DEPARTMENT OF MATERIALS SCIENCE AND ENGINEERING
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

3.205 THERMODYNAMICS AND KINETICS
Fall 2005

Mid Term Exam
1 1/2 hours

October 20, 2005
10:00 – 11:30 a.m.

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1. What is your name? _____

PROBLEM

2. _____ (20%)

3. _____ (15%)

4. _____ (20%)

5. _____ (15%)

6. _____ (15%)

7. _____ (15%)

GRAND TOTAL _____

2. Pure zinc oxide (ZnO) and zinc sulfide (ZnS) are equilibrated at 1000°C in an $SO_2(g)$ atmosphere at 1 atm pressure. The partial pressure of oxygen ($O_2(g)$) is experimentally measured to be 3.8 E-10 atm. The Gibbs free energy of formation of ZnO at 1000°C is –211 kJ/mol. The Gibbs free energy of formation of $SO_2(g)$ at 1000°C is –270 kJ/mol. ZnO and ZnS do not mix in either the liquid or solid phases.

   a. Write a balanced chemical equation with only these reactants and products.

   b. What is the Gibbs free energy of formation of ZnS?

   c. What is the partial pressure of $S_2(g)$?

3. Attached is an Ellingham Diagram for sulfides. It is based on diatomic sulfur gas, $S_2(g)$. [See for example the line for

$$2\ CO(g) + S_2(g) \Rightarrow 2COS(g)\ ]$$

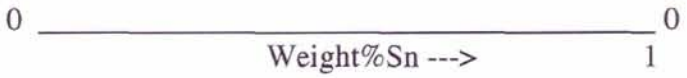
All other lines also represent the product of the reaction with $S_2(g)$.

a) Explain why the reaction for $2\ SO_3(g)$ has a steeper slope than $2\ SO_2(g)$.

b) In the presence of water, $SO_3(g)$ forms sulfuric acid, $H_2SO_4(l)$. If you were to bubble SO_3 through water at 298 k, would the slope of this reaction be positive or negative on an Ellingham diagram? Write the formula for the reaction and explain your reasoning.

4. Attached is the Lead-Tin phase diagram. For a temperature of 100°C

a. Plot the activity of Sn across the diagram, be quantitative and label relevant points.



b. Estimate the Henry's Law coefficient, , for small amounts of tin in nearly pure lead.

c. Would you expect the heat of mixing of lead and tin to be exothermic or endothermic? Briefly explain your reasoning.

5. A steam engine operating between 150 and 30°C performs 1000 joules of work.

a) What is the minimum quantity of heat which must be drawn from the heat source in order to obtain this amount of work?

b) Which of the following would give the greater increase in the efficiency of the engine:

i) an increase of ΔT in the temperature of the heat source, or

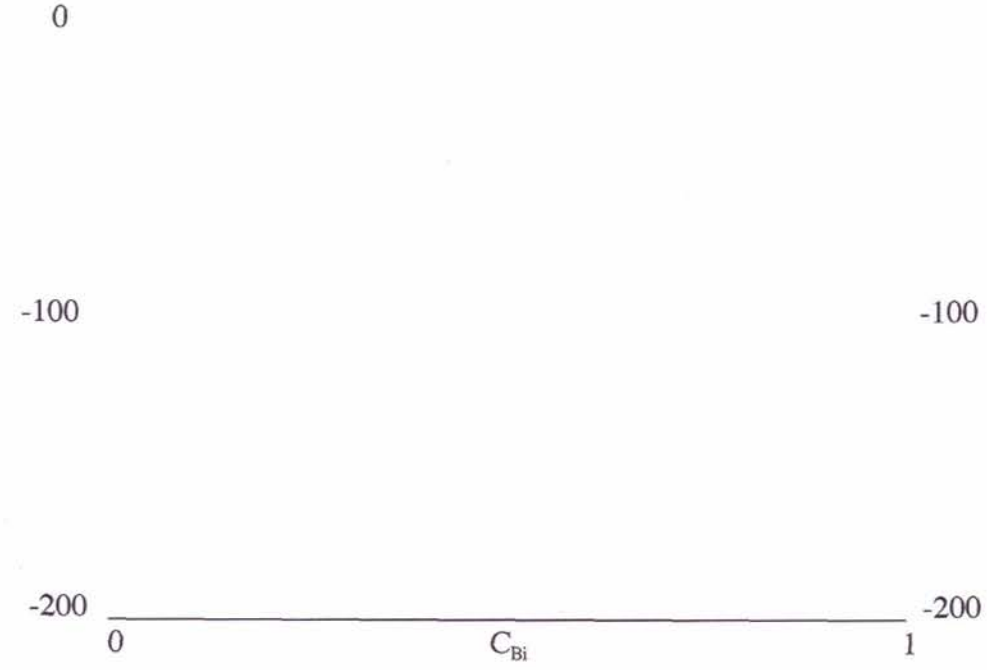
ii) a decrease of ΔT in the temperature of the heat sink?

Explain your answer.

6. Below is the Al – Bi binary phase diagram.

a. Draw a schematic of the Gibbs Free Energy vs Composition at 1100°C.

Given $G°$ (Al, 1100°C) = -72kJ/mol
$G°$ (Bi, 1100°C) = -123kJ/mol



b. On your diagram, show the partial molar Gibbs free energy of Al in a Al – 20% Bi alloy at 1100°C.

7. Using the Ellingham diagram attached, answer the following questions.

a) What is the partial pressure of oxygen above pure Si and pure SiO_2 at 1000°C?

b) If the system in part a) is in equilibrium, and then carbon is added to the system,

i) Would the oxygen pressure increase, decrease, or remain the same? Explain your answer.

ii) What other chemical species do you expect may form? For each, list whether it will be present as a solid, a liquid or a gas.

iii) Using the phase rule, how many components are present in *ii)* above? List them. How many phases are present? List them. How many degrees of freedom exist?

COMPONENTS **PHASES** **DEGREES OF FREEDOM**