

1. One mole of a gas at 300 K is compressed isothermally and reversibly from an initial volume of 10 L to a final volume of 0.2 L. Calculate the work done on the system if  
(a) The gas is ideal. (b) The equation of state of the gas is  $P(V-b)=RT$ , with  $b=0.03$  L. (10%)
2. Calculate the entropy of mixing per mole of air, taking the composition by volume to be 79%  $N_2$ , 20%  $O_2$ , and 1% Ar. (6%)
3. One mole of helium is compressed isothermally and reversibly at 100 °C and from a pressure of 2 bar to 10 bar. Calculate (a)  $w$ , (b)  $\Delta U$ , (c)  $\Delta S$ , and (d)  $\Delta G$ . (12%)
4. At 100 °C and 2 bar, the degree of dissociation of  $COCl_2(g)$  is  $6.30 \times 10^{-5}$ . Calculate  $K_p$ ,  $K_c$ , and  $K_x$  for the dissociation reaction.  
 $COCl_2(g) = CO(g) + Cl_2(g)$  (12%)
5. One mole of tin undergoes a phase transition  $Sn(\text{gray}) \rightarrow Sn(\text{white})$  at 1.00 bar and 18.0 °C. Calculate (a)  $\Delta U$ , (b)  $\Delta S$ , and (c)  $\Delta G$  for this transition. Given that the heat absorbed is  $2238 \text{ J mol}^{-1}$  and the densities of gray and white tin are  $5.75$  and  $6.55 \text{ g cm}^{-3}$ , respectively. (At Wt Sn:118.7). (9%)
6. For  $UF_6$  the vapor pressure (in Pa) for the solid and liquid are given by  $\ln P_s = 29.411 - 5893.5/T$ ,  $\ln P_l = 22.254 - 3479.9/T$ . Calculate the temperature and pressure of the triple point. (6%)
7. Given the probability density function of the Maxwell distribution of speeds of gas molecules  $F(V) = 4\pi(m/2\pi kT)^{3/2} V^2 \exp(-mV^2/2kT)$ ,  
(a) Derive the most probable speed  $V_p$ .  
(b) Calculate  $V_p$  for  $H_2$  molecules at 0 °C. (10%)
8. A rock contains 0.26 mg of  $^{206}Pb$  per 1.0 mg of  $^{238}U$ . Estimate the age of the rock. The half-life for the decay of  $^{238}U$  to  $^{206}Pb$  is  $4.5 \times 10^9$  yr. (10%)
9. Which of the following functions is an eigenfunction of the operator  $d/dx$ ? Give the eigenvalue of the corresponding eigenfunction. (a)  $k$ , (b)  $kx^2$ , (c)  $e^{kx}$ , and (d)  $\sin kx$ , ( $k$  is constant). (6%)
10. Write the Hamiltonian for  $H_2^+$  ion. (3%)
11. The eigen values of the rigid rotator is given by  $E_J = (h^2/8\pi^2 I)J(J+1)$  where  $I$  is the moment of inertia and  $J=0, 1, 2, \dots$ . Calculate the energies of the first three levels and find the energy difference between each level. (8%)
12. The percentage transmittance of an aqueous solution of disodium fumarate at 250 nm and 25 °C is 19.2% for a  $5.00 \times 10^{-4} \text{ mol L}^{-1}$  solution in a 1-cm cell. Calculate the absorbance ( $A$ ) and the molar absorption coefficient ( $\epsilon$ ). (8%)