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RESEARCH ARTICLE

The Details of the Photon Emission Process and a Derivation of the Formulas for Both Planck's Constant and the Photoelectric Effect

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Abstract

The photon emission process is described in detail, leading to formulas for Planck's constant and the photoelectric effect. In the latter case, the derived formula is similar to Einstein's equation, except it has a needed extra term. As photons are shown to be atomic sized, single electric field particles shaped as extremely thin washers moving at the local velocity of light in a direction orthogonal to the washer surface, neither wavelength nor frequency are variables. Moreover, it is seen that not all radiation consists of photons. Radio waves, for example, are not photons.

1. Introduction

Scientists have never been able to resolve why orbiting electrons in an atom do not radiate and how they move from outer to inner orbits in the photon emission process. Also, what exactly are the photons that are created? Are these emissions waves or particles? As they seem to be both, this mystery has given rise to what is known as the wave-particle paradox, a problem that has been unresolved for a very long time. This work will serve as a major step in understanding these issues.

The analysis proceeds as follows: First, key aspects of [1-4] are briefly discussed at the simplest levels needed for an understanding of the proposed theory. Then a formula for Planck's constant is derived, as well as a formula for the photoelectric effect. This latter result adds an extra term to Einstein's original version which is shown to be needed when the radiated energy is greater than the minimum possible amount. From both [1-4] and the proposed theory it is seen that photons are single-celled electric field particles shaped as thin washers. Thus, they are not waves and have no frequency, which is in agreement with the fact that frequencies are never directly measured in experiments. Instead, they generally are only implied by other results. Also, in contradiction to Einstein's contention, it is shown that not all electromagnetic emissions are photons. Radio waves, for example, are not photons.

2. Bohr

In the following analysis of Bohr[5], it is assumed that an electron in a given atomic orbit with radius r=A is knocked out of orbit and that electron from an outer orbit with radius r=B moves to replace it, where B>A. It is noted that subscripts using these letters refer to these radii. In the following equations V, K, U, and E are the orbital velocity, kinetic energy, potential energy, and emission radiation, respectively.

$$V^2 = k_0 / (mr) \quad (2.1)$$

$$K = m\,V^2 / 2 = k_0/(2r) \quad (2.2)$$

$$U = \int_\infty^r f\,dr = \int_\infty^r (k_0 / r^2)\,dr = -\,k_0 / r \quad (2.3)$$

$$E = -\,(\Delta K + \Delta U) = (k_0/2)\,(1/A - 1/B) \quad (2.4)$$

In the above Coulomb's constant, k_0, is defined as follows.

$$k_0 = e^2 / (4\pi\varepsilon_0) \approx 89.8755 \quad (2.5)$$

Concerning notation, V_A and V_B are defined as the steady state velocities for electrons in orbit at r =A and

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r = B, respectively, and similarly for kinetic energies K_A and K_B. Then, from (2.1).

$$V_B / V_A = (A / B)^{1/2} \quad (2.6)$$

Since A<B, it is noted from (2.4) that E>0, so that positive energy is radiated. Thus, E is not simply the difference in kinetic energies, K_B - K_A. Also, from (2.6) it is seen that $V_A>V_B$, which might seem strange because the emission process radiates energy while the electron also gains kinetic energy. The reason for this is due to the loss in potential energy, ΔU, which is given as follows.

$$\Delta U = U(A) – U(B) = k_0(1/B – 1/A) \quad (2.7)$$

3. Two Important Laws

At various stages in this work the results of [1-4] will be employed at different levels of detail, sometimes only at extreme brevity. The reader is directed to these papers for greater depth. In this section two of the laws derived there which play a major role in the upcoming analysis will be briefly discussed. The first law concerns the n^{th} atomic radius, r_n, for any atom in the n^{th} row of the periodic table, and is as follows.

$$r_n = n^2 r_0 \quad (3.1)$$

In this law n is a positive integer and r_0 is the Bohr radius, which is given as $r_0≈.0529$ nm. If, for example, an emission occurs with an electron movement from orbits r=B to r=A, then it is required that $A=n_A^2r_0$ and $B=n_B^2r_0$, where both n_A and n_B are positive integers satisfying $n_B>n_A$.

The second law has convincing merit in that it leads to a derivation of the photoelectric effect, a formula for Planck's constant, and a derivation of the row sizes of the periodic table. Though the physical nature of electron strings and atomic orbits are somewhat detailed and complicated, for the purposes of this work it will be sufficient to define them by the following law.

3.1 Law of Electrons

In any given atomic orbit, all of its electrons are strings which have certain specified field strengths. They are arranged in overlapping pairs of equal length in such a way that the outer field strength of the totality of all the electrons in that orbit is constant. Thus, the net result is that the total electric field emitted by the group is constant in space, and there is no radiation.

From the above law atomic orbits must exist as a collection of electron pairs. Thus, individual atoms cannot exist alone except when all their orbital rings have an even number of electrons. For example, the lithium atom cannot exist alone because its outer orbit consists of only one electron, which is an odd number. While the inner orbits of all atoms have an even number of electrons, this is not the case for the outer rows of roughly half of them. These atoms are unstable and cannot exist alone. Accordingly, they must combine with other atoms to form either molecules or compounds. For example, consider the third row of the periodic table, which consists of eight elements running from sodium to argon. Since the outer rows of sodium, aluminum, phosphorus, and chlorine have an odd number of electrons, these atoms cannot exist alone. This is not the case with magnesium, silicon, sulfur, and argon. From these laws the periodic table row sizes are determined in [1-4].

4. Photon Emission Analysis

4.1 Introduction

The emission theory is proposed in [1-4] entails a large amount of analysis. A given emission is the result of an orbiting electron pair moving from r=B to replace a pair which has been ejected from r=A. The total movement is divided into two steps, which are called Phases 1 and 2. In Phase 1 the pair moves from r=B to the outer orbit of r=A, and in Phase 2 the pair is absorbed in the r=A orbit. Instead of the detailed analysis given in [1-4], a simpler alternate theory is provided here that makes use of the conservation of electron angular momentum and leads to a more complete formulation of the photoelectric effect.

By way of note, since electrons exist as pairs, emissions are the result of an electron pair being knocked out of orbit at $r=A=n_A^2r_0$ and subsequently being replaced by a pair from $r=B=n_B^2r_0$, unless the replacement comes from outside the atom, which is not considered in this work. However, it is convenient to base the analysis on single electron moves rather than on pairs. In [1-4] it is shown that this assumption does not change any results and will not be re-argued here.

4.2 The Necessity of a Two Phase Process

The electron movement from r=B to r=A is divided into two phases, where T_1 and T_2 are the individual travel times. In Phase 1 the replacement electron moves from r=B to the outer A orbit, and in Phase 2 it is absorbed into the orbit. It is argued in [1-4] that the Phase 1 movement is made at constant angular momentum with no radiation, and the electron ends up circling the A orbit just outside it. It turns out that this two phase movement leads to very convincing results, especially concerning the derivation of the formulas for h, the photoelectric effect, and the periodic table row sizes. Since all the radiation is accomplished in Phase 2, the radiation time T appearing in the photoelectric formula satisfies $T=T_2$, where it is shown in [1-4] that $T_1>>T_2$.

In the next section Phase 1 is studied, wherein the replacement electron moves from r=B to its first arrival at r=A during time T_1, at which time the velocity has increased from its initial value of V_B to V_1 and the kinetic energy from K_B to K_1. This move involves the electron going around and around in relatively large swings and taking a relatively long time to do it. It is reiterated that this movement is accomplished at constant angular momentum with no radiation. Thus, the released photon energy is entirely accomplished in Phase 2 with the result that the radiation time T satisfies $T=T_2$. Though there is no radiation in Phase 1, it is noted that there is an increase in velocity stemming from a loss in potential energy. After the electron arrives at r=A, Phase 2 begins and is accomplished at a constant radius of r=A, where deceleration results in the release of a photon.

4.3 Phase 1

When the electron string first leaves its orbit at r=B, it is postulated that it expands and wraps around the entire B radius. It then spirals down to a radius of r=A in time T_1 at constant angular momentum without radiating, where it is shown in [1-4] that $T_1 >>T_2$. In Phase 1 the electron picks up kinetic energy equal to its loss of potential energy, all without radiating. Since $\Delta U<0$ in Phase 1, the electron kinetic energy K_1 when it first reaches r=A has increased in the move and is given as follows.

$$K_1 = K_B - \Delta U \tag{4.3.1}$$

From (2.2) $K_B=k_0/(2B)$ and from (2.3) $\Delta U=k_0\,(1/B - 1/A)$. Thus.

$$K_1=k_0/(2B)+k_0[1/A - 1/B]=k_0[1/A - 1/(2B)] \tag{4.3.2}$$

Since from (2.2) the kinetic energy at the end of Phase 2 is $K_A=k_0/(2A)$, then from (4.3.2).

$$K_1 - K_A= k_0[1/A - 1/(2B)] - k_0/(2A)=(k_0/2)(1/ - 1/B) \tag{4.3.3}$$

Thus, $K_1>K_A$, so that the following conclusion is drawn .

$$V_1 > V_A \tag{4.3.4}$$

This result makes sense because in Phase 2 the electron slows down and emits energy. Also, since the angular momentum is constant in Phase 1, then $mV_Br_B=mV_1r_A$, so that.

$$V_1 = V_B\, r_B /r_A \tag{4.3.5}$$

Thus, from this result, $V_1/V_A = (V_B/V_A)(r_B/r_A)$. Since from (2.1)

$V=[k_0 /(mr)]^{1/2}$, then, after a little algebra,

$V_1/V_A=[(1/r_B)/(1/r_A)]^{½}\,[r_B/r_A]=(r_B/r_A)^{1/2}$. Based on $r=r_0n^2$, it follows that.

$$V_1/V_A = (r_B / r_A)^{1/2} = n_B / n_A \tag{4.3.6}$$

This result will be very important in the following Phase 2 analysis.

4.4 Phase 2

In Phase 2 the electron initially wraps around just outside the A orbit, wherein from (4.3.6) the initial velocity V_1 exceeds the ending velocity V_A. During Phase 2 there is an electric force on the electron which causes it to undergo deceleration from V_1 to V_A. Finally, when its velocity is reduced fromV_1 to V_A, it is assumed the electron either gets meshed into, or has already meshed into, the A orbit, so that the atomic orbit becomes stable again.

An important aspect concerning this Phase 2 action is that it is assumed the decelerating force, F, is constant in magnitude. This assumption leads to various experimentally valid results, including formulas for Planck's constant, the photoelectric effect, and the row sizes of the periodic table. Assuming F is constant, the deceleration and therefore dV/dt are constant. As the electron meshes into the A orbit when it transverses the A circumference, the total distance covered by the electron from start to finish is $2\pi A$. Since its velocity decreases linearly in time, the total travel distance satisfies the following, where $T=T_2$

$$(V_1+V_A)\, T / 2 = 2\,\pi\, A \tag{4.4.1}$$

Since V_1 and V_A are the starting and ending velocities in Phase 2 and the velocity reduction is linear, then the average velocity is $(V_1+V_A) / 2$. It is noted that (4.4.1) is derived in [1-4] by a more extensive analysis which does not assume the constancy of angular momentum. From this equation.

$$T = 4\pi A / (V_1+V_A) \qquad (4.4.2)$$

As there is no change in potential energy in Phase 2, E is the decrease in kinetic energy. Thus, $E=(m/2)(V_1^2-V_A^2)=(m/2)(V_1+V_A)(V_1-V_A)$. Then, from these results $ET=[(m/2)(V_1+V_A)(V_1-V_A)][4\pi A/(V_1+V_A)]$. Thus.

$$ET = 2 \pi A m VA (V1/VA -1) \qquad (4.4.3)$$

Since from (4.3.6)$V_1/V_A=n_B/n_A$, then $ET=2\pi AmV_A(n_B/n_A-1)$. Since $A=r_0n_A^2$, then $ET=2\pi(r_0n_A^2)mV_A(n_B/n_A-1)=2\pi r_0mV_A(n_An_B-n_A^2)$.

Also, since $V_A=[k_0/(mA)]^{1/2}=[k_0/(mr_0n^2_A)]^{1/2}$, then

$ET=2\pi r_0m[k_0/(mr_0n^2_A)^{1/2}](n_An_B-n_A^2)$. Thus.

$$ET = 2\pi (mk_0r_0)^{1/2} (n_B - n_A) \qquad (4.4.4)$$

It is noted that $2\pi(mr_0k_0)^{½}$ in (4.4.4) is a constant, which herein will be called h because it is shown below to be equal to Planck's constant. Thus.

$$h = 2 \pi (mr_0k_0)^{½} \qquad (4.4.5)$$

Then, from this result and (4.4.4), the photoelectric effect is as follows.

$$ET = h (n_B - n_A) \qquad (4.4.6)$$

It is noted that frequency does not appear in (4.4.6) because photons are particles and not waves. It is also noted that the Einstein equation is generally given as E=hf, where f is the nonexistent frequency. However, since f=1/T in classical physics, then the photoelectric equation can be rewritten as ET=h. It is therefore seen that (4.4.6) has an extra multiplicative term, which is $(n_B - n_A)$.

In (4.4.5) the value of h can be closely estimated by inserting the following values: $k_0 \approx 89.8755$, $m \approx 9.9109 \times 10^{-31}$, and $r_0 \approx 5.29 \times 10^{-11}$. Using these values results in the following.

$$h \approx 6.62 \times 10^{-34} \qquad (4.4.7)$$

As this result arguably falls within the experimental values of Planck's constant, then h in (4.4.5) will be viewed as this constant. It is noted that, if ET=h in (4.4.6), it is required that $n_B=n_A+1$. Thus, in this case the replacement electron must come from the next higher orbit above r=A. Otherwise, ET>h, which is in contradiction to Einstein's result but arguably needed because in [1-5] both E and T increase with n_B. It is concluded that this derivation of the formulas for h and the photoelectric effect, as well as in [1-4] for the periodic table row sizes, gives credence to the proposed theory. It is reiterated from [1-4] that this analysis is valid when a pair of electrons replaces a pair, rather than a single electron replacing a single electron.

It is interesting that the formula for h as given by (4.4.5) was determined by Bohr in another form in his correspondence principle theory, in which he combined his planetary model of hydrogen with quantum mechanics in the special case when ET=h, $A=n^2r_0$, $B=(n+1)^2r_0$, and n->∞. However, it is noted that Bohr in his analysis postulated the validity of the photoelectric effect, which was not done in deriving (4.3.6). In addition, he also placed severe requirements on A and B and required that n->∞.

Very important, the theory proposed in this work applies only to the electron replacement of emissions and not to other forms of radiation. Therefore, Einstein is in error in contending that his formula covers all electromagnetic radiation. For example, it does not apply when the radiation which is caused by the controlled acceleration of a large number of charges in an antenna, such as is the case of radio waves.

5. Conclusion

This work extends the theory in [1-4] by a simper analysis which makes use of the principle of constant angular momentum. In so doing a formula for Planck's constant is derived. Very important, a formula for the photoelectric effect is derived which shows that Einstein's equation is not quite complete. Also, it is seen that both frequency and wavelength are nonexistent variables because photons are atomic sized, single celled electronic particles which are shaped as very thin washers. Moreover, Einstein's assumption that all electromagnetic radiation consists of photons is shown to be incorrect. Radio and TV waves, for example, are not photons.

It is noted that spectroscopy remains an important and useful scientific technique even though photons are not waves because the results generated from it uniquely define the source. This feature will be derived in an upcoming paper.

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