MATERIALVETENSKAP / PHYSICAL METALLURGY TFYA21

VT:1 2020; Björn Alling

Topical Questions for the examination of the course

Course literature is *Phase Transformations in Metals and Alloys, Porter & Easterling, 3rd Edition*

The questions are a helpful instrument for the studies. The exam will consist of a subset of them.

PART I

1. Which are the thermodynamic criteria for equilibrium in a
a) isolated system at fixed energy.
b) a system that can change its volume that is in contact with a large heat reservoir
Give equations and explain in words what they mean.

2. Define Gibbs free energy, G, and show for a one-component system in solid phase how the contributions to G and G itself varies typically with temperature.

3. Derive the expression for the driving force for solidification with a small undercooling, ΔT.

4. Derive the expression for the free energy of mixing, ΔG_{mix}, during formation of a binary solid solution.

5. Derive the expression for the entropy of mixing for an ideal solution of A and B atoms and make a schematic drawing of it as a function of the molar fraction of B atoms, and how it affects the free energy at low and high temperature, respectively.

6. What is the ”the chemical potential”? State the equilibrium condition for a binary alloy (elements A and B; two phases) with respect to the chemical potential.

7. What is meant by a regular solution in comparison with an ideal solution? What term is added in the free energy of mixing and how is it affected in that case? (do not make the derivation, but explain in words and draw the effect is a figure)

8. Derive an expression for the enthalpy of mixing for a regular solution ("broken bond model") for similar size of A and B atoms and when only nearest neighbors needs to be considered.

9. Why do the allotropes (different possible phases for one and the same component/element) that are stable at elevated temperature have higher enthalpies (H) than the allotropes that are stable at a lower temperature, for example, $H(\gamma\text{-Fe}) > H(\alpha\text{-Fe})$?

10. Show how the chemical potentials μ_A and μ_B for the elements A and B in a solution can be obtained by extrapolation of the tangent of the function $G(X_A, X_B)$ to $X_A = 0$ and $X_B = 0$, respectively.

11. If the free energy of mixing for a regular binary solution is given by:
$\Delta G_{mix} = \Omega X_A X_B + RT(X_A \ln X_A + X_B \ln X_B)$;
Produce expressions for how the chemical potential of atoms A and B are related to concentration.

12. In order to determine the equilibrium condition between two phases the so-called *tangent rule* is employed. Explain this rule with the help of free energy curves and explain what is obtained at equilibrium if a binary alloy has the composition X_0 where X_0 varies between $X_B = 0$ and 1.

13. Draw phase diagrams if the set of free-energy curves for an alloy are given for different temperatures.

14. What is meant by a ”*eutectic* phase diagram” and a ”*peritectic* phase diagram”?
Explain in words and with diagrams. When applicable, you should be able to indicate the *eutecticum* and *peritecticum* in a given phase diagram.

15. How does the exchange energy between A and B elements (in liquid and solid phase, respectively) influence the appearance of the phase diagram?

16. Explain in words and with schematic free energy curves how and why a solubility (miscibility) gap appears.

17. If two metals A and B (that form the phases α resp. β) have significantly different melting temperatures, how does that influence the appearance of the phase diagram for the A-B alloy?

18. Describe what information is obtained from the *Gibbs Phase Rule*.

19. The so called Gibbs-Thomson effect $\Delta G = 2\gamma V_m / r$, that Gibbs free energy increases due to a curved surface (radius *r*) for surface energy γ and molar volume Vm) has a pronounced influence on a material when the radius of precipitates, surface asperities or gas/liquid inclusions in shrinking into the nanometer scale. Please state at least two 'nano' phenomena that can be explained/predicted by the Gibbs-Thomson effect.