

### ***Tutorial Series N°3***

#### **Exercise 1**

Calculate the change in internal energy of each of the following systems:

- a- A system absorbs  $Q = 2 \text{ KJ}$  while supplying work  $W = 500 \text{ J}$  to the outside;
- b- A gas maintained at constant volume gives up  $Q = 5 \text{ KJ}$  ;
- c- The adiabatic compression of a gas produces work  $W = 80 \text{ J}$ .

#### **Exercise 2**

One mole of  $\text{N}_2(\text{g})$ , considered as an ideal gas, is heated from  $20^\circ\text{C}$  to  $100^\circ\text{C}$ .

Calculate :

- a- The amount of heat  $Q$  received by this system and its change in internal energy when the transformation is isochore
- b- The amount of heat  $Q$  received by this system and its change in enthalpy when the transformation is isobaric.
- c- The gas undergoes a reversible adiabatic expansion from state 1 of volume  $V_1 = 2.46 \text{ L}$  to state 2 of volume  $V_2$ .
- d- Calculate  $V_2$  if  $P_1 = 10 \text{ atm}$  and  $P_2 = 2 \text{ atm}$ .

Data:  $C_p(\text{N}_2, \text{g}) = 33 \text{ J. mol}^{-1} .\text{K}^{-1}$  and  $R = 8.314 \text{ J. mol}^{-1} .\text{K}^{-1}$

#### **Exercise 3**

Calculate the enthalpy change of 10g of ice whose temperature varies from  $-20^\circ\text{C}$  to  $100^\circ\text{C}$  under the pressure of one atmosphere.

The heats of mass of the pure substances are given:

$C_p(\text{H}_2\text{O, solid}) = 0.5 \text{ cal.g}^{-1} .\text{k}^{-1}$   $\Delta H_f = 80 \text{ cal g}^{-1}$  ,  $\Delta H_v = 539 \text{ cal g}^{-1}$

$C_p(\text{H}_2\text{O, liquid}) = 1 \text{ cal.g}^{-1} .\text{k}^{-1}$

#### **Exercise 4**

One mole of monoatomic ideal gas undergoes the following successive transformations:

- A reversible isothermal compression from an initial state 1 to a state 2
- A reversible adiabatic expansion from state 2 to state 3
- Isobaric heating which returns it to the initial state 1.

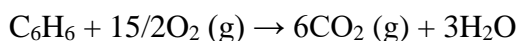
- 1) Calculate  $V_1, V_2, T_2, T_3$  if  $P_1=P_3= 2 \text{ atm}$  ,  $P_2=10 \text{ atm}$  and  $T_1=300 \text{ K}$ .
- 2) Represent the cycle of transformations on a Clapeyron diagram  $P(V)$  .
- 3) Calculate the following energies (in joules) for each transformation:  $Q, W, \Delta U, \Delta H$ .

#### **Exercise 5**

1. Write down the combustion reaction of solid oxalic acid ( $\text{C}_2\text{H}_2\text{O}_4$ ).
2. Calculate the standard enthalpy of this reaction,  $\Delta_r H^\circ_{298\text{K}}$  , at  $298 \text{ K}$  using the standard molar enthalpies of formation:  
 $\Delta H^\circ_f(\text{C}_2\text{H}_2\text{O}_4(\text{s})) = -1822,2 \text{ kJ/mol}$   
 $\Delta H^\circ_f(\text{CO}_2(\text{g})) = -393 \text{ kJ/mol}$   
 $\Delta H^\circ_f(\text{H}_2\text{O}(\text{l})) = -285,2 \text{ kJ/mol}$
3. Deduce the standard variation in internal energy,  $\Delta_r U^\circ_{298\text{K}}$ .

### Exercise 6

For the following reaction, at a temperature of 18°C and atmospheric pressure, we found a difference between the enthalpy and internal energy of the reaction ( $\Delta H - \Delta U$ ) of -0.9 kcal.



Were the benzene and water taken in a gaseous or liquid state?

### Exercise 7

One mole of ideal gas at an initial temperature of 298 K expands from a pressure of 5 atmospheres to a pressure of 1 atmosphere.

In each of the following cases :

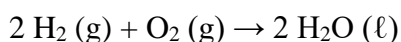
1. reversible isothermal expansion
2. irreversible isothermal expansion
3. reversible adiabatic expansion
4. irreversible adiabatic expansion

Calculate :

- a) the final temperature of the gas
  - b) the change in internal energy of the gas
  - c) the work done by the gas
  - d) the quantity of heat involved
  - e) the change in enthalpy of the gas
- we give :  $C_v = 3/2 R$  and  $C_p = 5/2 R$

### Exercise 8

Calculate the enthalpy change of the reaction at 100 °C



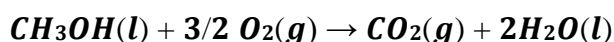
Substance	$\text{H}_2(\text{g})$	$\text{O}_2(\text{g})$	$\text{H}_2\text{O}(\text{l})$
$C_p (\text{J/K mol})$	$27,3 + 3,3 \cdot 10^{-3} T$	$29,9 + 4,2 \cdot 10^{-3} T$	75,2

Data: Standard enthalpy of formation of liquid water at 298 K :

$$\Delta H_f^\circ (\text{H}_2\text{O} (\ell)) = -286,0 \text{ kJ mol}^{-1}$$

### Exercise 9

Total combustion of one mole of liquid methanol under standard conditions of pressure and temperature releases 725.2 kJ according to the following reaction:



1- Calculate the standard molar enthalpy of formation of liquid methanol.

The standard molar enthalpies of formation of  $\text{H}_2\text{O}(\text{l})$  and  $\text{CO}_2(\text{g})$  are given.

$$\Delta H_{f,298}^\circ (\text{H}_2\text{O}, \text{l}) = -285.2 \text{ KJ. mol}^{-1},$$

$$\Delta H_{f,298}^\circ (\text{CO}_2, \text{g}) = -393.5 \text{ KJ. mol}^{-1}$$

2- Calculate the enthalpy of this reaction at 60°C.

The molar heats at constant pressure are given:

$$\begin{aligned}C_p(\text{H}_2\text{O}, \text{l}) &= 75.2 \text{ J. mol}^{-1} \cdot \text{K}^{-1}, \\C_p(\text{CH}_3\text{OH}, \text{l}) &= 81.6 \text{ J. mol}^{-1} \cdot \text{K}^{-1}, \\C_p(\text{O}_2, \text{g}) &= 34.7 \text{ J. mol}^{-1} \cdot \text{K}^{-1},\end{aligned}$$

$$\begin{aligned}C_p(\text{H}_2\text{O}, \text{g}) &= 38.2 \text{ J. mol}^{-1} \cdot \text{K}^{-1} \\C_p(\text{CH}_3\text{OH}, \text{g}) &= 53.5 \text{ J. mol}^{-1} \cdot \text{K}^{-1} \\C_p(\text{CO}_2, \text{g}) &= 36.4 \text{ J. mol}^{-1} \cdot \text{K}^{-1}\end{aligned}$$

### Exercise 10 for student

One mole of an ideal gas in its initial state ( $P_1=2 \text{ atm}$ ,  $V_1=14 \text{ L}$ ) undergoes the following cycle of reversible transformations:

**State 1  $\rightarrow$  State 2: isobaric heating which doubles its volume,  $V_2 = 2V_1$ .**

**State 2  $\rightarrow$  State 3: isothermal compression.**

**State 3  $\rightarrow$  State 1: isochoric cooling.**

1. Determine the state parameters ( $P$ ,  $V$  and  $T$ ) of the three states (1, 2 and 3).
2. Calculate the work, heat and change in internal energy for each transformation.

Given:

$$C_v = 3R/2 \text{ and } R = 8.314 \text{ J.mol}^{-1} \cdot \text{K}^{-1} = 0.0821 \text{ L.atm.mol}^{-1} \cdot \text{K}^{-1}.$$