

1. (20%)

One mole of N_2 gas is contained at 273 K and a pressure of 1 atm. The addition of 3000 J of heat to the gas at constant pressure causes 832 J of work to be done during the expansion.

Calculate:

(1) the final state of the gas,

(2) the values of ΔU and ΔH for the change of state,

(3) the values of c_v and c_p for N_2 . Assume that nitrogen behaves as an ideal gas, and that the above change of state is conducted reversibly.

(4) If the heat supplied was 1500 J, what was the final state if the expansion was also conducted reversibly at constant pressure?

(5) How much work was it done during the expansion?

2. (20%)

Calculate the change in enthalpy and the change in entropy when one mole of SiC is heated from 25°C to 1000°C. The constant pressure molar heat capacity of SiC varies with temperature as:

$$c_p = 50.79 + 1.97 \times 10^{-3} T - 4.92 \times 10^{-6} T^2 + 8.20 \times 10^{-8} T^3 \quad (\text{J/mole.K})$$

3. (20%)

Determine the maximum pressure of water vapor in wet hydrogen at 1 atm pressure in which chromium can be heated without oxidation occurring at 1500 K. Is the oxidation of Cr by water vapor exothermic or endothermic?

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4. (20%)

n moles of an ideal gas A and $(1-n)$ moles of an ideal gas B , each at 1 atm pressure, are mixed at total constant pressure. What ratio of A to B in the mixture maximizes the decrease in the Gibbs free energy of the system? If the decrease in the Gibbs free energy is ΔG^M , to what value must the pressure be increased in order to increase the Gibbs free energy of the gas mixture by $\frac{1}{2}\Delta G^M$?

5. (20%)

Al_2O_3 , which melts at 2324 K, and Cr_2O_3 , which melts at 2538 K, form complete ranges of solid and liquid solutions. The molar heat of melting of Al_2O_3 is 107,500 J, and assuming that $\Delta S_{m,\text{Cr}_2\text{O}_3}^\circ = \Delta S_{m,\text{Al}_2\text{O}_3}^\circ$ and that the solid and liquid solutions in the system Al_2O_3 - Cr_2O_3 behave ideally. Calculate a few points on solidus and liquidus lines (compositions versus temperatures) and draw the phase diagram of Al_2O_3 - Cr_2O_3 system.

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Table A-1 The standard Gibbs free energy changes for several reactions (standard states are noted by subscript)

Reaction	ΔG° , Joules	Range, K
$2Ag_{(s)} + \frac{1}{2}O_{2(g)} = Ag_2O_{(s)}$	$-30,540 + 66.11 T$	298-463
$Al_{(l)} = [Al]_{(l) \text{ wt\% in Fe}}$	$-43,100 - 32.26 T$	
$2Al_{(l)} + 1.5O_{2(l)} = Al_2O_{3(s)}$	$-1,687,200 + 326.8 T$	993-2327
$C_{(s)} + \frac{1}{2}O_{2(g)} = CO_{(g)}$	$-111,700 - 87.63 T$	298-2000
$C_{(s)} + O_{2(g)} = CO_{2(g)}$	$-394,100 - 0.84 T$	298-2000
$C_{(s)} + \frac{1}{2}O_{2(g)} + \frac{1}{2}S_{2(g)} = COS_{(g)}$	$-202,800 + 9.96 T$	773-2000
$C_{(gr)} + 2H_{2(g)} = CH_{4(g)}$	$-91,040 + 110.7 T$	773-2000
$C_{(gr)} = [C]_{(l) \text{ wt\% in Fe}}$	$22,600 - 42.26 T$	
$CaO_{(s)} + CO_{2(g)} = CaCO_{3(s)}$	$-168,400 + 144 T$	449-1150
$2CaO_{(s)} + SiO_{2(s)} = 2CaO \cdot SiO_{2(s)}$	$-118,800 - 11.30 T$	298-2400
$CoO_{(s)} + SO_{3(g)} = CoSO_{4(s)}$	$-227,860 + 165.3 T$	298-1230
$2Cr_{(l)} + 1.5O_{2(g)} = Cr_2O_3_{(s)}$	$-1,110,100 + 247.3 T$	298-1793
$2Cu_{(l)} + \frac{1}{2}O_{2(g)} = Cu_2O_{(s)}$	$-162,200 + 69.24 T$	298-1356
$2Cu_{(l)} + \frac{1}{2}O_{2(l)} = Cu_2O_{(s)}$	$-188,300 + 88.48 T$	1356-1509
$2Cu_{(l)} + \frac{1}{2}S_{2(g)} = Cu_2S_{(s)}$	$-131,800 + 30.79 T$	708-1356
$3Fe_{(l)} + C_{(gr)} = Fe_3C_{(s)}$	$29,040 - 28.03 T$	298-1000
$3Fe_{(gr)} + C_{(gr)} = Fe_3C_{(s)}$	$11,234 - 11.00 T$	1000-1137
$Fe_{(s)} + \frac{1}{2}O_{2(g)} = FeO_{(s)}$	$-263,700 + 64.35 T$	298-1644
$Fe_{(l)} + \frac{1}{2}O_{2(g)} = FeO_{(l)}$	$-256,000 + 53.68 T$	1808-2000
$3Fe_{(l)} + 2O_{2(g)} = Fe_3O_4_{(s)}$	$-1,102,200 + 307.4 T$	298-1808
$Fe_{(l)} + \frac{1}{2}S_{2(g)} = FeS_{(l)}$	$-150,200 + 52.53 T$	412-1179
$H_{2(g)} + Cl_{2(g)} = 2HCl_{(g)}$	$-188,200 - 12.80 T$	298-2000
$H_{2(g)} + I_{2(g)} = 2HI_{(g)}$	$-8370 - 17.65 T$	298-2000
$H_{2(g)} + \frac{1}{2}O_{2(g)} = H_2O_{(g)}$	$-247,500 + 55.85 T$	298-2000
$Hg_{(l)} + \frac{1}{2}O_{2(g)} = HgO_{(s)}$	$-152,200 + 207.3 T$	
$Li_{(g)} + \frac{1}{2}Br_{2(g)} = LiBr_{(g)}$	$-333,900 + 42.09 T$	1239-2000
$Mg_{(l)} + Cl_{2(g)} = MgCl_{2(l)}$	$-603,200 + 121.43 T$	987-1368
$Mg_{(l)} + \frac{1}{2}O_{2(g)} = MgO_{(s)}$	$-729,600 + 204 T$	1363-2200
$2MgO_{(s)} + SiO_{2(s)} = Mg_2SiO_4_{(s)}$	$-67,200 + 4.31 T$	298-2171
$MgO_{(s)} + CO_{2(g)} = MgCO_{3(s)}$	$-117,600 + 170 T$	298-1000
$MgO_{(s)} + Al_2O_{3(s)} = MgO \cdot Al_2O_3_{(s)}$	$-35,560 - 2.09 T$	298-1698
$Mn_{(s)} + \frac{1}{2}O_{2(g)} = MnO_{(s)}$	$-388,900 + 76.32 T$	298-1517
$N_{2(g)} + 3H_{2(g)} = 2NH_{3(g)}$	$-87,030 + 25.8 T \ln T + 31.7 T$	298-2000
$2Ni_{(s)} + O_{2(g)} = 2NiO_{(s)}$	$-471,200 + 172 T$	298-1726
$2Ni_{(l)} + O_{2(g)} = 2NiO_{(s)}$	$-506,180 + 192.2 T$	1726-2200
$\frac{1}{2}O_{2(g)} = [O]_{(l) \text{ wt\% in Fe}}$	$-111,070 - 5.87 T$	
$Pb_{(l)} + \frac{1}{2}O_{2(g)} = PbO_{(s)}$	$-208,700 + 91.75 T$	600-1158
$Pb_{(l)} + \frac{1}{2}O_{2(l)} = PbO_{(l)}$	$-181,200 + 68.03 T$	1158-1808
$Pb_{(l)} + \frac{1}{2}S_{2(g)} = PbS_{(s)}$	$-163,200 + 88.03 T$	600-1386
$PbO_{(s)} + SO_{2(g)} + \frac{1}{2}O_{2(g)} = PbSO_4_{(s)}$	$-401,200 + 261.5 T$	298-1158
$PCl_{4(g)} + Cl_{2(g)} = PCl_5_{(g)}$	$-95,600 - 7.94 T \ln T + 235.2 T$	298-1000