University of Jijel -Mohamed Seddik Benyahia
Department of Common Education
june 2025

Faculty of Natural and Life Sciences
Module: Thermodynamics and Chemistry of Mineral solutions

| Name: ................................ | Surname: ................................ | Group: |
|---|---|---|

# Resit exam

## Exercise 1

Consider an ammonia solution ($NH_3$) containing 0.1 mol/L. We denote by $K_b$ the basicity constant of $NH_3$, by C its molar concentration and by $\alpha$ its dissociation fraction.

1- Write down the dissolution reaction of $NH_3$ in water.

$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$ 0,5

2- Establish the relationship between C, $K_b$ and $\alpha$.

$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$

$t=0$: $C_B$ 0 0

$t_{eq}$: $C_B-(\alpha.C_B)$ $\alpha C_B$ $\alpha C_B$ 0,5

$K_b = \frac{[NH_4^+].[OH^-]}{[NH_3]}$ 0,25

0,25 $K_b = \frac{\alpha.C_B \times \alpha C_B}{C_B.(1-\alpha)} = \frac{C_B.\alpha^2}{1-\alpha}$

For weak bases $\alpha$ is small in front of "1". 0,25

$K_b = C_B \times \alpha^2$ 0,25

3- Knowing that the acidity constant ( Ka) of the ($NH_4^+/NH_3$) pair is $5 .10^{-10}$, determine the value of $\alpha$ for this solution.

$K_b = C_B.\alpha^2 \Rightarrow \alpha = \left(\frac{Kb}{C_B}\right)^{\frac{1}{2}} = \left(\frac{Kw}{Ka \times C_B}\right)^{\frac{1}{2}} = \left(\frac{10^{-14}}{5 \times 10^{-14} \times 0,1}\right)^{\frac{1}{2}}$ 0,25

$\alpha = 0,014 = 1,4\%$ 0,5

4- Calculate the pH of this solution.

$NH_3$ is a weak base: $pH = 7 + \frac{1}{2}(pKa + \log C_B)$ 0,25

$pH = 7 + \frac{1}{2}(-\log(5 \times 10^{-10}) + \log 0,1) = 11,1$ 0,25 0,5

5- 40 ml of the ammonia (0.1 M) solution is neutralized with HCl (0.4 N).

a- Write the total neutralization reaction.

$NH_3 + (H_3O^+, Cl^-) \longrightarrow NH_4^+ + Cl^- + H_2O$ 0,5

b- What volume of HCl solution must be added to neutralize the solution?

0,25 $C_{HCl}.V_{HCl} = C_{NH_3} \times V_{NH_3} \Rightarrow V_{HCl} = \frac{0,1 \times 40}{0,4} = 10\ ml$ 0,25

c- Calculate the pH value of the mixture at equivalence.

At equivalence point: pH of weak acid ($NH_4^+$); $pH = \frac{1}{2}(pKa - \log C_A)$ 0,25

$C_A = [NH_4^+] = \frac{C.V}{V_T} = \frac{0,1 \times 40}{50} = 0,08\ M$ 0,25

0,25 $pH = \frac{1}{2}(9,3 - \log(0,08)) = 5,19$



0,5

**Exercise 2**

The solubility product, Ksp, for manganese hydroxide, Mn $(OH)_2$, is $1.9 \times 10^{-9}$ at 25°C.

1- Calculate the solubility of Mn $(OH)_2$ in water .

$Mn(OH)_2 \rightleftharpoons Mn^{2+} + 2OH^-$ 1

$t=0$    0    0

$t_?$    $S$    $2S$ 0,8

$K_{sp} = [Mn^{2+}] . [OH^-]^2$ 0,25

$= S \times (2S)^2 = 4S^3$ 0,25

$K_{sp} = 4S^3 \Rightarrow S = \left(\frac{K_{sp}}{4}\right)^{\frac{1}{3}}$ 0,25

$= \left(\frac{1,9 \times 10^{-9}}{4}\right)^{\frac{1}{3}}$

$S = 7,8 \times 10^{-4}$ mol/l. 0,8

2- Calculate the pH at the start of precipitation.

$pH = 14 - pOH = 14 - (-\log[OH^-]) = 14 - (-\log 2S) \Rightarrow$

$pH = 14 + \log(2 \times 7,8 \times 10^{-4}) = 11,19$ 1

3- What is its solubility in 0.1 M of Mn $(NO_3)_2$.

$Mn(OH)_2 \rightleftharpoons Mn^{2+} + 2OH^-$

$t=0$    0,25    0,1    0    0,25

$t_?$    0,25    $0,1 + S'$    $2S'$    0,25

$K_{sp} = (Mn^{2+}) . [OH^-]^2$

$= (0,1 + S')(2S')^2$ 0,25

Making the assumption: 0,25

$S' \ll 0,1$ thus $0,1 + S' \simeq 0,1$

$K_{sp} = 0,1 \times 4 \times S'^2$

$S' = \left(\frac{K_{sp}}{0,4}\right)^{\frac{1}{2}} = 6,89 \times 10^{-5}$ M 0,8

$\frac{S'}{0,1} \times 100 = 0,06\% < 5\%$ 0,25

**Exercise 3**

A perfect gas undergoes the following successive reversible transformations:

1 → 2: Adiabatic with $T_2$=278.8 K and $P_2=10.098\times10^5$ Pa.

2 → 3: Isothermal.

3 → 1: Isochoric.

1- Calculate the volume $V_2$ and the pressure $P_3$.
2- Plot transformations on a Clapeyron diagram (pV ).
3- Calculate in Joules: W, Q, $\Delta U$, $\Delta H$, and $\Delta S$ during the three transformations.

**Given Data:** $V_1=4.4\times10^{-4}$ $m^3$; $T_1$=144 K; $P_1=10^5$ Pa ; $\gamma$=1.4 ; n=0.0368 mol ; Cp=29.09 $J.mol^{-1}.K^{-1}$ ; Cv=20.78 $J.mol^{-1}.K^{-1}$ ; R=0.082 L. $atm.mol^{-1}.K^{-1}$= 8.314 $J.mol^{-1}.K^{-1}$;

**Exercise 3**

① —Adiabatic— ② —Isothermal— ③ —Isochoric— ①

$T_1 = 144\,K$ $\quad T_2 = 278{,}8\,K$ $\quad T_3 = T_2$

$P_1 = 10^5\,Pa$ $\quad P_2 = 10{,}09 \times 10^5\,Pa$ $\quad \boxed{P_3 = ?}$

$V_1 = 4{,}4 \cdot 10^{-4}\,m^3$ $\quad \boxed{V_2 = ?}$ $\quad V_3 = V_1 = 4{,}4 \times 10^{-4}\,m^3$.

$n = 0{,}0368\,mol$, $\gamma = 1{,}4$.

0,8

1- Calculate the volume V2 and the pressure P3.

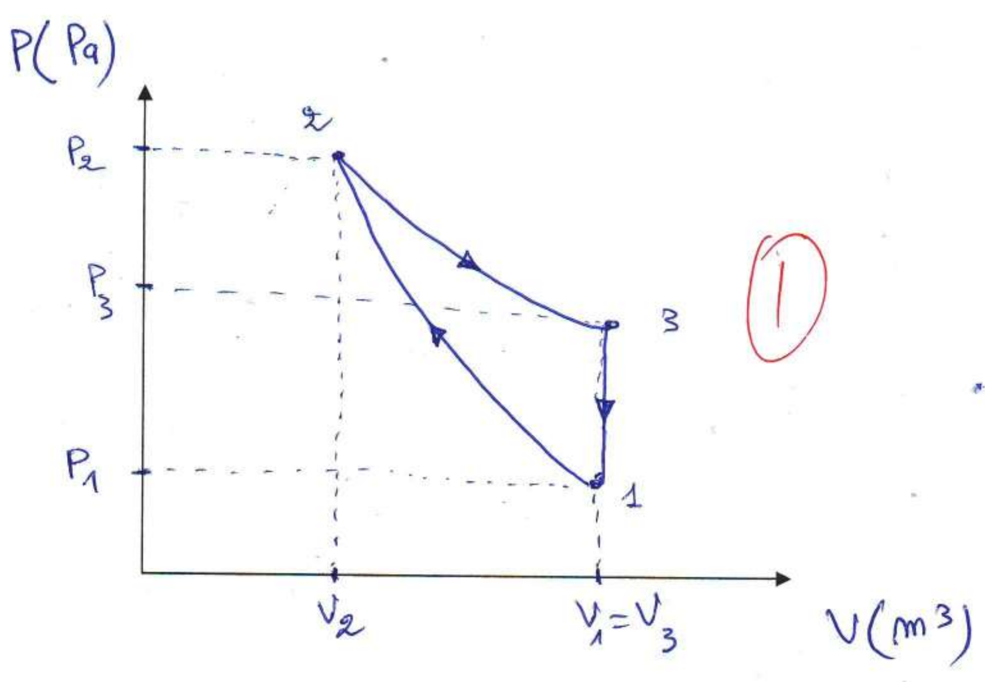
* $P_2 \cdot V_2 = nRT_2 \Rightarrow V_2 = \dfrac{nRT_2}{P_2} = \dfrac{0{,}0368 \times 8{,}314 \times 278{,}8}{10{,}09 \cdot 10^{-5}}$ 0,2

$V_2 = 8{,}45 \times 10^{-5}\,m^3$ 0,2

* $P_3 \cdot V_3 = nRT_3 \Rightarrow P_3 = \dfrac{nRT_3}{V_3} = \dfrac{0{,}0368 \times 8{,}314 \times 278{,}8}{4{,}4 \times 10^{-4}}$ 0,2

$P_3 = 19{,}38 \times 10^4\,Pa$ 0,2

2- Plot transformations on a Clapeyron diagram (pV ).




1

3- Calculate in Joules: W, Q, ΔU, ΔH, and ΔS during the three transformations.

| | $1 \longrightarrow 2$ | $2 \longrightarrow 3$ | $3 \longrightarrow 1$ |
|---|---|---|---|
| $W$ | $W = \Delta U$ 0,25<br>$= 103,08\ J$ | $W = -\int P.dV$ 0,25<br>$= -nRT \ln \frac{V_3}{V_2}$<br>$= -0,0368 \cdot 8,314 \cdot 278,8 \times \ln \frac{4,4.10^{-4}}{8,45.10^{-5}}$<br>$= -140,74\ J$ 0,25 | $W = 0$ 0,25 |
| $Q$ | $Q = 0$ 0,25 | $\Delta U = Q + W = 0$ 0,25<br>$Q = -W = 140,74\ J.$ | $Q = \Delta U = -103,08\ J$ 0,25 |
| $\Delta U$ | $\Delta U = nC_v \Delta T$ 0,25<br>$= 0,0368 \times 20,78 \cdot (278,8 - 144)$<br>$= 103,08\ J$ 0,25 | $\Delta U = 0$ 0,25 | $\Delta U = nC_v\ \Delta T$ 0,25<br>$= 0,0368 \times 20,78 \times (144 - 278,8)$<br>$= -103,08\ J.$ 0,25 |
| $\Delta H$ | $\Delta H = nC_p \Delta T$ 0,25 $= \gamma . \Delta U$<br>$= 0,0368 \times 29,09 \times (278,8 - 144)$<br>$= 144,3\ J$ 0,25 | $\Delta H = 0$ 0,25 | $\Delta H = nC_p . \Delta T$ 0,25<br>$= 0,0368 . 29,09 \times (144 - 278,8)$<br>$= -144,3\ J.$ 0,25 |
| $\Delta S$ | $\Delta S = 0\ J.K^{-1}.$ 0,25 | $\Delta S = nR \ln \frac{V_3}{V_2}$ 0,25<br>$= 0,0368 \times 8,314 \ln \frac{4,4 \times 10^{-4}}{8,45.10^{-5}}$<br>$= 0,5\ J.K^{-1}.$ 0,25 | $\Delta S = n C_v . \ln \frac{T_1}{T_3}$ 0,25<br>$= 0,0368 . 20,78 \ln \frac{144}{278,8}$<br>$= -0,5\ J.K^{-1}$ 0,25 |