ÉCOLE POLYTECHNIQUE

Département de génie chimique

Programme de métallurgie

MET 6208

ÉNERGÉTIQUE DES SOLUTION

Contrôle I

Jeudi, le 13 octobre, 2016

14:00 – 17:00

NOTES:
- All documentation permitted (open book exam)
- There are 7 questions and 3 figures

Le professeur: Arthur D. Pelton

Question 1 (3 points)

For Ca_2SiO_4,

h= -2309371 + 243.6602T-15379068T^{-2} – 4068.8$T^{0.5}$ J/mol

$s^0_{298.15} = 119.660$ J/mol · K

Calculate the molar entropy, s^0_{600}, at 600 K.

Question 2 (2 points)

The phase diagram of the $NaNO_3$-KNO_3 system is shown in Figure 1.

Assume that Raoult's Law and Henry's Law are obeyed by the α and β solutions. Calculate the activity coefficient $\gamma^0_{KNO_3}$ of KNO_3 in the α solution and the activity coefficient $\gamma^0_{NaNO_3}$ of $NaNO_3$ in the β solution when the two solutions are at equilibrium at the eutectic temperature of 494 K.

Question 3 (3 points)

The boiling point of pure H_2O (temperature where the vapour pressure = 1.00 atm) is 100.0 °C.

The standard entropy of vaporization of H_2O at 100.0 °C is

$$\Delta s^0_{vap} = 109.39 \text{ J/mol} \cdot \text{K}$$

In a 3.0 mol% solution of NaCl in H_2O at 100 °C, the activity of H_2O (relative to the pure liquid standard state) is $a_{H_2O} = 0.9418$

Assume that H_2O (gas) is ideal.

Calculate the boiling point of a 3.0 mol% solution of NaCl in H_2O (that is, the temperature where the vapour pressure is 1.00 atm.)

Question 4 (3 points)

The nitrogen content of liquid Fe in equilibrium at 1600 °C with a gas phase in which

$P_{N_2} = 1.0$ bar is 0.045 weight %.

Calculate the nitrogen content of liquid Fe in equilibrium at 1600 °C with a gas phase in which $P_{N_2} = 10.0$ bar, assuming that nitrogen dissolves in the liquid as monatomic N atoms, and that the liquid is a Henrian solution (that is, that γ_N is independent of composition).

Question 5 (3 points)

In a binary solution A-B,

$h^E = \omega X_A X_B$

$s^E = \eta X_A X_B$

where ω and η are constants and X_A and X_B are the mole fractions.

Write an expression for the activity of component A, a_A, as a function of X_A, X_B and T.

Question 6 (3 points)

In the phase diagram in Figure 2, the y-axis gives the equilibrium oxygen partial pressure, p_{O_2}.

The diagram applies at a constant $p_{SO_2} = 1.0$ atm. The phase fields indicate the regions of p_{O_2} and T where various solid oxides or sulphides are the stable phase. The lines indicate the conditions where two solid phases are stable.

(i) Taking the required data from the diagram, calculate ΔG^o of the following reaction at 900 K and at 1100 K:

$$FeS + SO_2 = FeS_2 + O_2$$

(ii) Calculate ΔH^o and ΔS^o of this reaction.

PUT YOUR NAME ON THE DIAGRAM AND HAND IT IN WITH YOUR ANSWER BOOKLET.

Question 7 (3 points)

The liquidus projection of the system

$Tl_2SO_4 - Li_2SO_4 - PbSO_4$ is shown in Figure 3.

All solid phases are stoichiometric (no solid solubility).

A liquid solution consists of 20 moles Tl_2SO_4, 40 moles Li_2SO_4 and 40 moles $PbSO_4$. The solution is cooled very slowly from the liquid state to 25 °C.

(a) Indicate (by putting arrows on the diagram) the crystallization path followed by the liquid during cooling.
(b) What is the temperature at which a solid phase first appear?
(c) What is the temperature at which the liquid phase completely disappears?
(d) Calculate, at 25 °C, the number of moles of each of the following constituents. Show clearly how you performed the calculations.
    (i) the primary constituent.
    (ii) the ternary eutectic constituent.
    (iii) the binary eutectic constituent.

PUT YOUR NAME ON THE DIAGRAM AND HAND IT IN WITH YOUR ANSWER BOOKLET.

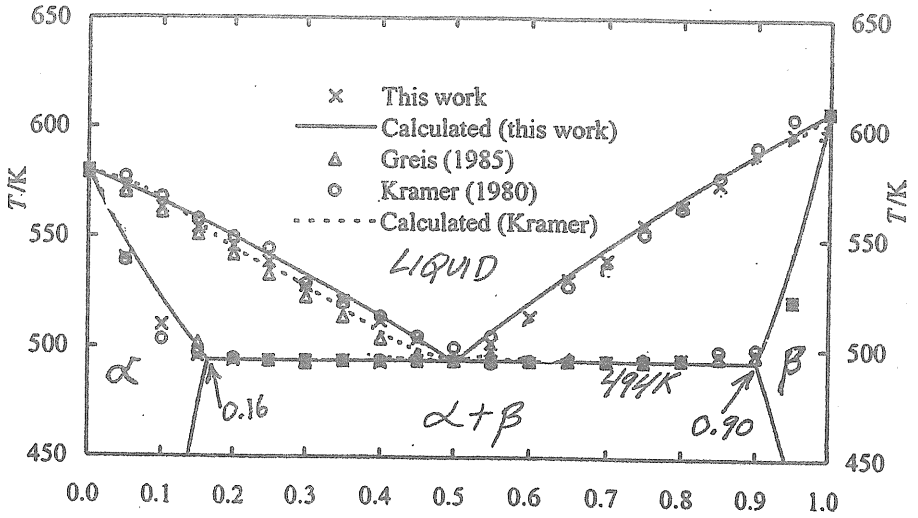

Figure 1

The phase diagram for the $NaNO_3$-KNO_3 system

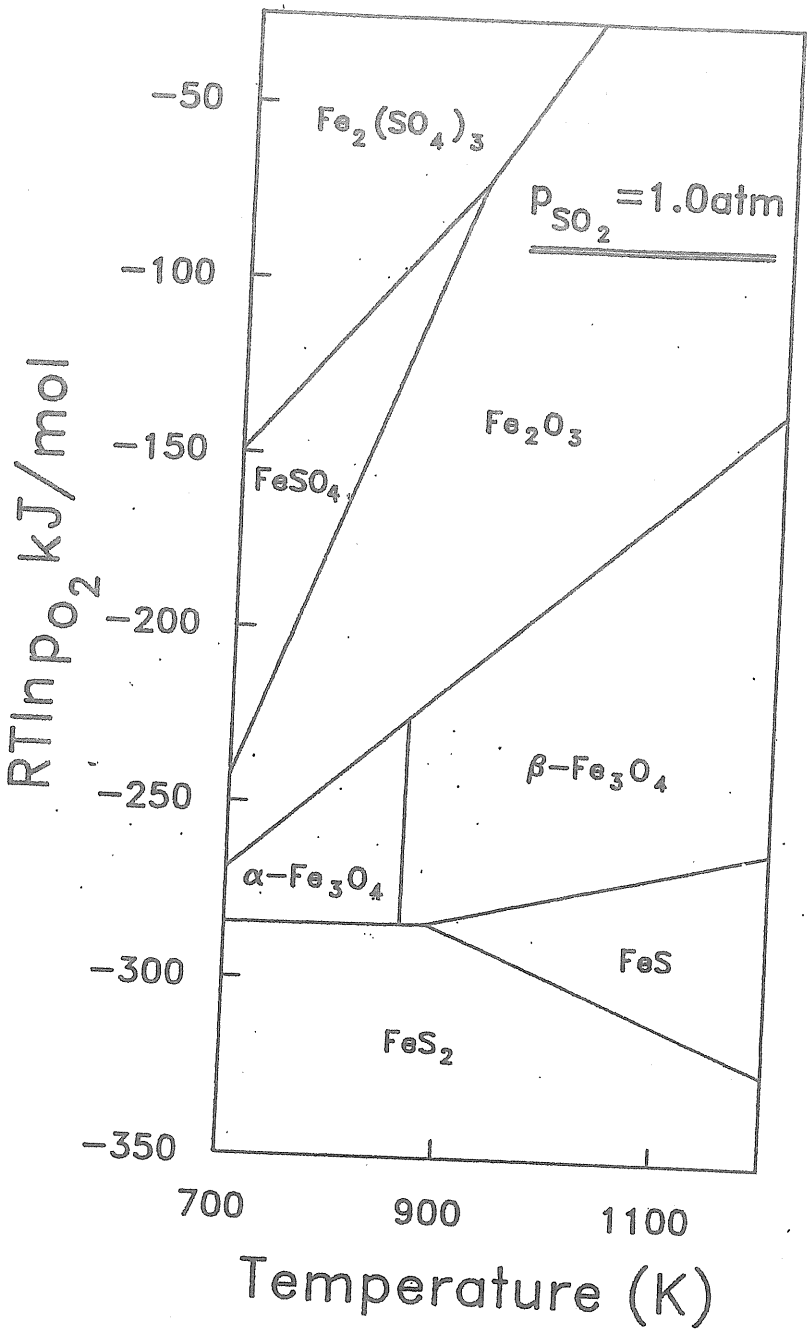
$Fe_2(SO_4)_3$
P_{SO_2} =1.0atm
Fe_2O_3
$FeSO_4$
β-Fe_3O_4
α-Fe_3O_4
FeS
FeS_2
−50
−100
−150
−200
−250
−300
−350
$RT\ln p_{O_2}$ kJ/mol
700
900
1100
Temperature (K)

Figure 2

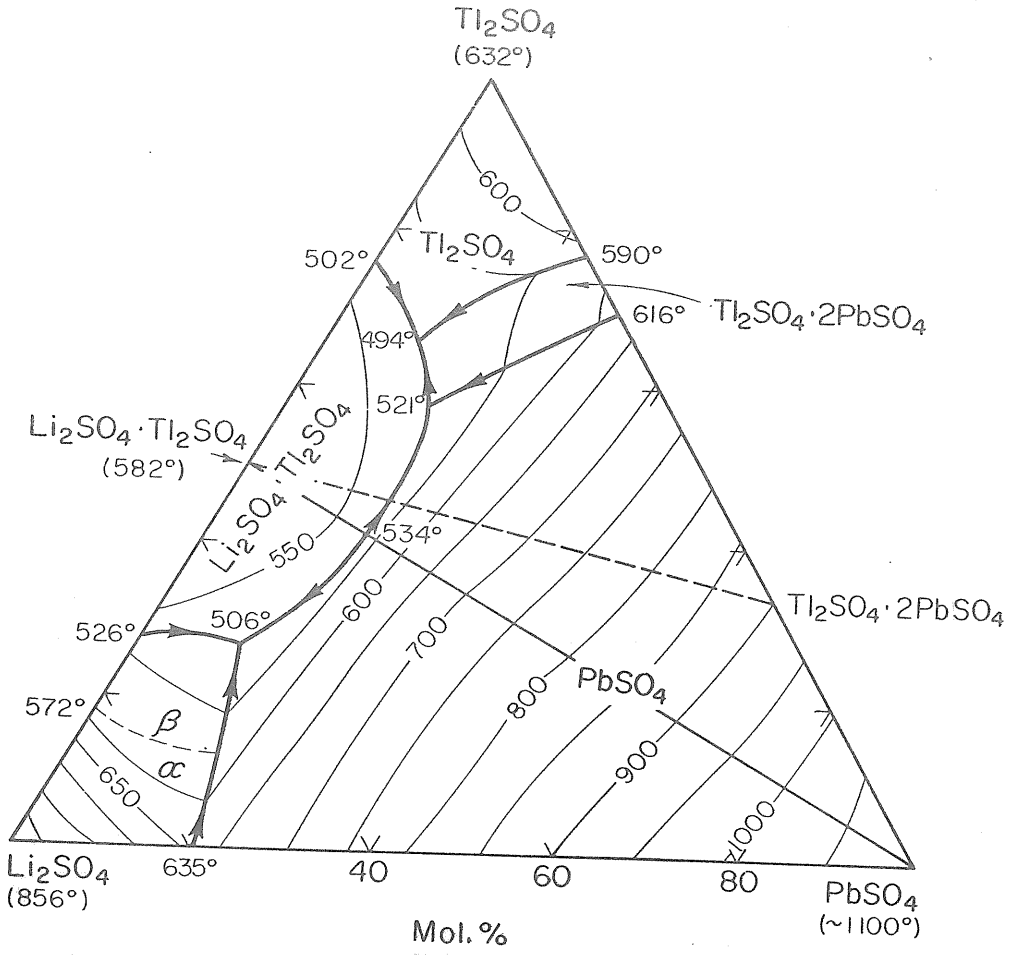
Tl_2SO_4
(632°)
600
Tl_2SO_4
502°
590°
616°
$Tl_2SO_4 \cdot 2PbSO_4$
494°
521°
$Li_2SO_4 \cdot Tl_2SO_4$
(582°)
$Li_2SO_4 \cdot Tl_2SO_4$
550
534°
$Tl_2SO_4 \cdot 2PbSO_4$
526°
506°
600
700
800
$PbSO_4$
572°
β
α
650
900
1000
Li_2SO_4
(856°)
635°
40
60
80
$PbSO_4$
(~1100°)
Mol. %

Figure 3