\Pi}{RT} = \frac{M}{\frac{288}{N}} = \frac{(92.0 \text{ kPa})}{(288 \text{ K})} \]

\[ M = \frac{\Pi}{RT} = \frac{(92.0 \text{ kPa})}{(0.08206 \text{ L atmos/mol K})} = 0.384 \text{ mol/L} \]

\[ b \approx M \approx 0.384 \text{ mol/kg} \]

\[ \Delta T = \frac{K \cdot b}{(186 \text{ °C/mol})} (0.0384 \text{ mole}) \]

\[ \Delta T = 0.7^\circ \text{C} \]

\[ T_f = 273^\circ - 0.7^\circ = 272.3^\circ \text{C} \]

8. (6 points) At 70°C, the vapor pressure of hexane is 900 torr and the vapor pressure of heptane is 350 torr. The two liquids form a nearly ideal solution. What is the mole fraction of hexane in a liquid mixture that boils at 70°C when the pressure is 1 atm (760 torr)? What is the mole fraction of hexane in the vapor produced?

\[ P = P_A + P_B \]

\[ = x_A P_A^* + x_B P_B^* \]

\[ = x_A P_A^* + (1-x_A) P_B^* \]

\[ 760 = x_A (900) + (1-x_A) (350) \]

\[ 760 - 350 = x_A (900 - 350) \]

\[ x_A = 0.745 \]

\[ y_A = \frac{P_A}{P_{tot}} = \frac{x_A P_A^*}{P_{tot}} = \frac{(0.745)(900)}{760} \approx \frac{671}{760} \approx 0.883 \]