University of Mohamed Khider, Biskra
Faculty of Exact Sciences **Duration: 2h**
Department Sciences of The Matter
First Year : 2025/2026

Exam in Chemistry 1

Exercise 1: (3 pts)

I. Let $^{A_1}_{54}Xe$ be a chemical element.

1. **Give its nuclear composition.**
2. **Calculate the binding energy per nucleon in MeV/nucleon.**

II. Consider the following nuclear reaction:

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{A}_{Z}X + ^{A_1}_{54}Xe + 2^{1}_{0}n$$

1. **Balance this nuclear reaction and specify its type.**
2. **This reaction releases an energy of - 2.955×10^{-11} J. Calculate the atomic mass of the element $^{A}_{Z}X$.**

III. The atomic mass of natural uranium is 238.039 g/mol and it has two isotopes: $^{238}_{92}U$, $^{235}_{92}U$. The natural abundances of these isotopes are X_1%, X_2%, respectively. Calculate the abundances of these two isotopes.

Element	**Proton**	**Neutron**	$^{A_1}_{54}Xe$	$^{238}_{92}U$	$^{235}_{92}U$	**C = 3.10^8m/s**
Mass in U	**1.00727**	**1.00866**	**139.89**	**238.0505**	**235.044**	

Exercise 2: (4.75 pts)

I- We consider the Paschen series of the emission spectrum of the hydrogen atom:

1. **Which transition corresponds to the spectral line of frequency ν = 23.36×10^{13} Hz?**
2. **Calculate the energy corresponding to this transition using two methods.**
3. **The wavelength corresponding to the second line of the Balmer series is λ_1=486 nm .Calculate, in terms of λ_1, the wavelength λ_2 corresponding to the third line of the Paschen series.**

II- For a hydrogen-like ion, the same electronic transition studied in Part I corresponds to a frequency $\nu_1 = 210.29 \times 10^{13}$ Hz.

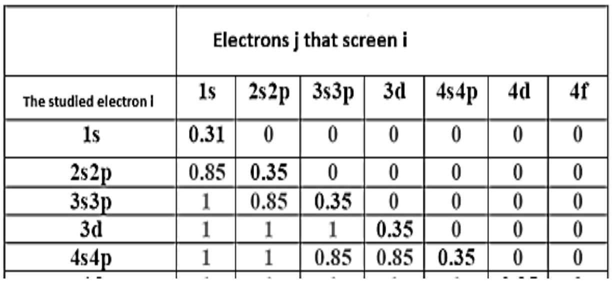
1. **Determine Z for this hydrogen-like ion.**
2. **Calculate the energy required to ionize this hydrogen-like ion starting from n = 5.**

h=6,62.10^{-34}J.s, $R_H = 1.1.\ 10^7$ m^{-1}; C= 3.10^8m/s

Exercise 3: (6.25 pts)

Let the following elements be given: $_{16}S$, $_{48}Cd$, $_{37}$Rb

1. **Write the abbreviated electron configuration using noble gas notation for each element in the ground state, then determine for each element: period, group, and column (summarize your answer in a table).**
2. **The elements $_{17}Cl$, $_{16}S$, $_{15}P$ belong to the same period. Arrange them in increasing order of atomic radius and justify your answer.**
3. **Determine the electronic configuration and atomic number of an element X that has 5 electrons in the outermost subshell defined by ℓ=1 and n=4 in the ground state. Is X a metallic element or not?**
4. **Using Slater's rules, calculate the first and second ionization energies of the atom $_2$He.**



The studied electron I	Electrons j that screen i						
	1s	2s2p	3s3p	3d	4s4p	4d	4f
1s	0.31	0	0	0	0	0	0
2s2p	0.85	0.35	0	0	0	0	0
3s3p	1	0.85	0.35	0	0	0	0
3d	1	1	1	0.35	0	0	0
4s4p	1	1	0.85	0.85	0.35	0	0

Exercise 4: (6 pts)

1- **Give the Lewis structures of the compounds <u>P</u>Cl_3 ; H<u>P</u>Be ; <u>N</u>H_4^+.**
2- **Does the compound PCl_3 have a dipole moment**
3- **If yes, indicate the partial charges on the atoms and the direction of the dipole moment for each bond.**
4- **What is the type of bond between the elements P and Cl?**

P(Z=15, ϰ= 2.1) ; Cl(Z=17, ϰ= 3.1) ; H(Z= 1) ; Be (Z= 4) ; N (Z= 7)

The model correction for the exam (chemistry 1 : 2025-2026)

Exercise 1:

I-

1- Nuclear composition

We consider the nucleus of xenon: ${}^{140}_{54}Xe$.

Number of protons Z = 54.

Number of neutrons N = A − Z = 140 − 54 = 86.

2- The Binding energy per nucleon:

$$\frac{E_b}{A} = \frac{\Delta m\, c^2}{A} = \frac{[Z\, m_p + N\, m_n - m(Xe)]\times c^2}{A}$$

$$\frac{E_b}{A} = \frac{(54\times1.00727 + 86\times1.00866 - 139.89)\times 931.5}{140} = 8.31 \text{ MeV/nucleon}$$

II-

1- ${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{\mathbf{94}}_{\mathbf{38}}X + {}^{140}_{54}Xe + 2{}^{1}_{0}n$

This is a nuclear fission reaction.

2- The atomic mass of the element ${}^{A}_{Z}X$.

$$\Delta E = \frac{-2.955 \times 10^{-11}}{1.6 \times 10^{-13}} = -184.68\, Mev$$

$$\Delta E = \Delta m.c^2 = \Delta m.931.5$$

$$\Longrightarrow \Delta m = \frac{\Delta E}{931.5} = -0.1982u$$

$$\Delta m = (m_f - m_i) = m_{{}^{94}_{38}X} + m_{{}^{140}_{54}Xe} + m_{{}^{1}_{0}n} - m_{{}^{235}_{92}U}$$

$$\Longrightarrow m_{{}^{94}_{38}X} = \Delta m - m_{{}^{140}_{54}Xe} - m_{{}^{1}_{0}n} + m_{{}^{235}_{92}U}$$

$$\Longrightarrow m_{{}^{94}_{38}X} = 93.953\, u$$

III- Abundance of uranium isotopes

$$\begin{cases} \bar{M}_U = \dfrac{m_{{}^{235}_{92}U}.X_1 + m_{{}^{238}_{92}U}.X_2\%}{100} \\ X_1\% + X_2\% = 100\% \end{cases}$$

- **Natural abundance of ${}^{235}_{92}U$:** $X_2\%$ =0.38%
- **Natural abundance of ${}^{238}_{92}U$**: $X_1\%$=99.62%

Exercise 2:

I-

1- Transition corresponding to the given frequency

The Paschen series corresponds to transitions: n_2=? → n_1=3

$$\nu = c.R_H\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)/ \quad n_2 > n_1$$

$$23.36 \times 10^{13} = 3 \times 10^8 \times 1.1.10^7 \times \left(\frac{1}{3^2} - \frac{1}{n_2^2}\right)$$

$$\Rightarrow n_2^2 = \frac{1}{0.0401} = 24.94$$

$$\Rightarrow n_2 \approx 5$$

2-Energy corresponding to this transition:

Method 1: Using Planck's relation

$$E_{ph} = \Delta E = h\,\nu = (6.62\times10^{-34}).(23.36\times10^{13}) = 1.55\times 10^{-19}\, J$$

Method 2: Using energy levels of hydrogen

$$E_{ph} = |\Delta E| = |E_f - E_i| = |E_3 - E_5|$$

$$\Delta E = = \left|\frac{-13.6}{9} - \frac{-13.6}{25}\right| = 0.97ev =) = 1.55 \times 10^{-19} J$$

3-

For the Balmer series:

The second line corresponds to the transition $n_i=4 \rightarrow n_f=2$

$$\frac{1}{\lambda_1} = R_H\left(\frac{1}{4} - \frac{1}{16}\right) = R_H\left(\frac{3}{16}\right)$$

$$\Rightarrow \frac{1}{\lambda_1} = \frac{3.R_H}{16}$$

For the Paschen series:

The **third line** corresponds to the transition $n_i=6 \rightarrow n_f=3$

$$\frac{1}{\lambda_2} = R_H\left(\frac{1}{9} - \frac{1}{36}\right) = R_H\left(\frac{3}{36}\right)$$

$$\Rightarrow \frac{1}{\lambda_2} = \frac{R_H}{12}$$

$$\frac{\frac{1}{\lambda_1}}{\frac{1}{\lambda_2}} = \frac{\frac{3.R_H}{16}}{\frac{R_H}{12}}$$

$$\Rightarrow \lambda_2 = \frac{9}{4}\lambda_1 = \frac{9}{4}.486 = 1093.5 \text{ nm}$$

II-

1-Determination of Z for the hydrogen-like ion

$$\nu_1 = c.Z^2.R_H\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) = 3 \times 10^8 \times Z^2 \times 1.1.10^7 \times \left(\frac{1}{9} - \frac{1}{25}\right)$$

$$Z^2 = \frac{210.29 \times 10^{13}}{3 \times 10^8 \times 1.1.10^7 \times \left(\frac{1}{9} - \frac{1}{25}\right)} = 9 \Rightarrow Z = 3$$

2- Energy required to ionize the ion from n= 5

$$E_i = \Delta E = E_\infty - E_5 = \frac{9 \times (-13.6)}{\infty^2} - \frac{9 \times (-13.6)}{25} = 4.896\, eV$$

Exercise 3:

1-

Element	configuration	Period	Group	Column
$_{16}S$	$_{10}$[Ne] $3s^2$ $3p^4$	3	VI_A	16
$_{48}Cd$	$_{36}$[Kr] $5s^2 4d^{10}$	5	II_B	12
$_{37}$Rb	$_{36}$[Kr] $5s^1$	5	I_A	1

2-Order of atomic radii

The atomic radius decreases as the atomic number increases across a single period from left to right.

$$r_{_{17}Cl} < r_{_{16}S} < r_{_{15}P}$$

The explanation for this: is that with an increase in the atomic number, the positive charges (number of protons) in the nucleus gradually increase while the principal energy levels within the period remain constant. As a result, the attractive force between the nucleus and the valence electrons increases, leading to a decrease in the atomic radius.

3-Identification of element X

$$X\ has\ 5\ electrons\ in\ the\ subshell\ defined\ by \begin{cases} \ell = 1 \ \Rightarrow p\ subshell \\ n = 4 \ \Rightarrow the\ subshell\ is\ \mathbf{4p} \\ and\ the\ noble\ gas\ preceding\ X \end{cases}$$

$${}_{Z}X: {}_{18}[Ar]\ 4s^2 3d^{10} 4p^5 \Rightarrow Z = 35$$

7>4 ⇒ X is a **non-metal**

4- First ionization energy of ${}_2He$ using Slater's rules

$${}_2He\ (g) \rightarrow {}_2He^+\ (g) + e^-$$

$$E_{i_1} = E_{{}_2He^+} - E_{{}_2He}$$

${}_2He$: $1s^2$ $E_{{}_2He} = 2E_{1s}$

${}_2He^+$: $1s^1$ $E_{{}_2He^+} = E'_{1s}$

$$E_{i_1} = E_{{}_2He^+} - E_{{}_2He} = 2E_{1s} - E'_{1s}$$

$$E_{i_1} = 2\frac{Z^{*2}E_H}{n^{*2}} - \frac{Z'^{*2}E_H}{n^{*2}} = 2\frac{(2-0.31\times 1)^2 \times (-13.6)}{1^2} - \frac{(2)^2 \times (-13.6)}{1^2}$$

$$E_{i_1} = 23.285\ eV$$

- Second ionization energy

$${}_2He^+\ (g) \rightarrow {}_2He^{2+}\ (g) + e^-$$

$$E_{i_2} = E_{{}_2He^{2+}} - E_{{}_2He^+}$$

${}_2He^{2+}$: $1s^0$ $E_{{}_2He^{2+}} = 0\ eV$

${}_2He^+$: $1s^1$ $E_{{}_2He^+} = E'_{1s}$

$$E_{i_2} = E_{{}_2He^{2+}} - E_{{}_2He^+} = -E'_{1s}$$

$$E_{i_2} = -\frac{(2)^2 \times (-13.6)}{1^2} = 54.4\ eV$$

Exercise 4: (pts)

1- Lewis structures of **P**Cl_3

${}_{15}P$: ${}_{10}$[Ne] $3s^2\ 3p^3$

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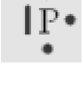

${}_{17}Cl$: ${}_{10}$[Ne] $3s^2\ 3p^5$

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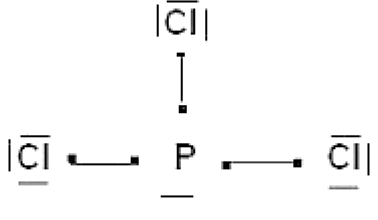

Lewis structures of H**P**Be

$_1H$: $1s^1$ 

$\boxed{\uparrow}$

$_4Be$: $_2[He]\ 2s^2$

$\boxed{\uparrow\downarrow}$ $\overline{Be}$

H — $\bar{P}$ = Be

$_4Be^*$: $_2[He]\ 2s^1 2p^1$

$\boxed{\uparrow}\ \boxed{\uparrow}\boxed{\ }\boxed{\ }$ 

Lewis structures of $\mathbf{N}H_4^+$

$_7N$: $_2[He]\ 2s^2 2p^3$ 

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$_1H^+$: $1s^0$

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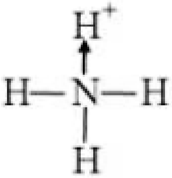

Or