**Chapter 04: Atomic Physics**

**1. The Bohr Atom**

1. 1/ What is the wavelength of light for the least energetic photon emitted in the Lyman series of the hydrogen atom spectrum lines?

2/ What is the wavelength of the line Hα in the Balmer series?

1. An atom can be viewed as a numbers of electrons moving around a positively charged nucleus. Assume that these electrons are in a box with length that is the diameter of the atom (0.2 *nm*). Estimate the energy (in eV) required to raised an electron from the ground state to the first excited state and the wavelength that can cause this transition.
2. According to the basic assumptions of the Bohr theory applied to the hydrogen atom, the size of the allowed electron orbits is determined by a condition imposed on the electron’s orbital angular momentum: this quantity must be an integral multiple of ** :

*mvr = n* = ;n = 1,2,3, ...

1/ Demonstrate that the electron can exist only in certain allowed orbit determined by the integer *n.*

2/ Find the formula for the wavelength of the emission spectra.

1. The result of the Bohr theory of the hydrogen atom can be extended to hydrogen-like atoms by substituting Ze2 for e2 in the hydrogen equations. Find the energy of the singly ionized helium He+ in the ground state in eV and the radius of the ground-state orbit.

**2. The Schrödinger Equation for the Hydrogen Atom**

1. Knowing that the wave function for the ground state of the hydrogen atom is



Where a is the Borh radius: a = 0.529 x 10-10, m = 52.9nm

1/ What is the value of the normalization constant A?

2/ What is the value of x at which the radial probability density has a maximum?

1. Calculate the probability that the electron in the ground state of the hydrogen atom will be found outside the Bohr radius.
2. The wave function of a particle is given as: ψ (*r*) = **

1/ Find *C* in terms of *a* such that the wave function is normalized in all space  
2/ Calculate the probability that the particle will be found in the interval -*a* ≤ *x* ≤ *a.*

1. How many distinct (**n**, **l**, **m,**) states of the hydrogen atom with **n** = 3 are there? Find the energy of these states.
2. Consider the n = 4 states of hydrogen.

(a) What is the maximum magnitude L of the orbital angular momentum?  
(b) What is the maximum value of Lz?  
(c) What is the minimum angle between **L** and the z-axis?

1. Represent all the possible orientations of the angular momentum with the value l = 0 ; 1 ; 2 ; 3
2. **(a)** Show that the total number of atomic states (including different spin states) in a shell of principal quantum number n is 2n2 .  
   **(b)** Which shell has 50 states ?

**3. Many-Electron Atoms and the Exclusion Principle**

**4. Quantum Computing**

1. Consider the quantum state: 

**(a)** Compute the probability to find the system in state  and in state ?

**(b)** Compute the probability of measuring and in the new basis: and 

**5. X-Ray Production and Scattering**

1. Electrons in an x-ray tube are accelerated by a potential difference of 10.0 kV. If an electron produces one photon on impact with the target, what is the minimum wavelength of the resulting x rays? Answer using both SI units and electron volts

**6. The laser**

1. In the helium-neon laser, laser action occurs between two excited states of the neon atom. However, in many lasers, lasing occurs between the ground state and the excited state.

1) Consider such a laser that emits at wavelength 550nm. What is the ratio of the population of atoms in state E1 to the population in the ground state E0 at room temperature?

2) For the condition of 1), at what temperature would this ratio to be 1/2?

**7/ Semiconductivity**

1. In germanium, the electron density in conduction band (and the hole density in valence band) is a function of energy gap Eg =0.7eV according to:



Because the conductivity is proportional to the number of carriers:



The resistivity of germanium at 20OC is 0.5Ω.m. What is its resistivity  
at 40OC?

1. For intrinsic gallium arsenide, the room temperature conductivity is 10-6 (Ω-m)-1; the electron and hole mobilities are, respectively, 0.85 and 0.04 m2/V-s. Compute the intrinsic carrier concentration *ni* at room temperature.
2. The number density *n*0 of conduction electrons in pure silicon at room temperature is about 1016 m-3. Assume that, by doping the silicon lattice with phosphorus, we want to increase this number by a factor of a million.

What fraction of silicon atoms must we replace with phosphorus atoms? The density mass of silicon is 2.33g/cm3, and the molar mass of silicon is 28.1g/mol.

1. To high-purity silicon is added 1023 m-3 arsenic atoms.

1/ Is this material *n*-type or *p*-type?

2/ Calculate the room-temperature electrical conductivity of this material  
We have: 

3/ Compute the conductivity at 100oC (373 K), we have:



1. An LED is constructed from a p-n junction on a certain Ga-As-P semiconducting material whose energy gap is 1.9 eV. What is the wavelength of the emitted light?
2. In a transistor, the collector current *I*C changes exponentially in function of the emitter voltage *V*S according to:



where *I*0 and *B* are constant for any given temperature.  
A transistor has a collector current of 4.7 milliamperes when the emitter voltage is 17 mV. At 28 mV, the current is 27.5 milliamperes. Given that the emitter voltage is 39 mV, estimate the current