1. For 1 mol ideal gas, $pv = RT$

a) Draw p-v diagram at $T = T_1, 2T_1, 3T_1$ (4 %)

b) Draw v-T diagram at $p = p_1, 2p_1, 3p_1$ (4 %)

c) Draw p-T diagram at $v = v_1, 2v_1, 3v_1$ (4 %)

d) Draw a 3D diagram (v-T-p) and show the curves from a) b) c) on this 3D diagram (8 %)

2. Heat capacity

a) Heat capacity at constant volume, C_v: Derive $C_v = \left(\frac{\partial U}{\partial T}\right)_v$ based on definition (4 %)

b) Heat capacity at constant pressure, C_p: Derive $C_p = \left(\frac{\partial H}{\partial T}\right)_p$ based on definition (4 %)

c) Derive $C_p = C_v + \left\{\left(\frac{\partial U}{\partial v}\right)_T + p\right\}\left(\frac{\partial v}{\partial T}\right)_p$ (8 %) and show $C_p = C_v + R$ for ideal gas (4 %)

3 Use equation: $dS = \frac{1}{T}(dU + pdV)$ to prove $TV^{\gamma-1}$ is constant for ideal gas under a reversible and adiabatic process ($\gamma = \frac{C_p}{C_v}$) (10 %)

4. 1 mol ideal gas is under reversible expansion from 1 liter to 3 liters at a constant pressure equal to 1 atm. Calculate the work (in Joule) created during this process. (5 %)

5. Draw two schemes to illustrate the effect of increasing pressure, p, on the chemical potential of the solid and liquid phases, and corresponding effects on the freezing temperature, T_f. One scheme illustrates T_f increases when p increases and the other one shows T_f decreases when p increases. Explanation should be provided. (10 %)

6. The standard Gibbs energy of formation of $PH_{3(g)}$ is 13.4 kJ/mol at 298 K. What is the reaction Gibbs energy when the partial pressure of the H_2 and PH_3 (assuming ideal gas) are 1.0 bar and 0.60 bar, respectively? (10 %) What is the spontaneous direction of the reaction in this case? (5%)

7. An average human DNA molecule has 5×10^8 dinucleotides (rungs on the DNA ladder) of four different kinds. If each rung were a random choice of one of these four possibilities, what would be the residual entropy associated with this typical DNA molecule? (10 %)

8. Schematically show the changes in thermodynamic properties, including volume, enthalpy, chemical potential, entropy, and heat capacity, accompanying first-order transition. (10 %)