The Open University of Sri Lanka
B.Sc. Degree Programme – Level 5 - 2009/2010
Department of Physics
PHU 3143 / PHE 5143: Atomic and Nuclear Physics

MODEL ANSWERS – Home Assignment

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1. (a) Alpha particles are doubly ionized helium atoms or just helium nuclei.
Refer suggested readings for the properties of alpha particles.

(b) Refer Atomic Physics Course Material.

(c) Refer Atomic Physics Course Material.

(d) Impact parameter, b = $\frac{a}{2}\cot\left[\frac{\phi}{2}\right]$ [symbols have their usual meaning]

$$= \frac{2Ze^2}{2\times 4\pi\varepsilon_o E}\cot\left(\frac{\phi}{2}\right)$$

$$E = \frac{Ze^2}{4\pi\varepsilon_o b}\cot\left(\frac{\phi}{2}\right)$$

$$E = \frac{47\times(1.6\times10^{-19})^2}{4\times\pi\times 8.86\times10^{-12}\times150\times10^{-15}}\times\cot(15)$$

$$= 2.69 \times 10^{-13}\ \text{J}$$

$$= \underline{1.68\ \text{MeV}}$$

2. (a) Assumptions and their significance

- Electrons orbit the nucleus. They are held in orbit by an electrostatic force. This justifies the basic condition required for circular motion.
- Electrons can only be in certain, permitted orbits and an electron does not emit radiation when it is in one of these orbits. This justifies why energy is not radiated by an accelerated charge as predicted by the electromagnetic theory.
- An electron only emits radiation when it jumps from a higher energy state to a lower state. This justifies the observed absorption / emission spectra.
- The radii of the allowed orbits are also quantized - each energy state has a specific radius proportional to h/2π. Angular momentum of electron will be mvr = nh/2π, n is principle quantum number and n = 1, 2, 3, … etc.. This justifies the observed absorption / emission spectra.

(b) No. An atom emits energy when jumping from one level to another level. So when you substitute n = ∞, it gives a definite value (you may substitute and try this). Therefore, the frequency and energy of any emitted photon are finite.

(c) We know that, $\frac{1}{\lambda} = \frac{m_e e^4}{8\varepsilon_o^2 ch^3}\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$ where λ is the wavelength, n_f and n_i are the quantum numbers of the final and initial levels and others are standard constants.

We also know that frequency, $\nu = \frac{c}{\lambda}$ and

Energy, $E = h\nu$

Substituting the standard constants and appropriate n_f and n_i values, wavelengths and hence the frequency and energy can be calculated. (You are expected to substitute all the standard constants and calculate them).

(i) For longest wavelength photon emitted in the Balmer:

Wavelength	=	6563 Å
Frequency	=	4.568×10^{14} Hz
Energy	=	1.892 eV

(ii) For shortest wavelength photon emitted in the Balmer:

Wavelength	=	3646 Å
Frequency	=	8.223×10^{19} Hz
Energy	=	3.40 eV

3. (a) (i) **Composition and Charge:**

Alpha particles are basically helium nuclei composed of two neutrons and two protons. The protons give alpha particles a positive charge. Beta particles are fast moving electrons and are negatively charged. Gamma rays are a form of energy that is part of the electromagnetic spectrum. They are neutral.

Speed and Penetration:

Alpha particles travel at about 1/20th the speed of light and can easily be blocked by paper. Beta particles travel almost at the speed of light and can be blocked by an aluminium sheet. Gamma rays travels at the speed of light and can only be blocked by a few centimeters of lead.

Deflection in an electric / magnetic field:

Alpha particles are heavy and deflect very little in an electric / magnetic field. Beta particles are lighter and have the greatest deflection in an electric / magnetic field. Gamma rays are neutral and so do not undergo any deflection.

Refer Nuclear Physics Course Material / any recommended Nuclear Physics text book for more details.

(ii) Alpha decay occurs when a nucleus has so many protons that the strong nuclear force is unable to counterbalance the strong repulsion of the electrical force between the protons.

According to classical physics, alpha particles do not have enough energy to escape the potential well from the strong force inside the nucleus. However, the quantum tunnelling effect allows alphas to escape even though they do not have enough energy to overcome the nuclear force.

(b) No. Generally age of a stone can not be measured by the Carbon-14 dating. Because living organism take up Carbon -14 from environment and once die this take up stops. The Carbon-14 dating technique makes use of this fact to determine the ages of artifacts that were once alive.

(c) Initial activity of 50.0 g sample would have been = 15 x 50 = 750 decays per minute.

Decay constant is $\lambda = \dfrac{0.693}{\text{half life}} = \dfrac{0.693}{5730 \times 365 \times 24 \times 60} = 2.03 \times 10^{-10}$ per minute

We know that, $\lambda t = -\ln\left(\dfrac{\text{present activity}}{\text{initial activity}}\right)$

$$t = -\frac{1}{2.03 \times 10^{-10}} \ln\left(\frac{200}{750}\right) = 5.74 \times 10^{9} \text{ min} = 10{,}928.8 \text{ years}$$

Age of the skeleton is 10,928.8 years

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