Department of Materials Engineering

MTRL 250 – Thermodynamics I

Final Examination – 2007

100 total marks — 12 December 2007, 3:30 pm

Open book, open notes, open mind — Duration: 2.5 hours

1. (25 marks)

A gas mixture consisting of 20 mol% GeI_4(g) and 80 mol% argon gas is led, at 900 K and a total pressure of 1.2 atm, over solid germanium (AW = 72.59) so as to form GeI_2(g). Assuming that equilibrium is attained:

a) (15) Determine the composition of the gas stream leaving the reactor, and

b) (10) Calculate the rate of consumption of Ge (in g/min) when the volumetric flow rate of the gas mixture is 15 litres/min (measured at 900 K and 1.2 atm).

Reaction	ΔG^O (J)
$Ge(s) + I_2(g) \rightarrow GeI_2(g)$	$-14{,}674 - 37.742\,T$
$Ge(s) + 2\,I_2(g) \rightarrow GeI_4(g)$	$-185{,}645 + 114.131\,T$

Hint: Virtually no iodine gas will be present in the final gas mixture, and can therefore be eliminated from your calculations.

Note: 1 atm = 101,325 Pa (or J/m^3)

Hint: You may find the quadratic equation useful:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \quad \text{where} \quad ax^2 + bx + c = 0$$

2. (15 marks)

Measurements of the saturated vapor pressure of liquid mercury give 0.5718 atm at 600 K and 0.8388 atm at 620 K.

a) (10) Calculate the heat of vaporization $\Delta H_{l\rightarrow g}$ of Hg.

b) (5) Calculate the normal boiling temperature $T_{l\rightarrow g}$ of Hg.

Show your work!

3. (35 marks)

Zinc and cadmium form regular liquid solutions. Using the following data for Zn activity in liquid Zn-Cd solutions at 723 K:

x_{Zn}:	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
a_{Zn}:	0.325	0.501	0.601	0.665	0.712	0.753	0.797	0.848	0.914

a) (10) Determine the best interaction parameter Ω for this system (a simple arithmetic mean would be suitable).

b) (10) Calculate $\Delta\overline{H}_{Zn}^{M}$, $\Delta\overline{H}_{Cd}^{M}$, ΔH^{M}, $-T\Delta S^{M}$, and ΔG^{M} at 723 K for x_{Zn} = 0.25, 0.5, and 0.75.

c) (15) Calculate the heat required to form an equimolar liquid solution of Cd and Zn at 723 K, starting with the two solid metals at 298 K. Is this more or less heat than would be required if Zn and Cd formed ideal liquid solutions? Show your work!

Heat capacity data:

$c_P = A + (B \times 10^{-3})T$ (J/mol/K)		
	A	B
Cd (s)	22.217	12.300
Cd (l)	29.706	–
Zn (s)	22.384	10.042
Zn (l)	31.380	–

Heat of fusion data:

	$\Delta H_{s\to l}$ (J/mol)	$T_{s\to l}$ (K)
Cd	6401	594
Zn	7279	693

4. (25 marks)

From measurements of the equilibrium $C(\gamma) + CO_2(g) = 2\ CO(g)$, the following values for the activity of carbon have been found as a function of the mole fraction x_C of carbon in austenite (γ-phase carbon steel) at 1000°C with graphite (pure solid carbon) as the standard state:

x_C :	0.01	0.02	0.03	0.04	0.05	0.06
a_C :	0.09	0.20	0.33	0.47	0.66	0.85

a) (15) Find the mole fraction and weight percent of carbon in austenite if a sample is brought into equilibrium with a mixture containing 99.5% H_2 and 0.5% CH_4 at a total pressure of 1 atm.

b) (10) Will austenite containing 0.4 wt.% C be carburized (have its carbon content increased) or decarburized (have its carbon content decreased) by a gas mixture containing 99% H_2 and 1% CH_4 at a total pressure of 2 atm and a temperature of 1000°C? Show your work!

Reaction	ΔG^{O} (J)
$C(s) + 2\ H_2(g) \rightarrow CH_4(g)$	$-\ 91{,}040 + 110.7\ T$

Atomic weights: C 12.011, Fe 55.847

Hints: You may find the following relationships useful:

$$\frac{(\text{wt.\%})_i}{100} = \frac{M_i x_i}{\sum_j M_j x_j} \quad \text{and} \quad x_i = \frac{\dfrac{(\text{wt.\%})_i}{100 M_i}}{\sum_j \dfrac{(\text{wt.\%})_i}{100 M_i}}$$

Also, either linear or graphical interpolation of the activity data will be sufficient.