CHEMISTRY 2
Test N°2
Time allowed: 1h30

No documents allowed. Only TI30 type calculators are authorized.
The 2 exercises are independent.
The schedule of mark is indicative.

General data:

R = 8.31 $J.K^{-1}.mol^{-1}$
1 atm = 1.013 bar = 1.013 10^5 Pa
Composition of air expressed in molar fraction: $x_{O_2} = 0.2$; $x_{N_2} = 0.8$

The effect of temperature on the variations of enthalpy and entropy will be neglected:

	Zn_{solid}	ZnO_{solid}	$O_{2\ gas}$	$C_{graphite}$	CO_{gas}	$SO_{2\ gas}$	$SO_{3\ gaz}$
$\Delta H^0_{f,298K}$ ($kJ.mol^{-1}$)		-348.3			-110.5	-296.8	-395.7
S^0_{298K} ($J.K^{-1}.mol^{-1}$)	41.6	43.6	205.0	5.7	197.6	248.0	256.4
Molar mass $g.mol^{-1}$	65.4	81.4	32.0	12.0	28.0	64.0	80.0

Fusion of Zn: T_{fusion} = 693K ; $\overline{\Delta H}^0_{fusion}$ = 6.7 $kJ.mol^{-1}$; $\overline{\Delta S}^0_{fusion}$ = 9.7 $J.K^{-1}.mol^{-1}$

Vaporization of Zn: T_{vap} = 1180K ; $\overline{\Delta H}^0_{vap}$ =114.8 $kJ.mol^{-1}$; $\overline{\Delta S}^0_{vap}$ = 97.3 $J.K^{-1}.mol^{-1}$

For any chemical reaction: $\Delta_r G_{T,p} = \Delta_r G^0(T) + RTLnQ$

EXERCISE I – Elaboration of zinc: *(9 points)*

We consider here the following chemical equilibria:

$$2C_{(graphite)} + O_{2\ (g)} \rightleftarrows 2CO_{(g)} \qquad equilibrium\ (a)$$

$$2Zn_{\ (g)} + O_{2\ (g)} \rightleftarrows 2ZnO_{\ (s)} \qquad equilibrium\ (b)$$

1) Calculate $\overline{\Delta H}^0_{298}$ *and* $\overline{\Delta S}^0_{298}$:
   a) For the forward reaction of equilibrium (a) with all reagents taken in their standard state at 298K
   b) For the forward reaction of equilibrium (b) with zinc at gaseous state and ZnO at solid state.

2) Show that the values of $\overline{\Delta G}^0_T$ at T = 1273 K for the forward reactions of equilibria *a* and *b* are respectively equal to: $\overline{\Delta_a G}^0_{1273}$ = - 448.6 $kJ.mol^{-1}$ and $\overline{\Delta_b G}^0_{1273}$ = - 411.3 $kJ.mol^{-1}$.

3) Write the reaction of elaboration of zinc ($Zn_{(g)}$) from carbon ($C_{graphite}$) and zinc oxide (ZnO_s). Show that the constant of that equilibrium is 5.8 at T=1273K.

4) A reactor of a constant volume of 10 L is completely emptied before carbon and zinc oxide are introduced into it. The reactor is then taken to a temperature of 1273 K which is kept constant in the following.

   a) When the system reaches the state of equilibrium at 1273K, calculate the partial pressure of each gas and the overall pressure.

b) Deduce the minimal mass of each reactant that must be introduced initially into the empty reactor in order to allow the equilibrium to be reached.

c) An experiment is conducted where 20 g of carbon and 100 g of zinc oxide are initially introduced into the reactor. Calculate the number of moles of each component present in the system in the final state. What is then the yield of the reaction of elaboration of zinc?

EXERCISE II. Homogeneous equilibrium at gaseous state : Synthesis of SO_3 (*11 points)*

(parts A, B, C and D may be treated independently)

The following homogeneous equilibrium is studied: $2\,SO_{2\,(g)} + O_{2\,(g)} \underset{\leftarrow}{\overset{\rightarrow}{}} 2\,SO_{3\,(g)}$ (1)

A] A gaseous mixture of the 3 reagents of the system is considered at an initial sate of equilibrium at **T=298K** under an overall **pressure P**.

1) In what direction (forward or reverse) will the equilibrium shift if:
   - T is increased under a constant P? Justify your answer.
   - the volume is reduced at a constant temperature? Justify your answer.

B] Study of the **equilibrium at 750 K**

2) Calculate the equilibrium constant $K^0_{750\,K}$ at $\mathbf{T_1 = 750K}$.

Equilibrium (1) is studied **at $\mathbf{T_1 = 750K}$** in a reactor containing a gaseous mixture initially made of 100 moles of SO_2 and 50 moles of O_2**.** The equilibrium is obtained under a **pressure $\mathbf{P_1}$**, and the yield in $SO_{3(g)}$ at the equilibrium is equal to 0.96.

3) Calculate the variance at the equilibrium.

4) Express the partial pressure of each component as a function of the overall pressure P_1.

5) Calculate the numerical value of P_1.

C] Another experiment is conducted using a gaseous mixture of SO_2 , O_2 and N_2 with molar fractions initially equal to 8% , 12 % and 80% respectively.
At T = 750 K, the equilibrium is obtained under a **pressure $\mathbf{P_2}$** where it is observed that 98% of the moles of SO_2 initially present have been converted into SO_3. It is specified that N_2 behaves here as an inert gas. At this state of equilibrium, determine:

6) the composition of the gaseous mixture at equilibrium.

7) the numerical value of P_2.

D] In a last experiment, equilibrium (1) is studied under a **pressure $\mathbf{P_3 = 0.1}$ bar** and a **temperature T'** , starting from an **initial gaseous mixture of $\mathbf{SO_2}$ and $\mathbf{O_2}$ in an unknown proportion**. When the equilibrium is reached, the analysis of the gaseous mixture reveals the presence of 3 moles of SO_2 ,1 mole of O_2 and 1 mole of SO_3.

8) Calculate the number of mole(s) of SO_2 and O_2 in the gaseous mixture at the initial state.

9) Deduce the yield in SO_3 at the equilibrium.

10) Calculate the value of temperature T'.