1. One mole of an ideal monatomic gas, initially at 0 ℃ and 1 bar, is put through each of the reversible steps below (in each case starting at 0 ℃ and 1 bar). Calculate w, q, ΔU, ΔH, and ΔS for each case.
   (a) Cooling at constant volume to -100 ℃.
   (b) Isothermal compression to 100 bar.
   (c) Constant pressure heating to 100 ℃.
   (d) Adiabatic expansion to 0.1 bar. (16%)
2. The equilibrium constant Kp for the reaction
   $N_2(g) + O_2(g) = 2\,NO$
   varies with temperature over the range of 1900 to 2600 K according to the equation
   $\ln(Kp) = 3.13 - 21900/T$ (unit of T : K)
   Calculate Kp, ΔG^o, ΔH^o, and ΔS^o at 2000 K. (12%)
3. Benzene and toluene form very nearly ideal solutions. At 80 ℃, the vapor pressures of benzene and toluene are 100.4 kPa and 38.7 kPa, respectively. For a solution containing 0.5 mole fraction of benzene and 0.5 mole fraction of toluene, what are the composition of the vapor and the total vapor pressure at 80 ℃? (12%)
4. (a) For a gas system that PV work is the only type of work involved, show that
   $$Cp - Cv = [P + (\frac{\partial U}{\partial V})_T](\frac{\partial V}{\partial T})_P$$
   and explain the meanings of the three terms $(\frac{\partial U}{\partial V})_T$, $P(\frac{\partial V}{\partial T})_P$, and $(\frac{\partial U}{\partial V})_T(\frac{\partial V}{\partial T})_P$
   (b) Starting from the definition of Helmholtz energy, A=U-TS, show that
   $$(\frac{\partial U}{\partial V})_T = T(\frac{\partial P}{\partial T})_V - P$$
   (c) For a van der Waals gas, show that $(\frac{\partial \overline{U}}{\partial \overline{V}})_T = \frac{a}{\overline{V}^2}$ (15%)
5. The standard electromotive force (E^o) of the cell
   $Zn(S) \mid ZnCl_2(0.05\ mol\ kg^{-1}) \mid AgCl(S) \mid Ag$
   is 0.9854 volts at 25 ℃. (a) Write the half-cell reactions and the cell reaction. (b) Estimate the mean ionic activity coefficient of 0.05 mol kg^{-1} $ZnCl_2$ using Debye-Hückel theory. (c) Calculate the electromotive force (E) and the reaction Gibbs energy ($\Delta_r G$) of the cell. (15%)
6. The collision diameter of H_2 at 25 ℃ and 1 bar is 0.247 nm. Calculate the average number of collisions experienced by one molecule in unit time (collision frequency, $z_{1(1)}$), the average number of collisions per unit time and unit volume (collision density, Z_{11}), and the mean free path. (15%)
7. Consider the series of first-order irreversible reactions
   $$A \xrightarrow{k_1} B \xrightarrow{k_2} C$$
   The initial concentration of A is $[A]_0$. Neither B nor C are present initially.
   (a) Derive the expression for the variation of [B] with time.
   (b) At what time does the concentration of B reach a maximum ? (15%)