THE FINE STRUCTURE CONSTANT
By Arnold G. Gulko

Introduction

The fine structure constant of atomic spectra is obviously important, but physics today does not understand it. This writer developed some limited understanding of this constant, but the problem involves some complexities which have not previously been resolved.

There are two aspects of the problem. First, we can consider the fine structure constant from the perspective of the relationship between the energy-based size of the electron and the spacing between the electron and proton in the hydrogen atom. This has the obvious advantage of bringing into consideration the structure of the hydrogen atom where the formation of that atom represents the simplest illustration of the formation of the fine structure.

Second, we can consider the fine structure from the perspective of the energy-based size, internal structure and action of the electron. Those factors are also involved in the formation of atomic spectra, and hence with the formation of the fine structure and its constant character. This consideration is more difficult than the first one because the structure of the hydrogen atom is not present to assist thinking. Moreover, there is an apparent inconsistency between the first consideration, as previously presented, and this one, and that inconsistency needs to be eliminated.

The existence of the fine structure constant

The hydrogen atom presents many problems, but we will focus attention upon the fine structure of its spectrum. When the electron and proton associate to form the hydrogen atom, energy is released. This energy is not released all at once, as one might suspect when the electron speeded by electrostatic attraction was stopped upon reaching its destination in the hydrogen atom. Also, this energy is not released promiscuously as might characterize an haphazard release of energy. Instead, in our quantum nature, when hydrogen forms energy is released in precisely related amounts to form a spectrum in which each amount of released energy forms what is seen to be (on casual examination) a series of lines. When any line is closely examined it is seen to be two closely spaced lines, and this is the fine structure of atomic spectra.

The spectrum of hydrogen is typical in that every element has a spectrum formed by lines which correspond to a series of precisely related amounts of energy. However, the lines formed by those amounts of energy are normally double lines, just as in the spectrum of the hydrogen atom. So all spectra has a fine structure.

The energy which forms each line has a wavelength, and each line of these closely spaced pairs has its own slightly different wavelength. When one subtracts the shorter wavelength from the longer wavelength one obtains the wavelength difference between the two lines, and this defines the spacing. When one then divides this wavelength difference by the longer of the two wavelengths in the double lines one always obtains the same ratio. This ratio is the fine structure constant. Since the numerator and denominator of this ratio are both lengths, the fine structure constant is a dimensionless ratio having a value close to 1 to 137.036.

The hydrogen atom from the perspective of its component particles

The hydrogen atom is the simplest atom because it is constituted by a single electron associated with a single proton. That atom is importantly related to the size and internal structure of the electron although the electron has no significant size in quantum mechanics. With the electron assumed to be generally spherical its radius is simply the length of the energy it contains (its Compton wavelength which is released on annihilation) divided by 2 π.

Physics ignores the size of the electron even though the electron's size, such as its radius based on its energy content, enables calculation of the size of the hydrogen atom. Thus, the average spacing between the electron and proton in hydrogen (known as the Bohr radius) can be calculated by simply squaring the energy radius and then dividing by the classical charge radius.

To illustrate the significance of the electron's energy-based size in establishing hydrogen's spectrum, if one divides the electron's energy-based radius by the average spacing between the electron and proton in the hydrogen atom, one obtains a ratio which corresponds with the fine structure constant of atomic spectra. This simple relationship for determining the fine structure constant is the one which brings the structure of the hydrogen atom into consideration.

As a further illustration of the significance of the electron's energy-based radius to hydrogen's spectrum, if one divides the electron's energy radius by the electron's classical charge radius, one again obtains a ratio which corresponds with the fine structure constant of atomic spectra. This relationship for determining the fine structure constant is independent of the structure of the hydrogen atom.

Despite the overwhelming simplicity and intrinsic strength of the above physical relationships physics today cannot explain how the fine structure constant comes into existence, and that constant is one of the very few constants in nature. The reason why physics ignores these simple and well-known physical relationships is because they are based on sizes which are inconsistent with the assumptions of quantum mechanics. In modern physics that which is inconsistent with quantum mechanics must be ignored.

The issue is whether we can employ an analysis of known facts to explain how the above discussed simple calculations determine the fine structure constant as a matter of physical reality. This demands that we understand the structure and action of the electron, something which physics today does not have available, so we start with a brief discussion of the vortex electron.

The vortex electron

In this writer's vortex theory charged particles are structured entities formed around a pair of centrally positioned vortex rings (helical knots) in which the helically moving energy constituting the two rings are in rolling contact. The paired rings circulate the remaining energy in these particles to produce charge as the energy moving through the paired rings is either laterally stretched or laterally compacted. When the rolling contact between the paired vortex rings is in one direction the circulated energy is laterally stretched and the charge provided by the release of this stretch to the surrounding energy is negative. When the rolling contact is in the opposite direction the circulated energy is laterally compacted, and the charge propagating away is positive.

It is noted in passing that charge is not an attribute of the energy constituting a vortex particle, but is, instead, generated by the motion of the energy in a particle which interacts with the paired vortex rings. Charge exists in space as a modification of the energy filling space, that modification being created when motion of the energy in a particle causes it to be modified and that modification is released to and propagates away through the surrounding energy.

To provide the electron's negative charge, the circulated energy enters the rings from opposite sides through the hole in each ring, and is expelled from between the two rings before returning to the hole in the other ring. The continuous energy motion constituting the electron thus exists in two portions, one on each side of the paired rings, and the interaction with the geometry of the paired rings laterally stretches the energy as it passes through the rings. This lateral stretch is quickly released deep within the physical confines of the circulated energy to form two tiny side-by-side rings where the lateral stretch is released.

The release of charge deep within the physical confines of an electron having a size established by its energy content makes no sense in existing physics, and it makes even less sense to have charge first become available far beyond the physical confines of the point-sized electron of quantum theory. But that is the size relationship which exists, and it is demanded by the vortex electron.

So the two key characteristics of a negatively charged particle, such as the electron, are: first, it circulates the energy which constitutes it in two connected portions; and second, as the energy in each portion is expelled from between the paired rings at the center of the electron in two opposite directions, it produces separate rings of charge release. This forms one ring of charge release on each side of the center of the electron, so the total energy content of the electron forms two rings of charge release. These two key characteristics determine many aspects of the electron and the hydrogen atom, and they are the source of the fine structure constant.

The vortex construction of the charged particles described above was shown to cause them to act in the same way that real charged particles act, as discussed in this writer's 1985 text "The Vortex Theory - Second Edition." That text was re-issued as "The Vortex Theory Revised" in 2006.

The association of the electron and proton to form hydrogen hinges upon the structure and action of the electron, so we must test the vortex construction of the electron by examining the formation of the hydrogen atom. As we do this we will focus our attention upon the two key characteristics of the electron as set forth above.

The association of the electron and proton

In the vortex theory a small amount of energy is taken from the energy circulating to constitute the electron and diverted to the proton (the diverted energy has a negative charge and is drawn to the proton [in unknown fashion] because the proton is positive). This diversion takes place as the energy of the electron moves past one ring of charge release. The proton neutralizes the diverted energy (by laterally compacting it) and returns it to the electron where half of the diverted energy piles up to be discharged when a balanced situation is encountered.

So we have three portions of energy provided by the electron and involved in the existence of the hydrogen atom. First, we have the energy constituting the electron. Second, we have the energy circulating back and forth between the electron and the proton which forms a double energy shell connecting these two particles. Third, we have the energy which is discharged to form hydrogen's spectrum which includes a fine structure.

The hydrogen atom thus provides a third key aspect of nature, namely: the existence of a double energy shell extending between associated particles. This double energy shell is important for many reasons, here because the fine structure constant comes into existence as an aspect of the energy diversion which forms the double energy shell.

The loss of energy in the formation of hydrogen

When the hydrogen atom is formed energy is lost in precise amounts to form hydrogen's spectrum. Since the fine structure constant is an aspect of that energy loss, we must ask what causes this loss of energy. This question is especially difficult for a point particle? Modern physics does not explain how the energy loss is caused, and this further undermines the intellectual basis for quantum mechanics.

The loss of energy is provoked by the electron's charge, so the energy loss might be directly proportional to the electron's charge. The electron's charge (e) is measured at a radial point in space, so the total charge is $4\pi\, e^2$. But, as its vortex structure suggests, only one of the two rings of charge is involved in the diversion of the electron's energy which forms the hydrogen atom, so we must divide by 2 to obtain the charge involved in creating the energy diversion which provoked the loss of energy. Since the energy diversion is directly responsible for the loss of energy we are trying to calculate, a mathematical measure of the energy loss should have half the electron's total charge as its numerator.

Our formula for the energy loss needs something in the denominator which is inversely proportional to the energy lost. Since less energy is longer, the longer the length of the back and forth motion in the energy shell the less energy in the shell and the less energy lost in its formation. So the length of the back and forth energy motion in the energy shell is inversely proportional to the amount of energy lost and must be placed in the denominator to force a greater length to produce a smaller energy loss. That length is π times the average spacing of the particles (a_n). Based on the above simple analysis we can correctly measure the energy loss (E_n) at any balanced state a_n:

$$E_n = -4\pi\, e^2/2/\pi\, a_n \quad \text{I}$$

Dividing by 2 in the numerator and canceling π from the numerator and the denominator gives us the known correct equation II for the energy loss at any stationary state, but without the vortex analysis this known equation is an arbitrary relationship which lacks explanatory value.

$$E_n = -2\, e^2/a_n \qquad \text{II}$$

So the vortex theory's two concepts for the formation of hydrogen, are: 1- half of the electron's charge is involved in the diversion of energy which forms hydrogen; and 2- the hydrogen atom results from the formation of a double energy shell between the particles. These two concepts enable the direct calculation of the energy loss (E_n) at any balanced state. It does this on a rational basis because the balanced states involve a relationship between the square of the attractive force between the particles and the length of the path of energy motion in the energy shell. Unlike modern physics which relies upon orbital motion to provide the desired spacing when orbital motion does not exist, we now have a rational basis for the quantum release of energy during the formation of atoms.

The fine structure constant

With the foregoing in mind, let us now direct our attention to the fine structure constant, starting with a more detailed consideration of the loss of energy in the formation of hydrogen.

In the vortex theory the energy lost (ejected to form hydrogen's spectrum) is half of the energy diverted from the electron, the other half going into the double energy shell which holds the particles together in a spaced-apart relationship. The energy in this shell increases in increments (one increment for half the energy length circulated in the electron) until a balance is created, sometimes with and sometimes without the last-added increment. Diversion of this last increment of energy from the electron causes half of the diverted energy to be added to the accumulated energy which is ejected while the other half is added to the energy shell. So a one-half increment addition reduces the length of the energy in the shell by an amount which provides the fine structure ratio with respect to the length of the energy previously accumulated. The other half increment addition increases the amount of energy lost to form the fine structure of hydrogen's spectrum.

As previously noted, the fine structure ratio is known to be the ratio of the electron's energy radius to the average spacing between the particles (the Bohr radius). This makes no sense in quantum mechanics in which the electron has no size and the action is unknown.

To summarize the action from the perspective of the hydrogen atom, in the vortex theory the fine structure constant is determined by the increment of energy lost when half the last increment of energy is diverted from the electron to the double energy shell to decrease the spacing between the particles in the hydrogen atom while the other half of the diverted energy is added to the energy which is lost. This increment of energy loss is directly proportional to half the Compton length of energy in the electron which is diverted ($\lambda_c/2$), and inversely proportional to the back and forth energy circulation which forms a double shell having a diameter of a_o and a back and forth length of $\pi\, a_o$. So the definition of the fine structure constant (α) is the straightforward ratio $\lambda_c/2/\pi\, a_o$. This is confirmed by multiplying the numerator and denominator of the known ratio of energy radius to Bohr radius by π so the numerator specifies half the Compton wavelength and the denominator specifies the energy length in circulation. This gives us:

$$\alpha = \pi\,(\text{energy radius})/\pi\, a_o = \pi\,(\lambda_c/2\,\pi)/\pi\, a_o = \lambda_c/2/\pi\, a_o \quad \text{III}$$

The energy released in forming hydrogen thus involves the ratio of half the energy length in the electron to the length of energy which forms an energy shell between the particles, so we have determined one important factor in forming hydrogen's fine structure constant from the perspective of the double energy shell which holds the electron in spaced apart relation to the proton. This provides one sensible explanation of how the fine structure constant comes into existence. Let us see whether we can further corroborate the above conclusion in which only half the electron's energy is involved by relating it to the total loss of energy in the formation of the hydrogen atom.

The Rydberg unit of energy

We previously calculated the electron's energy loss at various balanced states by relying upon the electron's charge, so when the principal quantum number is 1 we have the full amount of energy (13.603 eV [electron volts]) which is released in forming the ground state hydrogen atom. But how does the electron's charge cause a precise amount of energy to be discharged? It would assist understanding if we could calculate the unit of energy release directly from the energy content of the electron and matters, such as the fine structure constant, which can be determined directly from the sizes we have been able to establish.

Existing physics calculates the unit of energy release in an incomprehensible way when it relies upon the Rydberg unit of energy (Y) which employs the energy content of the electron and the fine structure constant (α) pursuant to the formula:

$$Y = (\alpha)^2 mc^2/2 \quad \text{IV}$$

Alpha (α) is the fine structure constant, the mass (m) of the electron is known and is the same for every electron at rest, and light speed (c) is a constant. So what we have is a small group of known natural constants and Rydberg found they were related, as per equation IV, to calculate the known unit of energy release (Y). The Rydberg unit of energy is thus an arbitrary finding which involves little fundamental understanding even after one has the formula.

mc^2 in the above Rydberg formula equals E, the energy content of the electron, and it is logical to expect the energy released when hydrogen is formed to be somehow related to the electron's total energy content (E). So the Rydberg unit of energy is an arbitrary association of the two factors which are obviously involved in the energy loss, namely: the electron's energy content and the fine structure constant which defines the incremental unit of energy loss. We can now set forth the Rydberg unit of energy release (Y) in a simplified form as:

$$Y = (\alpha)^2 E/2 \qquad \text{V}$$

The aspect of equation V of special interest to this analysis is that the energy of the electron must be divided by 2. In Rydberg's formula division by 2 is simply an arbitrary action required to make the equation calculate correctly. But in this writer's analysis division by 2 corroborates the vortex concept of the diversion of increments of energy half of which adds to the energy content of a double energy shell while the other half forms part of the energy lost to form hydrogen's spectrum.

So the concept of hydrogen being formed when the electron's energy length is diverted to form a double energy shell with half the diverted energy adding to the energy in the shell while the other half adds to the energy lost is corroborated by noting that Rydberg's formula for calculating the total energy lost when the hydrogen atom is formed requires the energy content of the electron to be halved.

Summary

It should be clear that the first aspect of the problem of understanding the fine structure constant in which the energy shell spacing the electron from the proton is included in the analysis has been accomplished. This writer previously mistakenly thought that only half the length of energy in the electron was diverted to the proton. But it is now clear that the entire length of energy in the electron was diverted to the proton with half that energy being added to the double energy shell to incrementally reduce its size, while the other half being lost to form hydrogen's spectrum.

The fine structure constant from the size, internal structure and action of the electron

The formula for the fine structure constant described previously which does not involve any aspect of the hydrogen atom is the ratio of the electron's energy radius to the electron's classical charge radius. In algebraic form, this simple formula is set forth below:

$$\alpha = \lambda_c/2\,\pi/r_e \qquad \text{VI}$$

This formula tells us nothing about how the fine structure constant is provided. Let us multiply this known formula by 2 π to obtain:

$$. \; \alpha = \lambda_c/2\,\pi\, r_e \qquad \text{VII}$$

This modified equation is ignored by modern physics, but from a vortex perspective it is very significant. Thus, in equation VII the fine structure constant is the ratio of the Compton wavelength of the electron to the length of one ring of charge release. This is exactly what it should be if the fine structure constant is the result of the energy diversion provided by one ring of charge release acting upon the length of energy in the electron, with only half of the increment of energy which is diverted being lost to form hydrogen's spectrum.

On preliminary consideration there appears to be an inconsistency between equation VII which relates the fine structure constant to the entire Compton wavelength of the electron and equation III which relates the fine structure constant to only half the Compton wavelength. But these two equation relate the electron's energy content to two different things, so the relation need not be the same. In equation III the relationship is to the length of the energy shell. In contrast, the relation in equation VII is to the length of the charge release line.

The significance of these two different equation is that equation VII involves the interaction with one ring of charge release, and it suggests that a certain increment of energy is diverted as the entire energy of the electron is involved with that one ring. But if there is a double energy shell formed to hold the electron in place with respect to the proton, then the diverted energy must perform two different tasks. First, some of that energy is lost to form hydrogen's spectrum, so that energy is not present to add to the double energy shell. Second, we need energy to form the double energy shell, and equation the Compton wavelength. Quite obviously, the action of the electron in having some of its energy diverted per equation twice as great as the energy which forms the double energy shell, so the electron includes some mechanism for dividing the diverted energy into two equal portions. The details of that mechanism is not presently known.