Chemistry Test # 1 (1h 30)

The 2 exercises are independent. No documents allowed. All answers must be justified.

Take: R=8.314 $J.mol^{-1}.K^{-1}$; $T_{0°C}$ = 273 K ; 1 atm = 760 torrs = 101325 Pa = 1.013 bar.

All gases may be considered ideal.

Exercise I: Isobaric L-V equilibria of binary mixtures of alcohols or alcohol-water (11 points. See data below)

Alcohols are organic molecules containing one or several OH group(s). This Exercise considers ethanol CH_3CH_2OH and 1-propanol $CH_3CH_2CH_2OH$.

1) Explain why these 2 alcohols are fully miscible at the liquid state, and why resulting binary mixtures can be considered as ideal solutions.

2) Establish the numerical relationship between the saturated vapor pressure of propanol P^*_{PropOH} (expressed in Torrs) and the temperature T (expressed in Kelvin) in the form: Ln P^*_{PropOH} = (A/T) + B with 1 decimal for A and 2 for B.

3) Consider a binary liquid solution of ethanol and 1-propanol in equilibrium with its vapor.

a) Calculate the variance of the system at equilibrium. Conclusion?

b) Demonstrate the litteral expressions of:

- X_{PropOH}, molar fraction of 1-propanol in the liquid solution, as a function of the overall pressure p and the respective saturated vapor pressure of each alcohol ;
- Y_{PropOH}, molar fraction of 1-propanol in the vapor.

c) Are these expressions in agreement with the variance caculated in 3a? Justify your answer.

d) Calculate X_{PropOH} and Y_{PropOH} (with 3 decimals) at L-V equilibrium at 350 K and an overall p of 425 Torrs.

e) When comparing them, do you consider that the value of Y_{PropOH} is consistent with the one of X_{PropOH}? Justify your answer.

4) 2000g of ethanol are mixed with 3000g of 1-propanol and the mixture heated to 350K. At this temperature, the system is constituted of 1 liquid phase in equilibrium with a vapor phase and the pressure is 425 Torrs.

a) What is the molar fraction of 1-propanol in each phase?

b) Using the lever rule, calculate ,at +/- 50 g, the masses of ethanol and 1-propanol and the total mass in each phase.

c) Check that your answers to 4b satisfy at max +/- 1 the principle of mass conservation of each constituent and the total mass.

5) a) Explain why ethanol and propanol are respectively fully miscible with water, but also why their aqueous solutions are not ideal.

b) Give a schematic plot of the L/V equilibrium phase diagram of water – ethanol mixture under the atmospheric pressure. Indication: ethanol is more volatile than water and the mixture with 93 % w/w of ethanol (7 % by weight of water) shows the minimal boiling temperature (78°C). It is NOT asked to calculate the boiling temperatures or to plot the diagram at scale, but the general aspect must be respected.

Data:

1-Propanol: M_{PropOH} = 60 g / mole ; P^*_{propOH} = 100 Torrs at 326.17 K and 700 Torrs at 368.31 K

Ethanol: M_{EtOH} = 46 g / mole ; Ln P^*_{EtOH} = - 4864.9 / T + 20.32 with P* in Torr

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Exercise 2: L-S equilibrium of NaCl-H_2O binary system. Application to road deicing (9 points. See data below)

Fig. 1 below shows the L/S equilibrium phase diagram of NaCl-H_2O binary system under a constant pressure of 760 Torrs. The compositions w_{NaCl} are given in mass fraction of NaCl.

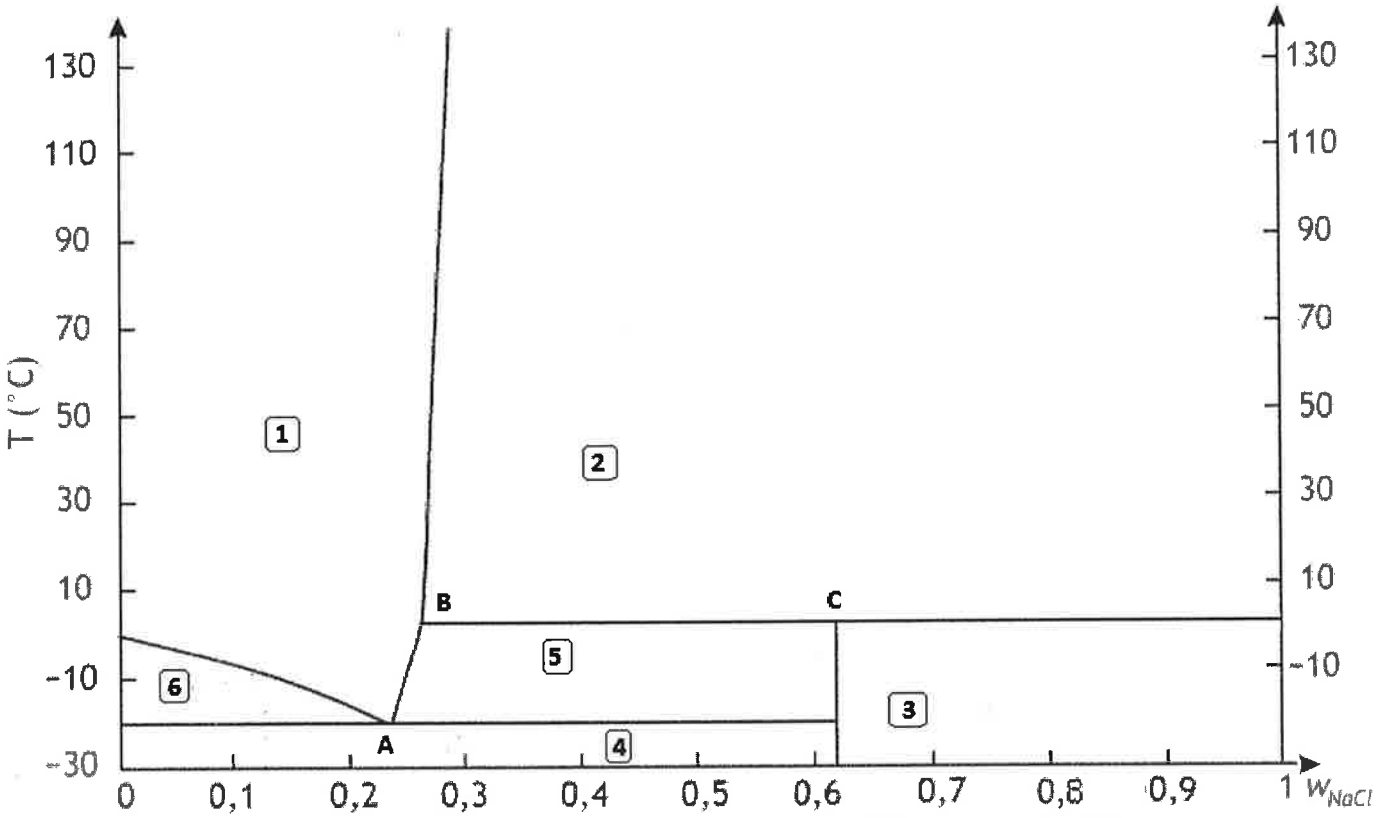

Figure 1: Isobaric L/S equilibrium phase diagram of NaCl – H_2O binary system (p=760 Torrs)

The coordinates of points A, B and C are respectively: T_A = -20°C, w_A = 0.24 ; T_B = 0°C, w_B = 0.27 ; T_C = 0°C, w_C = 0.62.

1) Determine the value of x in the chemical formula NaCl, x(H_2O) of the defined compound (hydrated sodium chloride). At which temperature does this compound melt and what type of fusion is observed here?
2) Indicate the phase(s) present in domains 1 to 6 of the diagram.
3) Name the singular point A and calculate the variance at this point.
4) Plot the thermal analysis line (temperature vs. time) when heating from -30°C to +30°C a mixture of mass fraction w_{NaCl} = 0.25. On each segment of the plot, indicate the initial and final approximate temperatures, the phase(s) present, the variance.
5) Sodium chloride (NaCl) may be spread onto roads in wintertime to protect them from ice formation or deice them. Below which temperature would this application be inefficient (justify your answer)?
6) At a temperature of -10°C, what would be the minimal and maximal masses of NaCl that should be spread to melt 1kg of ice and avoid the formation of hydrated sodium chloride NaCl, x(H_2O) $_{(sol)}$ which may also cause the formation of slippery areas.
7) 1 kg of salted water (w_{NaCl} = 0.10) is cooled from room temperature down to -30°C.
   a. At which temperature (approximately) will solidification begin?
   b. Indicate the nature of the phases and their respective mass at +/- 1 g at -10°C , and then at -30°C.

Data: M_{NaCl} = 58.5 g/mol M_{H2O} = 18.0 g/mol

Due to the uncertainties in reading the temperatures from the diagram, the masses calculated in this exercise will be given with no decimal (integer values).