CHEMISTRY 1 – Test n°2

Duration: 45 min

No document allowed. Only College type calculators are authorized
The schedule of marks is indicative only

Data:

$e = 1.602 \times 10^{-19}$ C $c = 2.998 \times 10^{8}$ m.s^{-1} $h = 6.626 \times 10^{-34}$ J.s $N_A = 6.022 \times 10^{23}$ mol^{-1}
$m_e = 9.11 \times 10^{-31}$ kg

I) Emission of X-Rays (13.5 pts)

Let's consider an X-rays tube with an anticathode made of an unknown metal **B**. The X-rays emission spectrum is constituted by a continuous background, the shortest wavelength observed being 0.1494 Å. Some discrete lines are also observed, two doublets with the following wavelengths: λ_1 = 0.1590 Å, λ_2 = 0.1598 Å, λ_3 = 0.1802 Å, λ_4 = 0.1851 Å (These two doublets being the most intense).
When plotted as a function of the wavelength, the variation of the mass attenuation coefficient (μ/ρ) of **B** presents a first discontinuity at 0.1536 Å.

1) **a-** How can you explain the existence of a continuous background? What does the observed lower limit correspond to?
b- Represent schematically the emission spectrum obtained for **B**, indicating the numeric data you have. Identify the transitions corresponding to the λ_1 to λ_4 wavelengths.

2) **a-** Which minimal potential difference needs to be applied to obtain this spectrum?
b- Compute the corresponding speed (in m.s^{-1}) the electrons had when they hit the anticathode. We will consider that they were generated with no initial speed and will neglect the relativist effects.

3) **a-** Using the data relative to Tungsten and Lead (see table below), give the atomic number of **B**.
b- Give the electronic structure of Lead. Which period and block does it belong to?

4) **a-** Using the given data, compute (in eV) the energy levels of **B** you have access to.
b- Represent schematically the energy levels diagram, specifying for each of them the values for the n, l, j quantum numbers.

	Symbol	Z	$\|E_K\|$ (eV)
Tungsten	W	74	69525
Lead	Pb	82	88005

II) Absorption of X-Rays (7.5 pts)

Two X-rays tubes made of different anticathodes are considered: one made of copper (Cu), the other made of Zinc (Zn). We wish to monochromatize the emission beams obtained with these two anticathodes. For this purpose we can use two 20 μm filters: one is made out of copper, the other out of Nickel (Ni). The variations of their mass attenuation coefficients as a function of the wavelength are given in supplementary material (see on the last page).

1) **a-** How does the monochromatization of an X-rays emission spectrum works? Explain the condition(s) an element needs to fulfill to be an efficient filter (you can use a scheme).
b- For each anticathode, give the filter(s) that can be used to monochromatize the X-rays beam.

2) Which anticathode/filter couple identified in **II-1-b** leads to the absorption of 99% of the $KM_{2,3}$ Ray? Qualify your answer.

	Zn	Cu	Ni
Available Anticathodes	X	X	
Available Filters		X	X
λ_K (Å)	1.284	1.381	1.489
$\lambda_{KL2,3}$ (Å)	1.437	1.542	1.660
$\lambda_{KM2,3}$ (Å)	1.295	1.392	1.500
$\lvert E_K \rvert$ (eV)	9657	8979	8328
$\lvert E_{KL2,3} \rvert$ (eV)	8629	8042	7470
$\lvert E_{KM2,3} \rvert$ (eV)	9575	8908	8267
Density (ρ; g.cm^{-3})	7.13	8.92	8.90

FORM

Bragg's law: $2d_{hkl} \sin\theta = \lambda$

Moseley's law: $\sqrt{\nu} = a(Z-b)$

Beer-Lambert law: $I = I_0 \exp(-\mu \rho l)$

Interplanar spacing :

$$\frac{1}{d_{hkl}^2} = \frac{\frac{h^2}{a^2}\sin^2\alpha + \frac{k^2}{b^2}\sin^2\beta + \frac{l^2}{c^2}\sin^2\gamma + \frac{2hk}{ab}(\cos\alpha.\cos\beta - \cos\gamma)}{1-\cos^2\alpha - \cos^2\beta - \cos^2\gamma + 2\cos\alpha.\cos\beta.\cos\gamma} + \frac{\frac{2kl}{bc}(\cos\beta.\cos\gamma - \cos\alpha) + \frac{2lh}{ca}(\cos\gamma.\cos\alpha - \cos\beta)}{1-\cos^2\alpha - \cos^2\beta - \cos^2\gamma + 2\cos\alpha.\cos\beta.\cos\gamma}$$

Relation between E and λ : E(eV) = 12400 / λ (Å)

Slater's rule: contribution of the electrons localized in the n' orbital on the screen constant which applies on an electron localized in the orbital n are gathered in the following table:

Orbital of the electron	*n'*<*n*-1	*n'*=*n*-1	*n'*=*n*	*n'*>*n*
1s	-	-	0.30	0
ns,np	1.00	0.85	0.35	0
nd	1.00	1.00	1.00 for *s* and *p* 0.35 for *d*	0

Supplementary material: Variation of the mass attenuation coefficients (μ/ρ) as a function of the wavelength observed for Nickel and Copper.