South Dakota School of Mines and Technology
Department of Materials and Metallurgical Engineering

MET 320 Final Exam Dec. 14, 2009

SEE DATA SHEET AT END OF EXAM - NO CALCULATORS – CLOSED BOOK AND NOTES
If a problem seems to be in error, state the trouble, state an assumed correction, and proceed.

1. a) One mole of ideal monatomic gas at 500 K undergoes an adiabatic compression from, 1 atm and 300 K to 10 atm. Find the final T.

   b) Two moles of ideal gas at 100 K and 1 atm are isochorically pressurized to 10 atm while exchanging heat with a heat sink at 1000 K. Find the final ΔS for the gas and the heat sink.

2. **FeO-Al_2O_3-SiO_2 (F-A-S) Ternary Phase Diagram**
   Show all constructions on the diagram.

   For the bulk composition marked,

   a) What is the bulk composition's
      i) Percent SiO_2 = _____

      ii) Percent FeO = _____

   b) What is the 1st crystal to appear upon cooling and at what T? _____

   c) What is the 2st crystal to appear upon cooling and at what T? _____

   d) What is the 3st crystal to appear upon cooling and at what T? _____

   e) What are the final 3 crystals? _____

   f) Characterize the system at 1400 °C

FeO–Al_2O_3–SiO_2

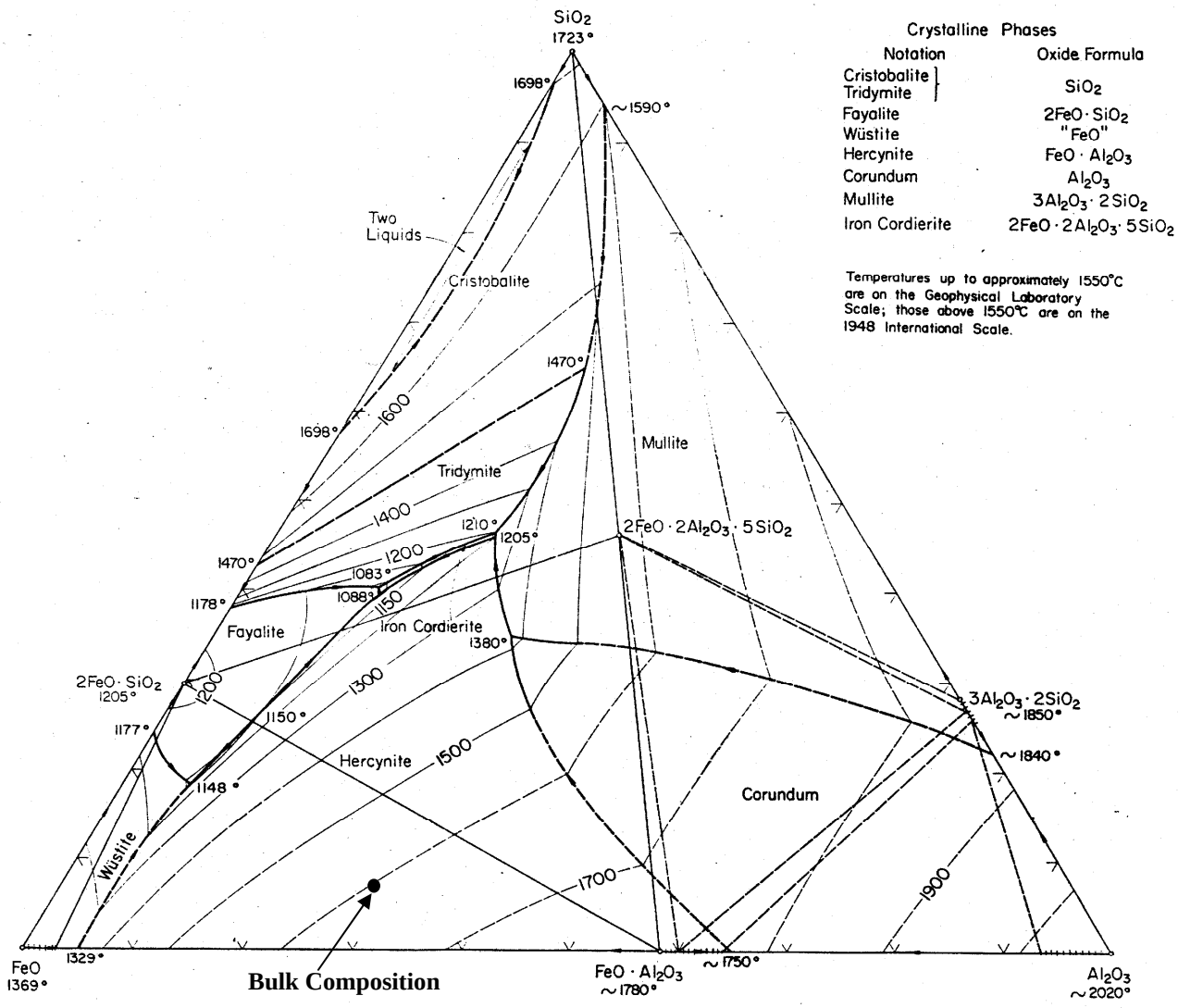


FIG. 696.—System "FeO"–Al_2O_3–SiO_2; composite. (Oxide Phases in Equilibrium with Metallic Iron).

E. F. Osborn and Arnulf Muan, revised and redrawn "Phase Equilibrium Diagrams of Oxide Systems," Plate 9, published by the American Ceramic Society and the Edward Orton, Jr., Ceramic Foundation, 1960.

3. **Ellingham Diagram**

Write your answers below and label construction lines on the attached Ellingham Diagram.

a) The pressure of O_2 in equilibrium with Si and SiO_2 at 1200 °C.

b) The H_2/H_2O ratio in equilibrium with Si and SiO_2 at 1200 °C.

c) The CO/CO_2 ratio in equilibrium with Si and SiO_2 at 1200 °C.

g) Label a circle showing the general region of the most noble metals on the diagram.

h) Label a circle showing the general region of the most stable oxides on the diagram.

i) Draw an arrow on the diagram showing the direction of decreasing oxygen potential.

j) Describe what you think would the equilibrium condition would be if a large amount of SiO_2 and Si were placed in a reactor with a relatively small amount of Mg, and MgO at 1200 °C.

4. Find the adiabatic flame temperature for the combustion of C with air (21% O_2, bal N_2) to form CO_2. The air temperature is -20 °C and the C is at 298 K. Use the provided text data sheet.

$$C\ (graphite) + O2(g) = CO2\ (g)$$

5. a) What is ΔG at 1000 K for the below reaction. The activity of Na relative to pure, liquid Na is 0.8, the pressure of titanium tetrachloride is 3 atm, the sodium chloride is pure liquid, and the Ti is pure, solid alpha.

$4Na_{(L)} + TiCl_{4\,(G)} = 4NaCl_{(L)} + Ti_{(S,\ Alpha)}$ $\qquad \Delta G°_{1000\ K} = -136.0$ Kcal/gfw

b) What cell potential would be required to reduce $MgCl_{2\,(L)}$ at 1100 K?

$MgCl_{2\,(L)} = Mg_{(L)} + Cl_{2\,(G)}$ (see data sheet)

6. a) Write the first 4 of Big 6 equations (exclude aqueous state) and describe the standard state for each.

b) What is the definition of the activity coefficient γ_i for a solid or liquid component in an alloy, magma, or slag?

c) What Maxwell Relation derives from dG = VdP – SdT?

7. A vessel maintained at a constant pressure of 10 atm is filled with 2 moles of H_2 and 1 moles N_2. These gases react to form NH_3. Find the equilibrium moles of NH_3.

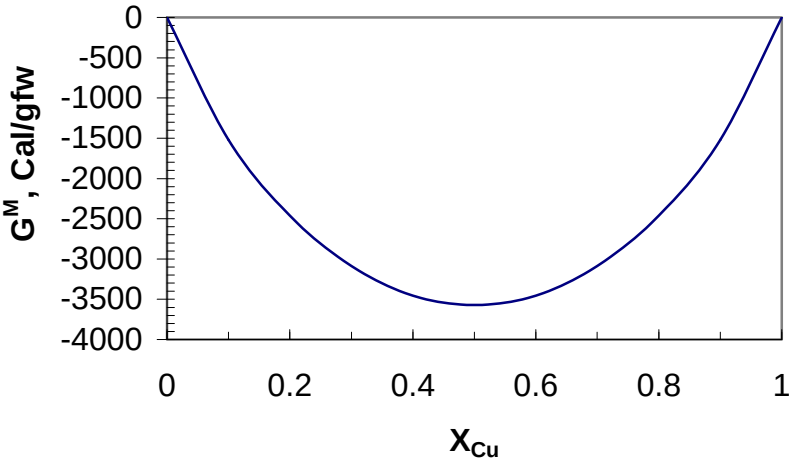
$$N_2 + 3H_2 = 2NH_3 \quad K=2.11$$

8. How many degrees of freedom are there in a system consisting of three condensed phases: one is primarily $Fe_{(l)}$, one is primarily $FeO_{(s)}$, and one is primarily $C_{(s)}$. There are two gas species: $CO_{2(g)}$ and $CO_{(g)}$? CO, CO_2, and C react as does FeO with C to make CO and Fe.

9. Show how to find the activity and the activity coefficient of Au in a liquid Au-Cu alloy at 1550 K that is 40 atomic percent Cu from the following data:

Gibbs energy of Mixing for the Liquid Au-Cu System at 1550 K

X_{Cu}	G^M
0	0
0.1	-1519
0.2	-2461
0.3	-3089
0.4	-3453
0.5	-3572
0.6	-3453
0.7	-3089
0.8	-2461
0.9	-1519
1	0



Gibbs Energy of Mixing for theLiquid Au-Cu System at 1550 K