THE FREQUENCY OF ELECTRON ROTATION AND THE FREQUENCY OF LIGHT EMITTED

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Abstract

We calculate the frequency of matter-wave of electrons orbiting the hydrogen nucleus at the ground state. It is the same as the value of light frequency corresponding to the ground state from the Rydberg's formula. The result will stimulate students' interest to further understand the mechanisms of quantum theory.

Keywords: Electron rotation, the Bohr radius, the frequency of light.

INTRODUCTION

The frequency of light emitted from an atom is the difference of energy of an electron at different orbits. However, there is no detailed investigation on the relation between the frequency of electrons orbiting the nucleus and the frequency of light emitted from the atom. We will study this relationship.

METHODOLOGY

We will consider a hydrogen atom from the classical picture. An electron is rotating around the nucleus. The speed of the electron is *v*. The mass of the electron is *m*. Coulomb's constant is *k*. The electric charge of the proton and the electron is *e*. The distance from the electron to the nucleus is *r*, which has the value of the Bohr radius. Then *E*, the total energy of the electron rotating around the nucleus is

$$E = 1/2\, mv\text{^}2 - k\, e\text{^}2/r \qquad (1)$$

The electric force on the electron is

$$F = k\, e\text{^}2/r\text{^}2 \; = ma = m\, v\text{^}2/r \qquad (2)$$

From (2),

$$k\, e\text{^}2/r\text{^}2 \; = m\, v\text{^}2/r$$

which can be simplified into,

$$v\text{^}2 = k\, e\text{^}2/rm$$

Or

$$v = e\sqrt{(k/rm)} \qquad (3)$$

We will calculate *f*, the frequency of the electron orbiting the nucleus,

$$f = v/2\pi r = e/2\pi r\ \sqrt{(k/rm)} \quad (4)$$

Applying the value of each parameter into (4), we get

$$f = 6.5796 \times 10\text{^}15 \quad (5)$$

This is the frequency of electron orbiting around the hydrogen nucleus at the ground state. Phase velocity is half of the particle velocity (Griffiths and Schroeter, 2018). If we regard an electron as a matter-wave moving around the hydrogen nucleus, then the frequency of this matter-wave is half of the frequency in (5). It is,

$$f\_MW = 3.2898 \times 10\text{^}15 \quad (6)$$

The light emitted from hydrogen atoms has the wavelength, λ, determined by the Rydberg formula,

$$1/\lambda = R(1/(n\_1\text{^}2\ ) - 1/(n\_2\text{^}2\ )), \quad n\_1 = 1,2,3 \ldots, n\_2 > n\_1$$

where *R* is the Rydberg constant. We may imagine that the wavelength of light corresponding to the ground state is when n_1 equals 1, or

$$1/\lambda = R\ 1/1\text{^}2\ = R \quad (7)$$

The frequency of light is,

$$f\_light = c\ 1/\lambda$$

where *c* is the speed of light and λ is wavelength.

From (7), the frequency of light associated with the ground state is

$$f\_light = c\ 1/\lambda = cR = 3.2898 \times 10\text{^}15 \qquad (8)$$

The results from (6) and (8) are equal. The frequency of light associated with the ground state is the same as the frequency of the matter-wave of an electron orbiting the hydrogen nucleus at the ground state.

From the perspective of de Broglie matter wave theory, the above result is very natural. However, many people, myself included, were unaware of and surprised by this relation. This result establishes a concrete relation between frequency of electron rotation around the nucleus and the frequency of light emitted. The result will stimulate students' interest to further understand the mechanisms of quantum theory.

REFERENCES

Griffiths, D.J. and Schroeter, D.F., 2018. *Introduction to quantum mechanics*. Cambridge University Press.