Do Atoms Really Have 'States'?

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The accepted quantum-mechanics model for an atom involves the concept of atomic 'state'; *i.e.* ground state, excited state, externally-perturbed state, *etc.* The different atomic states correspond to different possible solutions to a postulated differential equation that contains the empirical constant *h* originally discovered by Planck in connection with black body radiation. The different possible solutions imply different probability distributions for positions of the atom's electron(s). The different probability distributions imply different electron mean positions and momenta, and hence different energies; *i.e.* atomic states with different overall energies. The predicted energy increments between atomic states can be checked against observed spectroscopic data, and the accepted model has good predictive power for spectra from hydrogen and hydrogen-like atoms, but it becomes less than perfect for large atoms and/or atoms with many 'outer' electrons. So is this accepted model the only possible one? The present paper argues that indeed it is not; the paper offers and argues for an alternative model for atomic phenomena. This new model has the following attributes: **1)** it does not *a priori* assume Planck's constant, but instead derives it, **2)** it does not talk about different states of an individual atom, but rather associates different 'states' with different systems of *multiple* atoms, and **3)** it is useful in explaining some otherwise mysterious observations, and may be useful in suggesting other new observations to attempt. The basis for this new model for atomic phenomena lies in the theory of light propagation introduced by this author at PIRT VII: a physical model that accounts for and resolves the many paradoxes discussed in the literature of special relativity theory. The paper thus addresses the long-recognized need to achieve more reconciliation between the initially separate main theories of twentieth century physics: quantum mechanics and relativity theory.

1. Introduction

A scientific anomaly is generally some sort of mismatch between behaviors actually observed, as compared to behaviors expected on the basis of a currently accepted paradigm concerning physical reality. Anomalies are inherently important for challenging and advancing, or at least altering, our understanding of physical reality. Just consider a few examples:

1) In the world of astronomy, the Earth-centered Ptolemaic system made every planetary motion anomalous in some way. The extreme complexity drove Copernicus to think of a Sun-centered system instead. Later, the anomalous Sun spots observed by Galileo exploded the then-prevalent idea of celestial perfection. That opened the way for Kepler to think of orbits that were ellipses, rather than perfect circles or epicyclical nests of circles. It further opened the way for Newton to think in terms of deviations evolving in time rather than patterns held eternal, and so to come up with his force law. The universal character of Newton's law of gravitation invited all sorts of subsequent generalizations.

2) In the complicated world of electricity and magnetism, Coulomb formulated a law for interaction between charges that was in close analogy to Newton's law of gravitation. Ampère's law for current elements was only slightly more complicated. But the two phenomena, electricity and magnetism, remained separate; an anomaly in the context of Newton's quest for universality. Then Maxwell brought the two phenomena together. His unified theory involved an aether, quaternions, and integral equations. The complexity this theory invited more Newton-like reformulations. Hertz and Heaviside developed reformulations in terms of vectors and differential equations, and Einstein expunged the aether aspect of it with his special relativity theory (SRT).

3) In the world of matter and heat, the defining anomaly was blackbody radiation. As described by Maxwell, radiation would consist of waves, and confined within a cavity, the wavelengths would be confined to discrete values fitting between the walls. But the number of wavelengths allowed would nevertheless be countably infinite, and waving them all with democratically equal amplitude would take infinite energy (the so-called 'ultraviolet catastrophe'). The real blackbody spectrum was nothing like that. Short wavelengths, or high frequencies, were clearly disfavored. Planck explained the reality in terms of thermodynamics/statistical-mechanics, associating frequency to energy by a constant h. The logic was inverted by Born, using the same constant h to define the allowed wavelengths, not for a cavity, but rather for the interior of an atom. Thus we came to quantum mechanics (QM).

So in physics we are repeatedly confronted with experimental results that, if properly recognized as anomalous, raise novel theoretical questions. But too often we just don't *see* the anomalies, and the questions they raise, because an accepted paradigm blinds us. The present paper takes note of several phenomena related to QM that are presently understood only imperfectly at best. It deals with some troubling questions that these phenomena raise, and it offers some possible answers. The phenomena noted are as follows:

1.1 The Periodic Table

Prior to the development of QM, our knowledge about atoms was codified in Mendelev's Periodic Table (PT). Figure 1 shows an abbreviated representation of the PT. It is a two-dimensional display of information about chemical elements, the elements being arranged in order of increasing nuclear charge, and separated into rows such that members of columns all have similar chemical properties. The rows of the PT are usually interpreted as corresponding to successive atomic 'shells'. For large atoms, interior electron shells are filled and non-reactive, and chemical properties are entirely determined by the electrons in the outermost shell. The elements listed to the far right are noble gasses: they have perfectly filled outer shells; they are chemically non-reactive.

H_1	**Periodic Table of the Elements**	He_2
Li_3	...... 2+8=10=	Ne_{10}
Na_{11}	...... 10+8=18=	Ar_{18}
K_{19}	.... 18+18=36=	Kr_{36}
Rb_{37}	.... 36+18=54=	Xe_{54}
Cs_{53}	.... 54+32=86=	Rn_{86}
Fr_{87}	.... 86+32=118=?	118

Figure 1. Periodic Table (PT). Annotations to the right call attention to the pattern followed by the row lengths.

Being empirical, the body of knowledge captured in the PT is important background information for QM. An example of this knowledge is the pattern followed by the lengths of rows. Note that the row lengths are: 2, 8, 8, 18, 18, 32... That would mean electron shells with electrons numbering 2, 8, 8, 18, 18, 32. If the last row of the PT went to completion, it would probably also contain 32 elements. The pattern is clearly row length equal to $2N^2$ for $N = 1,2,2,3,3,4...$, *etc.* This pattern displays obvious repeats of N (whatever N may physically be). Why?

1.2 Atomic States

With the advent of QM, it became of interest to try to explain the PT in terms of the atomic states offered by QM. But the atomic states follow a pattern different from that seen in the PT. The quantum states are distinguished first by radial quantum number $n = 1,2,3,4...etc.$ Then for each quantum number n, there are states for angular momentum quantum number $l = 0,1,...,n$. Then for each quantum number l, there are states for spin quantum number $s = \pm 1/2$. So for given n, there are $2n^2$ states. And then the set of all quantum states follows the pattern $2n^2$ for $n = 1,2,3,4...$, *etc.* This comes to 2, 8, 18, 32, 50..., *etc.* Unlike the empirical N seen repeated in the pattern of the PT of the chemical elements, there are no repeat appearances of radial quantum number n. One might well think there ought to be some correlation between atomic shells and a radial quantum numbers. But clearly, the shell structure of the PT is simply not matched by the radial-quantum-number states offered by QM. Failing a simple match, one might at least hope that, as one goes to higher atomic number, the standard quantum states would get filled up in a predictable order. But in fact, attempting to follow the filling order produces a most complicated mess.[1] The filling sequence sometimes jumps around, so the $l = 0$ states for some $n+1$ start filling before the $l = 2$ or 3 states for n are done filling. This happens for $n = 3,4,5,6$, and probably would continue that way if there were more stable elements. Also, the filling order can go $l = 0$, then $l = 2$, then $l = 1$, then $l = 3$. As for $l > 3$, those states never fill at all. This mess is usually attributed to the complex, many-body nature of the atomic problem. But really, we seem to need some new ideas about the PT and/or the atomic states.

1.3 Spectroscopy

When QM was invented, the forefront of scientific advance was perceived to lie in spectroscopy because of the extreme detail and precision of data it offered. In spectroscopy, the spectral lines that occur are characterized in part by differences in inverse square integers, and in part by the so-called Rydberg factor[2]

$$R_\infty = \frac{2\pi^2 m_e e^4}{ch^3} \frac{Z^2}{1 + m_e / M}$$

where m_e is electron mass, M is nuclear mass, and Z is nuclear charge. The inverse square integers are seemingly well understood in terms of radial quantum numbers, and the Rydberg factor is generally thought to be well understood in terms of electron state energies. But there is something noteworthy about it. Note the involvement of the nuclear charge Z: it appears squared, as if the nucleus as a whole were interacting with the population of electrons as a whole. In short, spectral lines act as if the nucleus were naked, like a cluster of positive charges, and as if the electrons too were in a spatially separated cluster of negative charges.

This image of the atom is in conflict with the older image of the atom developed from the PT: electron 'shells', inner shells filled, and at most one outer shell unfilled; partially filled for most elements, and completely filled for noble gasses. The PT-based image would suggest shielding of the nucleus by the filled inner shells of electrons. While large atoms require tiny corrections and adjustments to Rydberg factor, there is nothing so major that it could correspond to the effect of the nucleus being shielded by inner electron shells. Thus spectroscopy suggests that the electron-shell idea could be wrong. It suggests

[1] See, for example, H. Semat, **Introduction to Atomic and Nuclear Physics**, Chapter 8, Table 8-1 (Rinehart & Co., Inc., New York, 1960).

[2] See, for example, Reference 1, Chapter 7, Section 3.

that atoms could involve electrons in clusters rather than electrons in shells.

2. About Light

The current concept of 'wave/particle duality' is applied to light because neither of those two models proves entirely satisfactory by itself. Light propagation exhibits interference effects, which suggest continuous, oscillating waves, but emission and absorption events appear to be discrete and quantized, and that suggests individual, localized photon bullets. So light is a wave or a photon, as needed. That is the twentieth-century duality of light. The wave model begs the question: what *kind* of wave? One needs an expanding spherical wave for emission, a plane wave for energy-conserving propagation, and a converging spherical wave for absorption. Maxwell's equations can support any of the three, but cannot switch between them - unless one can imagine instantaneously changing boundary conditions. The photon model similarly begs the question: what kind of photon? One needs localized photons for emission and absorption, but one needs enormously extensive photons to explain coherence and non-local effects of entanglement. Thus we seem to need some new kind of model for light.

The conventional models for light, whether as photons or waves, assume steady, linear propagation across space, characterized by a constant c. This author has argued[3,4] for a new model, one that acknowledges two steps: expansion from a source, followed by collapse to an absorber, with each step being characterized by a characteristic constant $2c$.

If there is any relative motion between source and absorber, there are important consequences to the choice of model. The conventional models lead to an interesting contrast: Radiation fields from a moving source appear to emanate from the retarded position of the source, whereas Coulomb-Ampère forces do not. The classical model developed at the turn of the century by Liénard and Wiechert[5] includes some factors that essentially expunge the retardation from Coulomb-Ampère forces, making their origin appear to be almost the present but unknowable position of the source. The validity of the Liénard-Wiechert model has been challenged extensively.[6] One point to add here is the following: In modern quantum electrodynamics, electromagnetic forces are all envisioned as being carried by photons: real photons for radiation fields, and virtual photons for Coulomb-Ampère forces. One supposes that virtual photons are somewhat like real ones, at least in regard to propagation directions and times. So how could they travel fundamentally different directions?

[3] C. Whitney, "How Can Paradox Happen?", Proceedings of PIRT VII, 338-351 (2000).

[4] C. Whitney, "Finding Absolution for Special Relativity Theory - Parts III, II, & I", Galilean Electrodynamics **8**, 9-15 (1997) & **7**, 63-69 & 23-29 (1996).

[5] For a discussion that is English-language and modern, see J.D. Jackson, **Classical Electrodynamics**, Second Edition, Chapter 14 (John Wiley & Sons, New York, Chichester, Brisbane, Toronto, Singapore, 1975).

[6] See, for example, C. Whitney, "A Gedanken Experiment with Relativistic Fields" and references cited there, Galilean Electrodynamics **2**, 28-29 (1991).

The new two-step model resolves such issues. All the photons behave the same way. But there are other issues raised instead, discussed in the next Section.

3. Light Signals in the Hydrogen Atom

In the hydrogen atom, electromagnetic signals must travel between the electron and the proton to convey Coulomb-Ampère forces. With all such communications modeled in terms of two-step light, each step with parameter $2c$, the electron sees the proton in half-retarded position, and *vice versa*, the proton sees the electron in half-retarded position. With sources seen in half-retarded positions, the attractive forces in the atom are not central, and not even parallel. As a result, two previously unanticipated effects occur: the atomic system has a torque and even a net force on it. Such effects are quite inconsistent with Newtonian mechanics because they upset the usual conservation of energy and momentum. But Newtonian mechanics has instantaneous action at a distance, whereas electrodynamics has finite propagation speed. This makes a big difference.[7] One way to understand the situation is to recognize that finite propagation speed implies fields, and fields can be repositories for energy, momentum, angular momentum, *etc*. Conservation of any kind works out correctly only if one includes the fields in the inventory. If one looks only at the particles, then conservation fails.

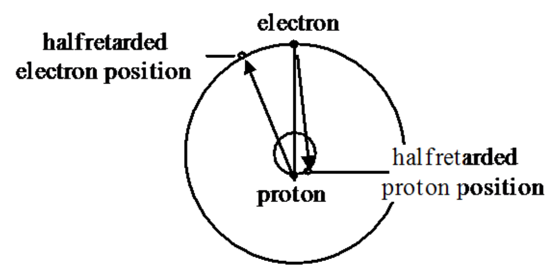

Figure 2. Two-step light signals in the Hydrogen atom.

3.1 Enhanced Energy Loss

The classical problem that motivated the development of the QM model for atoms was the energy loss by radiation expected from any system involving an accelerating charge, like the orbiting electron. Two-step light makes that problem even *worse*. The result of the unbalanced force on the atomic system is more acceleration, and hence more radiation.

Consider the classical analysis for radiation loss from the hydrogen atom. It takes the center of mass of the atom to be essentially fixed, and the radiation to be mainly from the electron. The classical radiation power P_R emanating from the orbiting electron alone amounts to

[7] See, for example, P. Cornille, "Newton's Third Principle in Post-Newtonian Physics: Part I: Theory, and Part II: Interpretation and Experiment", Galilean Electrodynamics **10** (3) 43-49 (1999) and **11** (4) 69-73 (2000).

$$P_e = \frac{2e^2}{3c^3} a_e^2 = \frac{2e^2}{3c^3}(r_e\Omega^2)^2 = \frac{2e^2}{3c^3}\left[\frac{e^2/m_e}{(r_e+r_p)^2}\right]^2$$

The corresponding tiny radiation power from the orbiting proton alone amounts to

$$P_p = \frac{2e^2}{3c^3} a_p^2 = \frac{2e^2}{3c^3}(r_p\Omega^2)^2 = \frac{2e^2}{3c^3}\left[\frac{e^2/m_p}{(r_e+r_p)^2}\right]^2$$

The two contributions together actually add coherently, so in fact the total radiation power is

$$P_{e+p} = \frac{2e^2}{3c^3}(a_e + a_p)^2 = \frac{2e^2}{3c^3}\left[(r_e+r_p)\Omega^2\right]^2$$

or

$$P_{e+p} = \frac{2e^2}{3c^3}\left[\frac{e^2}{(r_e+r_p)^2}\left(\frac{1}{m_e}+\frac{1}{m_p}\right)\right]^2 = \frac{2e^2}{3c^3}\left(\frac{e^2/\mu}{(r_e+r_p)^2}\right)^2$$

where μ is the classical 'reduced mass' of the system. This result is formally more complete than, and slightly larger than, but really hardly different from, the usually-quoted result of classical analysis.

But in the present analysis, even this more complete result is still not anywhere near *truly* complete. Sources are seen in half-retarded positions, so forces do not balance, $\mathbf{F}_p \neq -\mathbf{F}_e$. This means that the center of mass of the hydrogen-atom system must execute an orbit too, on top of what the individual particles do. (This behavior invites association with the well-known 'zero-point motion' that such a system retains even as absolute temperature goes to zero.) The center-of-mass orbit affects the radiation loss from the system: with a center-of-mass orbit, there is more acceleration and hence more radiation. In fact there is a lot more. The circulating center of mass recalls another similar situation that has been long known and well documented. Recall the anomalous magnetic moment of the electron. The anomaly is that the electron circulating in an atom has too little magnetic response to the nuclear charge, which from the viewpoint of the electron is circulating around it like a current and should generate a magnetic field. The earliest explanation given for the anomalous-magnetic-moment is that a coordinate frame attached to the electron and made to circulate with it by successive infinitesimal Lorentz transformations in locally radial directions naturally precesses (the so-called Thomas precession).[8] This precession makes the nuclear charge appear to go slow, cutting the apparent current and resultant magnetic field in half.

The Lorentz-transformation/precession explanation for the anomalous-magnetic-moment result depends upon rather arcane mathematics (after all, it took the time from 1905 to 1927, plus a serious experimental mystery, for anyone even to notice). That kind of explanation would not survive without the whole body of SRT, which the present line of research generally seeks to question. So a more physical explanation is needed here. Refer to Fig. 3. It shows the circular path to be traversed, with several arbitrary right triangles inscribed. The axes of the Thomas-precessing coordinate frame are always parallel to the sides of the local right triangle. An arbitrary point on the path is also shown. Observe that the point has the same angle in relation to all the coordinate-axis pairs shown. So as the circulating, rotating coordinate frame travels through the point, the point appears to travel a straight line. And as it passes through the coordinate origin, it has maximum velocity and no acceleration. So at least in a small neighborhood near its origin, the circulating, rotating coordinate frame is *functionally inertial*. That is what makes it Nature's choice!

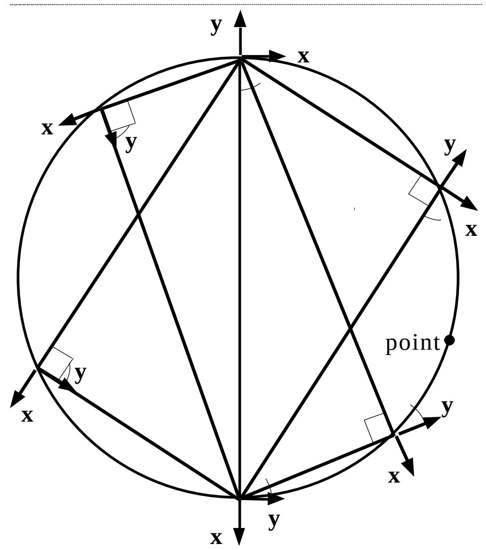

Figure 3. Physical interpretation of Thomas precession.

The result of the Thomas precession in the present situation is that orbit frequency Ω in the local, circulating, center-of-mass coordinate frame is equivalent to effective acceleration frequency 2Ω in the global, non-rotating, inertial coordinate frame where the radiation would be delivered. As a result, the total radiation power is

$$P_R = \frac{2e^2}{3c^3}\left[(r_e+r_p)(\underline{2}\Omega)^2\right]^2 = \frac{\underline{\underline{2^5}}e^2}{3c^3}\left[\frac{e^2/\mu}{(r_e+r_p)^2}\right]^2$$

or approximately.[9]

$$P_R \approx 2^4 P_e = \frac{2^5 e^6/m_e^2}{3c^3(r_e+r_p)^4}$$

3.2 Energy Gain

The result of a torque on the atomic system is a rate of energy gain to the system. Consider the hydrogen atom. Torque is

[8] L.T. Thomas, "The Kinematics of an Electron with an Axis", Phil. Mag **3**, 1-22, 1927).

[9] C. Whitney, "Begging the Questions", Journal of New Energy 5 (2) 56-63 (2000).

generally $\mathbf{T} = \mathbf{r} \times \mathbf{F}$. For the torque on the electron, we have $\mathbf{T}_e = \mathbf{r}_e \times \mathbf{F}_e$ where $\mathbf{F}_e$ has magnitude $e^2 / (r_e + r_p)^2$. With two-step light, the direction of $\mathbf{F}_e$ is half-retarded, and hence rotated from the direction $\mathbf{r}_e$, by the small angle $\frac{v_p}{2c} = \frac{m_e}{m_p} \frac{v_e}{2c}$. Altogether, $\mathbf{T}_e$ is normal to the orbit plane and has magnitude

$$T_e = r_e \frac{e^2}{(r_e + r_p)^2} \frac{m_e}{m_p} \frac{v_e}{2c} = \frac{r_e e^2}{(r_e + r_p)^2} \frac{m_e}{m_p} \frac{v_e}{2c}$$

There is also torque on the proton. Where the light particle, the electron, sees a tiny tangential force, but has a large orbit, the heavy proton, sees a large tangential force, but has a tiny orbit. So the proton ends up seeing the *same* torque as the electron; that is, $\mathbf{T}_p = \mathbf{r}_p \times \mathbf{F}_p = \mathbf{r}_e \times \mathbf{F}_e$. The system overall sees total torque $\mathbf{T} = \mathbf{T}_e + \mathbf{T}_p \equiv 2\mathbf{T}_e$. The torque implies energy gain at the rate $P_T = T\Omega$. With torque magnitude $2T_e$, and with $\Omega = v_e / r_e$,

$$P_T = \frac{e^2}{(r_e + r_p)^2} \frac{m_e v_e^2}{m_p c}$$

The factor $m_e v_e^2$ in P_T can be approximated by using the Virial theorem. Note that $m_e v_e^2 = m_e r_e^2 \Omega^2$, and $m_e r_e^2 \approx m_e r_e^2 + m_p r_p^2$, so $m_e v_e^2$ is approximately twice the total kinetic energy of the electron/proton system. Then by the Virial theorem, $m_e v_e^2 \approx e^2 / (r_e + r_p)$. Thus

$$P_T \approx \frac{e^4 / m_p}{c(r_e + r_p)^3}$$

4. Implications

4.1 Balance

For steady state, the energy loss due to radiation has to balance the energy gain due to torquing; that is, $P_R = P_T$, or $\frac{2^5 e^6 / m_e^2}{3c^3 (r_e + r_p)^4} = \frac{e^4 / m_p}{c(r_e + r_p)^3}$. This equation of balance can be solved for $r_e + r_p$, yielding $r_e + r_p = 32 m_p e^2 / 3 m_e^2 c^2$. This comes to 5.5×10^{-9}cm. One can compare this approximation for $r_e + r_p$ to the accepted value for r_e, 5.28×10^{-9}cm; close, although not perfect consistency.

The more interesting point is that, according to conventional QM, r_e is supposed to be evaluated by $r_e = h^2 / 4\pi^2 \mu e^2$, where h is Planck's constant, presumed to be a Fundamental Constant of Nature. The important thing is that, since r_e can be obtained from a different formula, $r_e \approx r_e + r_p = 32 m_p e^2 / 3 m_e^2 c^2$, it is suggested that Planck's constant may not necessarily be so fundamental after all.

4.2 Stability

The viability of the derivation of Planck's constant proposed above depends upon the stability of the proposed balance between energy loss due to radiation and energy gain due to torquing: the balance point must be guaranteed stable. Recall that the energy loss rate due to radiation was inversely proportional to orbit radius to the fourth power, and that the energy gain rate due to torquing was inversely proportional to orbit radius to the third power. That seems to mean that for orbit radii smaller than the equilibrium orbit radius, the radiation dominates, and for orbit radii larger than the equilibrium orbit radius, the torquing dominates. So if the orbit radius would be smaller than the equilibrium one, it should decay and gets even smaller, and if it would be larger than the equilibrium radius, it should grow and gets even larger. Thus there is a stability issue to resolve.

The resolution of this issue lies in the consideration of a broader class of orbits; not just circles, but more generally ellipses. With such a generalization, the orbit 'radius' $r = r_e + r_p$ becomes a time function. It has time derivatives $\dot{r}$, $\ddot{r}$, $\dddot{r}$, *etc.* This situation implies another energy exchange mechanism, dependent on delay like the torquing energy gain due to rotation is, but associated instead with radial excursion.

The impact of radial excursion can be estimated nominal force magnitude is e^2 / r^2 and the actual force magnitude is e^2 / r_h^2, where the subscript h refers to 'half-retarded', but can also be read as 'having something to do with Planck's constant'! The difference between nominal and actual force magnitude can be estimated by power series expansion. Given

$$r_h \approx r - \dot{r} r / 2c + \tfrac{1}{2} \ddot{r} (r / 2c)^2 - \tfrac{1}{2 \times 3} (r / 2c)^3 + \ldots,$$

we have

$$\frac{e^2}{r_h^2} - \frac{e^2}{r^2} \approx -2 \frac{e^2}{r^3} (r_h - r) \approx +2 \frac{e^2}{r^3} \left[\frac{\dot{r} r}{2c} - \frac{1}{2} \frac{\ddot{r} r^2}{(2c)^2} + \frac{1}{2 \times 3} \frac{\dddot{r} r^3}{(2c)^3} - \ldots \right]$$
$$\approx \frac{e^2 \dot{r}}{r^2 c} - \frac{e^2 \ddot{r}}{4 r c^2} + \frac{e^2 \dddot{r}}{24 c^3} - \ldots$$

This force difference creates an $\dot{r}$-associated energy loss rate of

$$P_{\dot{r}} \approx \frac{e^2 \dot{r}^2}{r^2 c} - \frac{e^2 \dot{r} \ddot{r}}{4 r c^2} + \frac{e^2 \dot{r} \dddot{r}}{24 c^3} - \ldots$$

The impact this has on the overall balance between energy loss and gain can be estimated by estimating the various derivatives. Given some characteristic radial excursion Δr, the derivatives of r are all proportional to Δr, and they oscillate at base frequency equal to the orbit frequency Ω, and have mean square value $(\Delta r)^2 / 2$. The oscillation means that $\dot{r}$ and $\ddot{r}$ (and all even order derivatives of r) are out of phase, and time-average to zero, so all terms of that form can be dropped. The remaining terms are estimated by

$$P_{\dot{r}} \approx \frac{e^2(\Delta r)^2\Omega^2}{2r^2 c} + \frac{e^2(\Delta r)^2\Omega^4}{48c^3} + \ldots$$

Using Newton's $\mathbf{F} = m\mathbf{a}$ in the form $m_e r_e \Omega^2 = e^2/(r_e + r_p)^2$, we can insert $\Omega^2 \approx e^2/m_e r^3$ to form

$$P_{\dot{r}} \approx \frac{e^4(\Delta r)^2}{2cm_e r^5} + \frac{e^6(\Delta r)^2}{48c^3 m_e r^6} + \ldots$$

So the overall balance becomes

$$\frac{e^4}{m_p c r^3} - \frac{2^5 e^6}{3c^3 m_e^2 r^4} - \frac{e^4(\Delta r)^2}{2cm_e r^5} - \frac{e^6(\Delta r)^2}{48c^3 m_e^2 r^6} + \ldots = 0$$

Multiplying through by r^6 we have

$$\frac{e^4}{m_p c} r^3 - \frac{2^5 e^6}{3c^3 m_e^2} r^2 - \frac{e^4(\Delta r)^2}{2cm_e} r - \frac{e^6(\Delta r)^2}{48c^3 m_e^2} + \ldots = 0$$

Considering only the terms displayed, this is a cubic equation. Its standard CRC-handbook form is $y^3 + py^2 + qy + r = 0$, the meaning of r here being a constant. Quoting the CRC: "The cubic equation may be reduced to the form the form $x^3 + ax + b = 0$ by substituting for y the value, $x - p/3$. Here $a = \frac{1}{3}(3q - p^2)$ and $b = \frac{1}{27}(2p^3 - 9pq + 27r)$. For solution let, -

$$A = \sqrt[3]{-\frac{b}{2} + \sqrt{b^2/4 + a^3/27}}, B = \sqrt[3]{-\frac{b}{2} - \sqrt{b^2/4 + a^3/27}},$$

then the [solution] values of x will be given by, $x = A + B$, $-\frac{A+B}{2} + \frac{A-B}{2}\sqrt{-3}$, $-\frac{A+B}{2} - \frac{A-B}{2}\sqrt{-3}$ …" These roots are all real if A and B are complex conjugates, which requires $b^2/4 + a^3/27 < 0$. The p, q and r and are all negative, so $a = \frac{1}{3}(3q - p^2)$ and $b = \frac{1}{27}(2p^3 - 9pq + 27r)$ are negative. And $b^2/4 + a^3/27 < 0$ is possible so long as ΔR is not too large.

Having three real roots means that the middle one of the three will correspond to a stable balance, even though the two other roots may seem to imply unstable balance. So even in the degenerate limit of the circular orbit, the single solution is actually three solutions, one of which is a stable balance.

5. Extensions

5.1 Excited System States

The conventional idea about the so-called 'excited states' of an atom involves a single electron teetering in an upper shell, ready to fall back to a lower shell with an available opening. A clue pointing to a different kind of model lies in the known fact that light emission is always a little bit laser-like in that photons get emitted not as singletons, but rather in bursts.[10] This suggests that atoms get excited not as singletons, but as groups. For example, suppose 'excitation' of the hydrogen to principal quantum number n actually involves $n = n_H$ hydrogen atoms all working together in some coherent way.

In the journal Galilean Electrodynamics, we have occasionally had reports and commentary about the most unusual phenomenon of apparent clustering together of electrons.[11,12,13] The phenomenon is widely known; related literature cited in the third of those references is quite extensive, and some of it appears in the most widely circulated physics journals. The existence of electron clusters suggests an atomic model featuring clusters rather than electron shells. In particular, suppose that n_H hydrogen atoms work together in a manner such that the n_H electrons make one cluster, and the n_H protons make another cluster, and the two clusters make a scaled-up super hydrogen atom.

The replacement of single particles with clusters must affect both the radiation energy loss rate and the torquing energy gain rate, and the balance between them. Every factor of e and every factor of m_e or m_p scales by n_H. For the radiation, starting from $P_R = \frac{2^5 e^6 / m_e^2}{3c^3(r_e + r_p)^4}$ one finds the energy loss rate scales by n_H^4. For the torquing, starting from $P_T = \frac{e^4 / 2m_p}{c(r_e + r_p)^3}$ one finds the energy gain rate scales by n_H^3. The solution radius for system balance therefore scales as $r_e + r_p \to r_{n_H} = n_H(r_e + r_p)$.

The overall system orbital energy then scales as $E_1 \to E_{n_H} = n_H^2 E_1 / n_H = n_H E_1$. This energy result is exactly the same as the orbital energy of n_H *separate* atoms *not* clustered together in a super atom. The implication is that the energy that comes out as photons from the cluster system when the system comes apart is *not*, as generally believed, orbital in origin. It is instead the positive energy required to form the charge clusters. **This is a completely novel view.**

The evidence from spectroscopy is that the energy required to bring the $n_H{}^{th}$ hydrogen atom from complete separation to complete integration into an existing super atom of $n_H - 1$ atoms clustered, thus forming a super atom of n_H atoms clustered, is $|E_1|[(n_H - 1)^{-2} - n_H^{-2}]$. The inverse squares can be understood as follows. The radial scaling $r_{n_H} = n_H(r_e + r_p)$ suggests that all linear dimensions scale linearly with n_H. If so,

[10] J.P. Wesley, **Classical Quantum Theory**, Chapter 7 (Benjamin Wesley, Weiherdammstrasse 24, 78176 Blumberg Germany 1996).

[11] P. Beckmann, "Electron Clusters", Galilean Electrodynamics **1**, 55-58 (1990); see also **1**, 82 (1990).

[12] H. Aspden, 'Electron Clusters' (Correspondence) Galilean Electrodynamics **1**, 81-82 (1990).

[13] M.A. Piestrup, H.E. Puthoff & P.J. Ebert, "Correlated Emissions of Electrons", Galilean Electrodynamics **9**, 43-49 (1998).

the volume of the clusters scales as n_H^3. The number density of charges in clusters therefore scales as $n_H / n_H^3 = n_H^{-2}$. The positive energy locked in the pair of clusters therefore depends on the number density in the clusters. This is something like having energy proportional to pressure, as is seen in classical thermodynamics.

If this multi-atom model captures the real behavior behind atomic excitation, and if one attempts to model that behavior in terms of a single atom with discrete radial states identified with a principal quantum number n, then the radial scaling has to be $r_1 \rightarrow r_n = n^2 r_1$, as is seen in standard QM.

5.2 Non-Degenerate System States

QM and spectroscopy both suggest that the principal quantum number n identifies not a single atomic configuration, but a family of them, with the family members differing slightly in energy. In QM, these family members are distinguished by the angular momentum quantum number l, the spin quantum number s, the composite total electron angular momentum j, and further combinations with nuclear spins. The energy differences associated with l are intrinsic to atoms and are expressed in terms of the 'fine structure constant' α. Other energy differences require magnetic fields to expose.

So can the present model lead to a family of slightly different configurations for each n_H? To see some possibilities, consider some ideas about the structure of electron clusters. Figure 4 illustrates a candidate pattern for the development of electron clusters. This pattern is based, not on the QM model with quantum numbers n, l, s, but rather on the obvious structure revealed by the Periodic Table (PT). Section 1 noted that the PT has rows of length $2N^2$ for $N = 1,2,3,4$, with repeats of N given by $N = 1,2,2,3,3,4...$, and left the meaning of N to be determined. Here, N identifies a layer in an electron cluster. Everything is quite neat for completed layers (noble gasses), but incomplete layers (other elements) could exist in a variety of configurations.

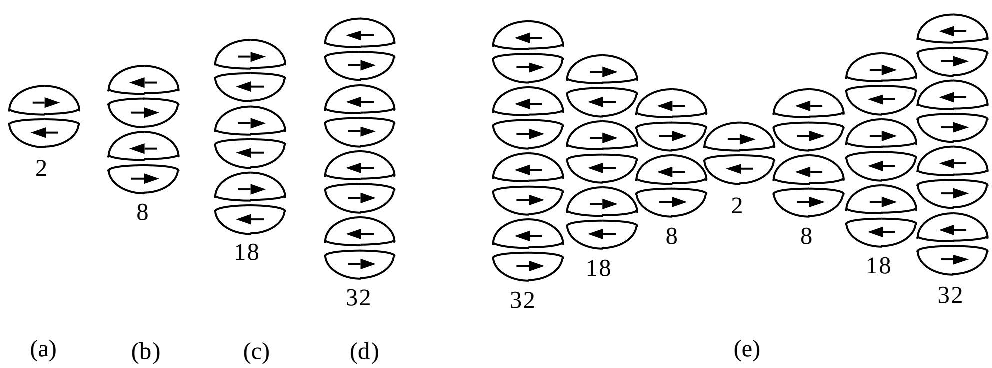

Figure 4. Electron charge clusters. Hemispherical units represent individual electrons. Arrows represent magnetic moments. Pairing of opposite magnetic moments represent the phenomenology described by Fermi-Dirac statistics. Spherical-pair units form square layers seen edge on in (a) through (d), corresponding to the $2N^2$ for $N = 1,2,3,4$ from the PT. The layers form the dumbbell-shaped stack shown by (e), corresponding to the repeats $N = 1,2,2,3,3,4...$ shown by the PT.

Conclusion

This work represents the current status of a very long journey that has extended over several decades. The reader who looks into the author's earlier works on related subjects will see in nascent form many ideas that are here developed much better. While many details still remain for future work, this author now believes quite firmly that, when Nature shows us quantization, she is *not* counting up 'states' of an individual atom. Certainly she is *not* doing something so arcane as enumerating possible solutions to a differential equation about the complex amplitude of a probability wave describing the position and momenta of constituents in that individual atom. Much more straightforwardly, Nature is just counting up atoms in multi-atom configurations. And the different multi-atom system states possible with different configurations may be more properly understood in terms of the configurations themselves, rather than the traditional ideas of angular momentum, spin, *etc*.

At least one multi-atom theory for quantum phenomena has been introduced at PIRT conferences before: the ensemble interpretation of QM advocated by E.J. Post[14,15,16] has since found continuing attention.

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14 E.J. Post, "The Copenhagen Delusions of a Dutch Uncle", Galilean Electrodynamics **8**, 83-86 (1997); from PIRT V, 348-351 (1996).

15 E.J. Post, "Do we Dare to Understand Quantum Mechanics?", Galilean Electrodynamics **12**, 71-75 (2001).

Appendix: Inside Charge Clustering

The task of explaining charge clustering is far from trivial. The problem is that, on elementary grounds, charges of the same sign are supposed to repel. That is just Coulomb's law. So explaining the observed facts requires some other effect that could work in opposition to Coulomb repulsion. So we seem to be in need of some ideas to explain anomalous attraction. The paragraphs below develop a candidate idea: radiation reaction.

The Standard Approach on Radiation Reaction

Whenever an electromagnetic charge accelerates, or a gravitational mass accelerates, radiation is created. Radiation carries energy away into space, so radiation is an energy loss mechanism for the source. It must put a dragging reaction-force term into whatever differential equation describes the motion of the source charge or mass.

However, achieving a mathematical description for radiation reaction is a far-from-trivial task. The problem lies with so-called runaway solutions to equations implementing Newton's law (see Jackson[17]). The problem with a runaway solution is that it seems to defy the 'arrow of time', and potentially on a scale that is far from microscopic.

The argument goes as follows. We have $\mathbf{F} = m\mathbf{a}$, where $\mathbf{F}$ is force, m is mass, $\mathbf{a}$ is acceleration, $\mathbf{a} = d\mathbf{v}/dt$, $\mathbf{v}$ is velocity, t is time. Such an equation implies a time rate of change of energy along a path, described by power $\mathbf{P} = \mathbf{F}\cdot\mathbf{v}$. In the case of a charge e moving in an electric field $\mathbf{E}$, there is a driving force $\mathbf{F} = e\mathbf{E}$, making an energy gain $P_e = e\mathbf{E}\cdot\mathbf{v}$, and there is an energy loss due to radiation power $P_r = 2e^2a^2/3c^3$. The factor $2e^2/3c^3$ is often abbreviated $m\tau$, where τ is a characteristic time. The total power is $P = P_e - P_r = e\mathbf{E}\cdot\mathbf{v} - m\tau a^2 = m\mathbf{a}\cdot\mathbf{v}$. Two terms there are conveniently of the form **"...·v"** from which one can infer at least the important component of force. But $m\tau a^2$ is not in the right form; to change it to that form, one invokes integration by parts:

$$\int a^2 dt = \int \mathbf{a}\cdot d\mathbf{v} = \mathbf{a}\cdot\mathbf{v}\Big|_{\text{limit1}}^{\text{limit2}} - \int d\mathbf{a}\cdot\mathbf{v} = \int \mathbf{v}\cdot\mathbf{j}dt$$

where $\mathbf{j}$ is 'jerk', $\mathbf{j} = d\mathbf{a}/dt$. Then one asserts a reason to justify $\mathbf{a}\cdot\mathbf{v}\Big|_{\text{limit1}}^{\text{limit2}} = 0$. For example, one asserts '$\mathbf{a}$ is always orthogonal to $\mathbf{v}$ so $\mathbf{a}\cdot\mathbf{v} = 0$', or '$\mathbf{a}\cdot\mathbf{v}$ is constant', or 'the system goes through cycles, so there exists a time interval such that $\mathbf{a}\cdot\mathbf{v}$ is the same at both limits'. The power equation then reads $P = e\mathbf{E}\cdot\mathbf{v} + m\tau\mathbf{j}\cdot\mathbf{v} = m\mathbf{a}\cdot\mathbf{v}$, from which one can guess $\mathbf{F} = e\mathbf{E} + m\tau\mathbf{j} = m\mathbf{a}$. Supposing there is no $\mathbf{E}$ at all, the force equation implies $\tau d\mathbf{a}/dt = \mathbf{a}$. One solution is perfectly reasonable: $\mathbf{a} = \mathbf{a}_{ok} \equiv 0$. But there is also another solution, and it is questionable: $\mathbf{a} = \mathbf{a}_? = \mathbf{a}_0\exp(t/\tau)$, where $\mathbf{a}_0$ is the acceleration at $t = 0$, which can be non-zero if $t = 0$ is, for example, when $\mathbf{E}$ turns off, or the charged particle is kicked. This questionable solution gets bigger and bigger as time goes by; it is the runaway solution.

There is, however, a counter-argument to the above conventional argument about runaway solutions. The counter-argument hinges on the condition $\mathbf{a}\cdot\mathbf{v}\Big|_{\text{limit1}}^{\text{limit2}} = 0$. If $\mathbf{a} = \mathbf{a}_? = \mathbf{a}_0\exp(t/\tau)$, then $\mathbf{v} = \mathbf{v}_0 + \int \mathbf{a}dt = \mathbf{v}_0 + \mathbf{a}_0\tau(e^{t/\tau} - 1)$. For t big enough, $\mathbf{a}\cdot\mathbf{v} \to a_0^2\tau e^{2t/\tau}$. This is monotonically increasing, and so is inconsistent with $\mathbf{a}\cdot\mathbf{v}\Big|_{\text{limit1}}^{\text{limit2}} = 0$. It is, therefore, impossible to have $\mathbf{a} = \mathbf{a}_?$ except if $\mathbf{a} \neq \mathbf{a}_?$, a contradiction.

A Different Approach to Radiation Reaction

A potentially better approach to examining the two solutions with radiation reaction is to revert to the equation before integration by parts: $e\mathbf{E}\cdot\mathbf{v} - m\tau a^2 = m\mathbf{a}\cdot\mathbf{v}$. This is a quadratic equation in the component of $\mathbf{a}$ along $\mathbf{v}$, a_v: $Aa_v^2 + Ba_v + C = 0$, with $A = m\tau$, $B = mv_a$ (the v_a being the component of $\mathbf{v}$ along $\mathbf{a}$), and $C = -e\mathbf{E}\cdot\mathbf{v}$. The quadratic equation has solutions

$$a_{v\pm} = \left[-B \pm \sqrt{B^2 - 4AC}\right]\Big/2A$$

That is,

$$a_{v\pm} = \left[-mv_a \pm \sqrt{(mv_a)^2 + 4m\tau e\mathbf{E}\cdot\mathbf{v}}\right]\Big/2m\tau$$

Assuming that $\mathbf{E}$ is small, power series expansion can be used to evaluate the square root in $a_{v\pm}$. In general

$$(x+y)^n \approx x^n + nx^{n-1}y + \frac{n(n-1)}{2}x^{n-2}y^2 + \frac{n(n-1)(n-2)}{2\times 3}x^{n-3}y^3 \ldots$$

In particular, with $x = (mv_a)^2$, $y = 4m\tau e\mathbf{E}\cdot\mathbf{v}$, and $n = 1/2$, one has

$$\sqrt{(mv_a)^2 + 4m\tau e\mathbf{E}\cdot\mathbf{v}} \approx mv_a + \frac{1}{2}\frac{4m\tau e\mathbf{E}\cdot\mathbf{v}}{mv_a} - \frac{1}{8}\frac{(4m\tau e\mathbf{E}\cdot\mathbf{v})^2}{(mv_a)^3} + \frac{1}{16}\frac{(4m\tau e\mathbf{E}\cdot\mathbf{v})^3}{(mv_a)^5} \ldots$$

So for the first one of the two solutions,

$$a_{v+} \approx \frac{e\mathbf{E}\cdot\mathbf{v}}{mv_a} - \frac{(e\mathbf{E}\cdot\mathbf{v})^2 m\tau}{(mv_a)^3} + 2\frac{(e\mathbf{E}\cdot\mathbf{v})^3(m\tau)^2}{(mv_a)^5} \ldots$$

The first term here is consistent with the baseline expected $\mathbf{a} = e\mathbf{E}/m$. The second term does fight against $\mathbf{E}$, and can be interpreted as some sort of radiation reaction. But it goes away

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16 E.J. Post, **Quantum Reprogramming** (Kluwer Academic Press, Dordrecht-Boston, 1995).

17 J.D. Jackson, **Classical Electrodynamics**, Second Edition, Chapter 17 (John Wiley & Sons, New York, Chichester, Brisbane, Toronto, Singapore, 1975).

if **E** goes away. The third term is negligible. Altogether, this is a normal, well-behaved solution.

The other one of the two solutions is

$$a_{v-} = -\frac{v_a}{\tau} - \frac{e\mathbf{E}\cdot\mathbf{v}}{mv_a} + \frac{(e\mathbf{E}\cdot\mathbf{v})^2 m\tau}{(mv_a)^3}\ldots$$

With no $\mathbf{E}$, this solution comes to $a_{v-} = -v_a / \tau$, and supposing $\mathbf{a}$ and $\mathbf{v}$ to be parallel, it implies $d\mathbf{v} / dt = -\mathbf{v} / \tau$, or $\mathbf{v} = \mathbf{v}_0 \exp(-t / \tau)$. This solution also is no run-away; if anything, it is instead a *capture* solution. It tends to suppress any relative velocity that may exist between interacting bodies. It thereby holds the bodies at some steady stand-off range.

With no runaway solution at all, there is no troubling conflict implied within this analysis approach. The second radiation reaction solution is, however, of considerable interest in the context of charge clustering. It suggests a capture phenomenon that serves as a candidate explanation for phenomena such as electron clustering.