PHY2005 – Atomic Physics – Assignment 1

Solutions to be uploaded to Canvas by **10pm** on **FRIDAY FEB 4th 2022.**

Attempt all questions

Please upload a single pdf file, and make sure the scan is readable.

The assignment will be marked out of 20.

Q1 The Lyman α transition of hydrogen has wavelength λ=121.6 nm. Calculate:

(a) the wavelength of the Lyman α transition (**to three significant figures**) for positronium.

[*Positronium* is a bound system of an electron and a positron. Positrons have the same mass as electrons, but opposite electric charge.]

(b) the wavelength (**to three significant figures**) of the single-electron ion transition identified by the last digit of your student number in the list below.

Last digit of student number	Ion	Series	Line
1	C^{5+}	Balmer	β
2	B^{4+}	Balmer	γ
3	Be^{3+}	Balmer	β
4	Li^{2+}	Balmer	γ
5	Be^{3+}	Balmer	γ
6	Be^{3+}	Paschen	β
7	B^{4+}	Paschen	β
8	C^{5+}	Paschen	γ
9	C^{5+}	Paschen	β
0	Li^{2+}	Paschen	γ

[Li = lithium, Be = beryllium, B = boron, C = carbon.]

[10 marks]

[CONTINUES ON NEXT PAGE]

Q2 **(a)** The wavefunction, expressed in spherical polar coordinates (r, θ, ϕ),

$$\psi = f(r) \cos\theta$$

is an eigenstate of both L_z, and $\boldsymbol{L}^2$. $f(r)$ can be **any function** that depends only on r. If the orbital angular momentum of a particle described by this wavefunction were measured, state the value that would be found for:

(i) The z-component of the orbital angular momentum.

(ii) The magnitude of the orbital angular momentum.

(b) Give an example wavefunction, expressed in spherical polar coordinates, that is an eigenstate of $\hat{\boldsymbol{L}}^2$ with quantum number $l = 1$ but **NOT** an eigenstate of $\hat{L}_z$. As above, you may give you answer in terms of a general function, $f(r)$, of the radius coordinate but you must give a specific functional dependence on θ and ϕ that is physically reasonable. Briefly justify your answer.

[4 marks]

Q3 **(a)** For the Bohr model of the hydrogen atom, calculate the speed, v, of the electron for principal quantum number $n = 2$. Give your answer as a percentage of the speed of light.

(b) Using your knowledge of special relativity from L1, estimate the ***difference*** between the *relativistic kinetic* energy, T_{rel}, of an electron moving at the speed calculated in part (a) and the *classical kinetic* energy $T_{classical} = \frac{1}{2} m_e v^2$. Give your answer in eV.

[*Hint: Pay attention to the accuracy of your calculation. Using a Taylor series expansion may help*.]

(c) Express your answer to part (b) as a percentage of the Bohr-model energy of an electron with $n = 2$. Comment on the implication of this value for theories that aim to predict the fine-structure data given in Table 3 of the lecture notes.

[6 marks]

[You may wish to make use of the fact that the relativistic kinetic energy can be expressed as $T_{rel} = mc^2 - m_0 c^2$, where m is the relativistic mass and m_0 is the rest mass.]

[Note: Your L1 physics notes on special relativity will help you with Q3.]

[END OF ASSIGNMENT]