# UNIVERSITY OF OSLO

## Faculty of mathematics and natural science

**Exam in: MEF 3000 / MEF 4000**
**Examination date: 8.12.04**
**Examination time: 9:00-12:00 (3 hours)**

**The problem set is on 3 pages. The appendixes are: 2 copies each of three grids/templates, that may be used in the tasks: 1b, 2a and 2d. There are also a larger version of an alternative phase diagram for tasks 2b-d.**

**Allowed aids: Calculator.**

*Control that the task set is complete before answering the problems!*

**Task 1: (33 %)**

For the structure Pyrolusite (β-$MnO_2$), the following information is given:

Spacegroup: $P4_2/mnm$
Unit cell dimensions: $a$ = 4.40 Å, $c$ = 2.88 Å.
Mn in 2(a) position (0,0,0)
O in 4(f) position (0.3046, 0.3046, 0)

In the International Tables of Crystallography we find the following symmetryrelations: These apply to both types of atoms:

$$x,x,0 \quad \bar{x},\bar{x},0 \quad \bar{x}+\tfrac{1}{2},x+\tfrac{1}{2},\tfrac{1}{2} \quad x+\tfrac{1}{2},\bar{x}+\tfrac{1}{2},\tfrac{1}{2}$$

a) What type of Bravais lattice, and what crystal system is this?

How many formula units are there in the cell?

Give the corresponding point group symbol for this space group.

b) Draw the structure as a projection on the ab plane. Feel free to use the appended grid.

c) What is the distance between Mn and O?

d) What is the coordination for Mn?
How many Mn atoms are each O atom bonded to?

e) What types of connections are there between the polyhedra?

**Task 2: (33 %)**

Given the following information for a phase diagram with the components A and B:

The phase α contains maximum 5 wt.% of component B and melts at 500 °C. It undergoes a phase transition ($\alpha \rightarrow \alpha'$) in the temperature interval 270 – 280 °C, where 280 °C applies to a composition of 0 wt% B and 270 °C for a composition of 5 wt.% B.

The phase δ contains 17 wt. % B, has a neglectable solid solubility, and is only stable above 250 °C. The phase can be formed by a peritectic reaction with α and the melt at 430 °C.

In the composition range between the δ- and γ-phases, the lowest possible melting temperature is 362 °C, and the melt has then a composition of 33 wt. % B.

The phase γ contains 40 wt. % B and has a neglectable solid solubility. It undergoes a first order transition at 300 °C and melts congruently at 470 °C.

The phase ε contains 55 wt. % B and is stable up to 340 °C. At this temperature, it undergoes a peritectic reaction with the melt and the high-temperature modification of the γ-phase.

In addition there is an eutectic reaction at the temperature 320 °C from melts with a composition of 72 wt. % B.

The phase β melts at 490 °C and has a maximum solid solubility of the component A of 7 wt. % A.

a) Sketch the phase diagram with basis in the information over. Feel free to use the appended grid.

   **Note!** If you have had problems with task a), then you can use the phase diagram on the next page as basis for the tasks b-d).

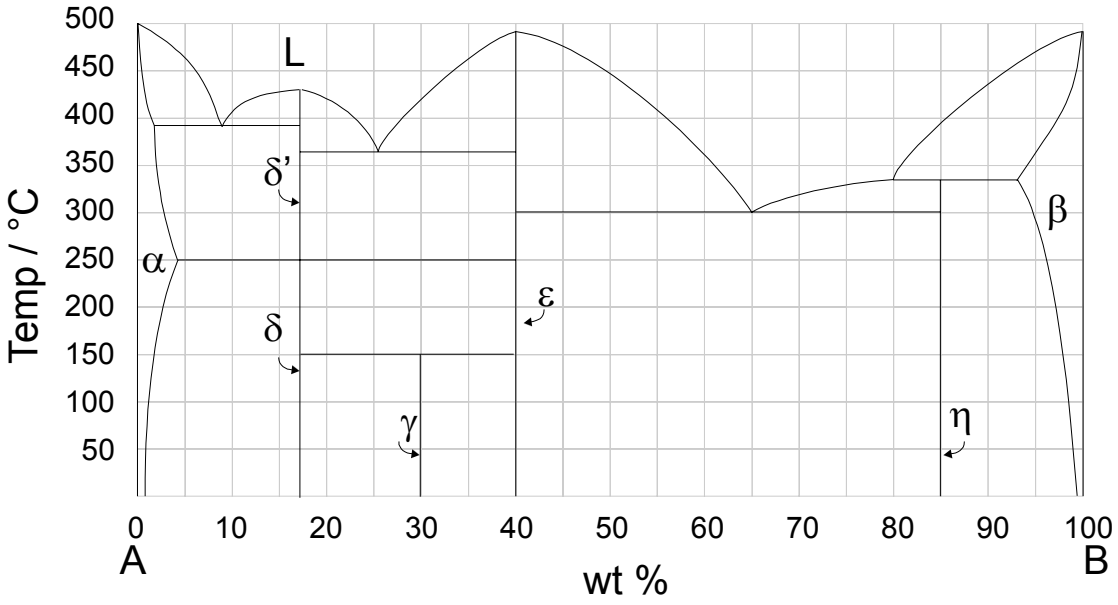
b) Mark the liquidus and solidus curves (use different colors or patterns/thickness).

c) Describe the invariant reactions.
   (P + F = C + 1)

d) Draw and comment the cooling curves for a sample with composition 35 wt. % B from 490 °C. Assume chemical equilibrium under the whole progress.

# Note!

If you have had problems with task a), then you can use the phase diagram below as basis for the tasks b-d). You will also find this appended in a larger format.




**Task 3: (34 %)**

a) Describe the differences between isolators, semiconductors and metals using band structure description.

b) What are the characteristic features of superconductors? Explain the difference between type I and type II superconductors.

c) In AgCl the interstitial $Ag^+$ ions have two possible mechanisms for migration. Illustrate these. Which is the dominant? Show the ionic conductivity as a function of temperature. How will impurities/doping influence the ionic conductivity in AgCl? Compare with doped NaCl.

d) What are the characteristic features for ferroelectric materials? Describe a typical hysteresis loop for a ferroelectric. Show the relationship between the relative permittivity ε' and the temperature above the Curie temperature for a ferroelectric material.

e) Describe the Curie and Curie-Weiss laws for paramagnetic, ferromagnetic and anti-ferromagnetic materials. Write the equations and show graphs. Explain the differences.