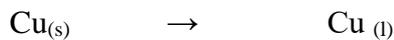
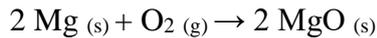


**Tutorial Series N°4**

**Exercise 1**

A. Predict the sign of  $\Delta S_{\text{reaction}}$  (positive or negative) for the following reactions:



One mole of liquid water at room temperature  $\rightarrow$  one mole of liquid water at  $50^\circ\text{C}$

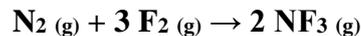
B. Which of the following processes are accompanied by an increase in entropy?

1) evaporation of water - 2) precipitation of  $\text{AgCl(s)}$  - 3) condensation of water vapour to ice - 4) mixing of natural gas ( $\text{CH}_4$ ) and air - 5) dissolution of  $\text{KBr(s)}$  in water

**Exercise 2**

$\text{NF}_3$  is a synthetic gas that is a powerful greenhouse gas (GHG) with a global warming potential (GWP) 17,000 times greater than that of  $\text{CO}_2$  (over 100 years) and a lifetime in the atmosphere of 740 years.

Predict the sign of  $\Delta S^\circ$ , then calculate the value of  $\Delta S^\circ$  for the reaction, using the following data:



Substance	$S_{298\text{K}}^\circ \text{ (J/mol}\cdot\text{K)}$
$\text{F}_2 \text{ (g)}$	203
$\text{N}_2 \text{ (g)}$	192
$\text{NF}_3 \text{ (g)}$	261

**Exercise 3**

Determine the change in entropy when one mole of ice at  $-10^\circ\text{C}$  is transformed into one mole of water at  $25^\circ\text{C}$  under atmospheric pressure.

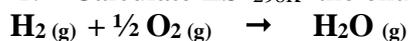
Given: Normal melting temperature of ice  $t_f = 0^\circ\text{C}$

Latent heat of fusion or enthalpy of fusion of ice  $L_F = \Delta_F H_{273,15\text{K}}^\circ = 6019 \text{ J mol}^{-1}$   
 $C_p(\text{ice}) = 37,62 \text{ J mol}^{-1}\text{K}^{-1}$  ;  $C_p(\text{water}) = 75,24 \text{ J mol}^{-1}\text{K}^{-1}$

**Exercise 4**

A.

1. Calculate  $\Delta S_{298\text{K}}^\circ$  the entropy change of the following reaction:



knowing that:

$S_{298\text{K}}^\circ (\text{H}_2\text{(g)}) = 31,2 \text{ cal mol}^{-1}\text{K}^{-1}$  ;  $S_{298\text{K}}^\circ (\text{O}_2\text{(g)}) = 49,0 \text{ cal mol}^{-1}\text{K}^{-1}$  ;  $S_{298\text{K}}^\circ (\text{H}_2\text{O(g)}) = 45,1 \text{ cal mol}^{-1}\text{K}^{-1}$

2. For this same reaction, what would be the change in entropy ( $\Delta S^{\circ}_{800K}$ ) at 800 K.  
*We give* :  $C_p(\text{H}_2(\text{g}))= 6,9 \text{ cal mol}^{-1}\text{K}^{-1}$  ,  $C_p(\text{O}_2(\text{g}))= 7,0 \text{ cal mol}^{-1}\text{K}^{-1}$  et  $C_p(\text{H}_2\text{O}(\text{g}))= 8,0 \text{ cal mol}^{-1}\text{K}^{-1}$

**B.** Calculate the entropy change that accompanies the preparation of a mixture of ideal gases made up of 1.00 moles of oxygen and 2.00 moles of hydrogen, in the absence of a chemical reaction and when the process is isothermal.

### Exercise 5 (for students)

Combustion of methane leads to the following reaction:



Calculate for this reaction under standard conditions:

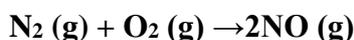
1. The standard entropy change of reaction  $\Delta_r S^{\circ}_{298K}$
2. The standard entropy change  $\Delta_r S^{\circ}_T$  at  $T=373,15 \text{ K}$

*Data:*  $R= 8,314 \text{ J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$

Compounds	$\text{CH}_4(\text{g})$	$\text{O}_2(\text{g})$	$\text{CO}_2(\text{g})$	$\text{H}_2\text{O}(\text{l})$
$S^{\circ}_{298K} (\text{J}\cdot\text{mol}^{-1} \text{K}^{-1})$	186,26	4205,14	213,74	69,91
$C_p (\text{J}\cdot\text{mol}^{-1} \text{K}^{-1})$	35,31	29,36	37,11	75,29

### Exercise 6

Calculate the standard free enthalpy  $\Delta G^{\circ}$  at  $25^{\circ}\text{C}$  of the following reaction:



In an aqueous medium and in acidic solution, hydroxylamine  $\text{NH}_2\text{OH}$  is capable of fixing a proton in an instantaneous equilibrium to give the hydroxylamonium ion



Calculate the standard free enthalpy of the reaction.

*Data* :  $\Delta_f G^{\circ}(\text{NH}_2\text{OH})=-23,35\text{kJ}\cdot\text{mol}^{-1}$ ;  $\Delta_f G^{\circ}(\text{NH}_3\text{OH}^+)=-57,61\text{kJ}\cdot\text{mol}^{-1}$ ;  $\Delta_f G^{\circ}(\text{H}^+)=0 \text{ kJ}\cdot\text{mol}^{-1}$

### Exercise 7

Calcium carbonate  $\text{CaCO}_3(\text{s})$  decomposes according to the reaction :



a) Is this reaction thermodynamically possible under standard conditions?

The enthalpy and entropy of the reaction are assumed to be independent of temperature.

The following are given: the molar enthalpies of formation and the absolute molar entropies in the standard state:

	$\text{CaCO}_3(\text{s})$	$\text{CaO}$	$\text{CO}_2$
$\Delta H^{\circ}_{f,298K} (\text{KJ}\cdot\text{mol}^{-1})$	-1210.11	-393.14	-634.11
$S^{\circ}_{298K} (\text{J}\cdot\text{K}^{-1}\cdot\text{mol}^{-1})$	92.80	213.60	39.71