CHEMISTRY 1 – Test n°1

Duration: 45 min

No document allowed. Only « collège » type calculators are authorized.
The marking-scheme is for information only.

General 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} $R_H = 109678.8$ cm^{-1} $m_e = 9.11 \times 10^{-31}$ kg
The value provided for Rydberg's constant is valid for any hydrogen-like system.

Atom	H	He	Li	Be
Z	1	2	3	4

I) Electronic configuration (4 points)

1) Spell out Pauli's principle, Klechkowski's and Hund's rules. (You can advantageously use a scheme if needed.)

2) How many electrons can be found at most in a *f*-type sub-shell? Qualify your answer.

II) Humphreys' series for hydrogen (10 points)

This part deals with the case of the **hydrogen atom**.

1) Establish the relationship for the energy of a given level n, and then calculate the values for the 8 first energy levels for hydrogen. The results will be expressed in **eV**, to within 0.01 eV.

2) Represent these levels on a Grotrian's diagram.

In the emission spectrum observed for hydrogen, let's consider the Humphreys' series which **short-wavelength limit** is $\lambda_{lim} = 3.28$ µm

3) On which energy level **n** does the electron fall down for the Humphreys' series?

4) For this series, to which transition does the **long-wavelength limit** correspond? What is the corresponding value (λ_t, expressed in **nm**) ?

5) Represent these two transitions in the Grotrian's diagram.

6) To which energetic domain does this series correspond to?

7) One excites the hydrogen atom using an electro-magnetic radiation which frequency band spreads from 3.23×10^{15} to 3.24×10^{15} Hz.

a) Determiner the energy **level/level(s)** that is/are reached with the excitation.

b) Considering all the emission lines observed resulting from the previous excitation, what is the percentage of the emission lines which actually correspond to the Humphrey's series?

III) <u>Hydrogen-like system</u> (6 points)

1) Let's consider photons which are defined by their wavelength, the value being $\lambda_i = 19.3$ nm. When these photons are used to irradiate a given hydrogen-like ion, this one is ionized and the electron is ejected such that its speed is 1.86×10^6 m.s^{-1}.

a) Calculate the wavelength, noted as λ_e, in Å, associated to the ejected electron.

b) Determine the ionization energy of the hydrogen-like ion (**in kJ.mol^{-1}**). Identify the hydrogen-like ion (presented under the form $_ZX^{n+}$).

2) One excites this hydrogen-like ion using an electro-magnetic radiation which frequency band spreads from 3.23×10^{15} to 3.24×10^{15} Hz (the same as the one used in the previous problem). How many lines are observed on the corresponding emission spectrum?

3) In this question, the same hydrogen-like system is excited using a **beam of electrons.**
The aim here is to observe at least **one line** corresponding to the Humphreys' series for this hydrogen-like system (that is to say a line such that the electron priory excited falls down on the energy level n which value was determined in the previous problem, question II-3)).
Give the minimum value for the energy of the incident electrons (**in eV**) such that this line is observed (the arrival and departure levels for this line will be specified).

Reminder : Kinetic energy for an electron : $E_k = \frac{1}{2} m_e v^2$

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