Instituto Politécnico de Tomar

Final Test **Chemical Thermodynamics II** – 09 June 2015

R = 8.314 J.K^{-1}mol^{-1} = 0.082 atm L mol^{-1}K^{-1}; 1 atm = 101325 Pa = 760 mmHg

k_B = 1.381×10^{-23} J.K^{-1}; h = 6.626×10^{-34} J.s; c = 3×10^{8} m.s^{-1}

Maximum allowed time: 2H30m

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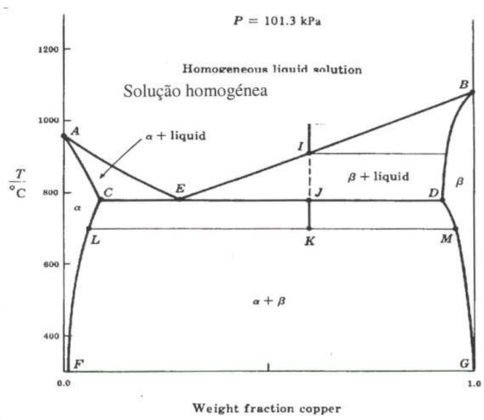
1. The mixture toluene (1) + bromociclopentane (2) presents a deviation to ideality at a temperature of 340 K that can be quantified by the expression $G^E/RT = 1.6\, x_1\, x_2$. At that temperature the vapor pressures of the two substances are respectively 200 and 130 mmHg. Considering the ideality of the gas phase:

1.1. Calculate the composition of the azeotrope at this temperature and the correspondent pressure.

1.2. Outline the diagram *p*,x,y at the temperature of 340 K.

2. Consider the following phase diagram for the binary system Cu/Ag.



2.1. Describe briefly the diagram represented, and apply the lever rule to the points I and K.

2.2. A mixture with about of 20% of Cu is cooled from 1000 °C to 700 °C. Describe the evolution of the system during this cooling, indicating the phases formed and their compositions.

3. Write the expression that gives you the partition function of a system with two levels of energy, being the non fundamental triply degenerate. Calculate the ratio of population at 500 K between the two levels knowing that they have a difference of energy corresponding to 6.1×10^{-21} J.

4. Calculate the heat capacity, C_P, at 25 °C, of the following substances: a) nitrogen, N_2; b) water, H_2O. The frequencies of the normal modes of vibration are in the following table:

Molecule	**ν / cm^{-1}**
N_2	2360
H_2O	1654, 3825, 3935

5. Consider the Debye model for solids.

5.1. Knowing that the C_V cooper at 60 K is 8.7 $J.K^{-1}.mol^{-1}$, make a prediction of the value at 25 K, using the Debye model at low temperatures:

$$C_V = \frac{12\pi^4 Nk}{5}\left(\frac{T}{\theta_D}\right)^3$$

5.2. Estimate the value of θ_D and envisage the heat capacity of copper at room temperature.