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Process and the Dirac Electron: Pauli Exclusion and Electron Pairing for the Helium Atom

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Abstract

The problem of the behaviour of atomic electrons is analysed by physically interpreting the Dirac relativistic equation for the electron with its positive and negative energy solutions coupled to the oscillation, which allows the energy of the electron to decay to zero. This approach changes the electron of classical and quantum physics into a series of becoming and perishing events which is the physical analogue of the fundamental process of Whitehead's doctrine of organic realism. When the analysis is extended to the other components of the atom their behaviour is congruent with quantum theory and dependent upon the rules of special relativity. The physical features that emerge from the theory include like-charge repulsion, electron pairing, Pauli exclusion and virtual-photon mediated electrodynamics for the helium atom. The theory is background independent and without a need for fields or waves. Virtual photon-mediated interactions among charged particles are limited physically, by the effects of the rules of special relativity upon the geometry of the oscillation, to antisymmetrical two-particle ensembles. Nothing is put in by hand.

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"I am sure that history does not repeat itself in physics . . . The reason is this. Any schemes—such as 'think of symmetry laws', or 'put the information in mathematical form', or 'guess the equations'—are known to everybody now, and they are all tried all the time. . . . the answer cannot be one of these . . . There must be another way next time."

R. P. Feynman [1]

1. Introduction

The foundation of Whitehead's doctrine of organic realism is the becoming and perishing of individual, discrete events[1]. It is almost eighty years since his metaphysical theory of process was published [2] and so far its relevance for the physics of the microscopic world remains unclear. The question arises: can a satisfactory reinterpretation of twentieth-century physics be achieved which is clearly and distinctly organic, in Whitehead's sense, and which brings with it the two major achievements of quantum theory and special relativity? Just as important is the question: can such a reinterpretation contribute to a better understanding of the microscopic world by the provision of improved explanations of well known phenomena? This paper has the

[1] The term "event," used here, and Whitehead's term "actual occasion" have the same meaning; a single complete becoming. His use of 'event' denotes a plurality of actualisations. (ref 2, 73)

ambitious task of offering a tentative reply in the affirmative to both questions.

Various models of electronic structure and behaviour have been employed in seeking to understand atomic phenomena. All such models assume some degree of physical continuity for atoms and their constituents. The field concept is a central element of that continuity. By contrast, the present scheme interprets the physical consequences of the Dirac equation for the electron in such a manner that an ideal electron consists of an organic process of serial becoming and instantaneous, changeless perishing. The electron and its geometric relations with the world are transformed from the classical picture of a continuous fundamental object, indivisible and without parts, to a composite object comprised of just one component; the electron is rendered discrete in space and time. A fully discrete spacetime model of the atom is introduced in which there is no temporal or spatial continuity of internal or external geometric relations among atomic constituents, it is an epochal theory of the atom. A natural consequence of the discrete spacetime process is Pauli exclusion and electron pairing, which in this paper is applied to the constituents of the helium atom. The theory is cast in the particle framework without a need of fields or waves.

Efforts to understand the atom within a framework of quantum mechanics have been hampered by the absence of underlying physical principles which lead naturally to the kinematics of quantum systems. Unlike classical theories of mechanics and gravitation, quantum theory lacks a physical basis—it is essentially a theory of outcomes divorced from the action from which they arise. The absence of criteria that distinguish classical and quantum kinematics has meant that classical concepts of continuity of motion and its dynamics have been ascribed to quantum systems by default. However, the continuity assumption is neither required by the central tenets of quantum theory nor supported by phenomena. Observation leaves the question open.

The chemistry problem of electron energies, first dealt with seventy years ago, is still solved by the use of four quantum numbers. Their provision of unique energies of atomic electrons fulfils the requirements of the Pauli exclusion principle, first devised in 1925 to explain atomic spectra [3]. Like the problem of the absence of a physical foundation for quantum mechanics, generally, Pauli exclusion cannot be deduced from basic principles. This deficiency was raised by Pauli in his original paper and still troubled him twenty years later [4]. Despite subsequent developments in quantum mechanics and atomic theory the question of why only classes of antisymmetrical states of two-particle ensembles should be allowed by Nature has remained unanswered for eighty years. It may be summarised by saying that: although the behaviour of matter and energy is never found to be contrary to the exclusion principle there is no explanation, in terms of atomic behaviour, that makes it turn out that way.

The mutual affinity of electrons for chemical pairing on one hand and like-charge repulsion on the other remains a problem without a natural resolution. In the late nineteen twenties, the potential for negative energies, one of the most surprising quantum features of microscopic matter, was revealed by Dirac's discovery of his relativistic equations for the electron. Negative energy states of the electron cannot be understood in either a quantum or classical framework; they are seemingly unphysical and therefore something in addition to real energy, as it is usually understood. They too lack a physical foundation.

In the present scheme, a reinterpretation of the physical consequences of the Dirac equation couples the oscillation and negative energy states of the electron. The ideal electron then consists of an oscillation between positive and negative energy states. The dynamics of the coupling require that positive energy electrons decay into negative energy states, a fact that Dirac sought to counter by the introduction of the anti-electron. It will be seen that the occupancy of the negative energy states cannot be understood in classical terms that include electrons with positive charge. Instead, they are quantum potentials from which positive energy electrons arise. In one sense, the discrete scheme here described extracts an enduring but unstable particle from the Dirac electron.

Two consequences of the theory are an electron pairing bond and Pauli exclusion; each is a requirement of the theory, of which like-charge repulsion is also a part. It will be shown that the discrete scheme which arises from the coupling of the oscillation with the negative energy states is sufficient foundation for a simple, adequate and consistent theory of the electromagnetic interaction among the constituents of the helium atom, from which follow both its quantum mechanical features and its classical manifestations.

The theory evolves in a particle framework as it applies to the electron, the proton and the photon—reified fields and waves are not part of the theory. The physical properties of importance are mass and electric charge, which are possessed by individual electrons and protons and absent from photons. Central to the theory is an extension of the well known concept of discontinuity of values of quantum variables to the quantum system itself. Consistent with the minimisation of assumptions, space and time are interpreted as Leibnizian geometric relations among objects. Consequently, there is neither space nor time apart from the objects they relate, and they too are rendered fully discrete by the theory.

The paper is divided into seven parts. Part 2 presents a physical interpretation of the Dirac equation with its oscillation and negative energy solutions. Part 3 introduces the becoming electron. Part 4 deals with discrete photon annihilation and creation and the virtual photon. Part 5 introduces photon-mediated electron interactions, like-charge repulsion and discrete Pauli exclusion. Part 6 extends the theory from pure electrons to the proton–electron interaction and the helium atom. Part 7 summarises the analysis.

2. A physical interpretation of the Dirac electron

2.1. The discrete electron and the Dirac equation

The oscillating energy states limit the physical behaviour of electrons and how they can interact via virtual photon exchange in certain definite ways. As a consequence, every element of the electron and its geometrical relations are rendered discrete in space and time. So as to generalize the concept among the other components of the atom, the same analysis is postulated, by extension, to apply to nucleons and the photon.

Dirac's own comments are interpreted as consistent with the discrete approach. When he introduced his relativistic equation for the electron he was puzzled by two of its features, which he expressed as follows: “It is found that an electron which seems to us to be moving slowly, must actually have a very high frequency oscillatory motion of small amplitude superposed on the regular motion which appears to us.” and “These quantum equations are such that, when interpreted according to the general scheme of quantum dynamics, they allow as the possible results of a measurement of kinetic energy either something greater than mc^2 or something less than $-mc^2$.” [5].

The fact that there are negative energy solutions to the Dirac equation created a problem because positive energy electrons would be unstable, they would tend to decay into negative energy states. Negative energy electrons were regarded as unphysical and a flaw in the theory. Dirac solved the problem by proposing that each negative energy state was occupied by a single electron which, by Pauli exclusion, prevented the decay of positive energy electrons into the same state. His motivation for his theory which gave rise to the positron, as the antiparticle of the electron, was the imperative to remove by transformation the unphysical negative energy states. The transformation replaced the opposite of the positive energy of the electron with the opposite of its electric charge, in order to maintain a connection with the real world.

2.2. The physical meaning of negative energy states

Energy for the present theory is defined, as in classical physics, as: the quantity that is the measure of the capacity of a system for doing work. And energy is always the energy of something; it is never free of an object or system. In the discrete scheme, all the energy (including mass) of the electromagnetic sector is the energy of the becoming of events.

Dirac introduced the concept of positive and negative energy states with his relativistic equations for the electron, which allow the possible results of a measurement of kinetic energy to be positive or negative. The mathematical representation of the allowed energy states gives them the relation of opposites, which is denoted in the usual way by positive (+) and negative (–) symbols. For the present scheme, being physical, the mathematical relation of opposites is replaced by its physical analogue.

Positive energies are those usually associated with real and tangible objects such as the classical electron – physical states have positive energy. The central postulate of the theory is: the opposite of the energy of the real electron is identical with the energy of the opposite of the real electron. The opposite of the real (physical) electron is the potential electron. The necessarily abstract nature of the mathematical representation of negative energy states, which are the opposite of those of the real classical electron, do not extend naturally to the real physical domain. The physical consequence of coupling energy states with the oscillation is interpreted to transform the Dirac electron into serial actual and potential phases. This analysis adopts the Aristotelian distinction between real and potential when applied to physical objects [6]. The opposite of the real electron is the potential electron, and *vice versa*. The potential phase of the oscillation is analogous to a virtual electron.

The potential phase of the electron is devoid of values for all physical quantities, including energy. An energy of a magnitude of less than zero does not belong to the actual phase, it is a potential to achieve actual (positive) energy of that magnitude in a subsequent actual phase. Thus, the physical meaning of the mathematical representation of positive and negative energy states is the mutual opposites of the energy states of an actual and a potential electron. The physical opposite of (positive) energy is no energy.

3. The becoming electron

The electron, in the zero-energy phase of its oscillation, is bereft of all spacetime relations both internal and external, because without energy in any form it can have neither mass nor any other objective property. The description, or definition, of a zero-energy entity cannot employ spatial or temporal terms—it is therefore independent of space and time. Distance, duration, motion, mass, energy and electric charge are all absent for the electron during its phase of pure potential. Physical properties, including geometric relations, arise during the subsequent phase of becoming.

Successive actual phases of an electron are separated by space and time. A particular spacetime locus which is occupied by the actualised electron arises at the *completion* of each actual phase, it was not there, laying in wait. The arrival of the object therefore coincides with the arrival of its spacetime region.[2] Such an arrangement is fully congruent with Einstein's contention that in the absence of matter there is no spacetime. The gravitational field and spacetime are identical and without matter there is neither.

In conformity with the matter–force distinction as applied to the terms 'fermion' and 'boson', the former being a matter particle and the latter a force or binding particle, the two phases of the postulated oscillation are fermionic and bosonic. The fermionic phase is energetic and actual and the bosonic phase is purely potential. Successive fermionic phases are connected by an intermediate bosonic phase. The objective or fermionic phase grows out of the potential phase; it takes time and occupies space as it acquires energy and its other properties, including electric charge. All of which is the realization in the actual phase of what may be predicted or expected from its potential phase. The instantaneous potential phase embraces all its initial conditions.

The mass component of the energy of becoming is related to its duration. The oscillation is characterized by a gradual and energetic becoming of the actual phase and upon completion it terminates instantaneously into the potential phase–there is no being. Successive potential phases of the oscillation render the enduring electron fully discrete in space and time. The rôles of space and time are exactly equivalent in the description of the enduring electron. The objective

[2]The arrival of the object recurs at the becoming of each event of which it is composed. That becoming is pregeometrical, it happens prior to the geometry which relates it to its contemporaries and antecedents, which are becoming and changelessly perishing events in the lives of itself and other enduring objects.

components of the electron are equally separated by space and time intervals. The equivalence of space and time for the Dirac equation is physically realized in the epocal theory of the electron.

Actual phases may be said to tunnel from one to the next via an intermediate bosonic phase. The transition between successive fermionic phases is indistinguishable from a quantum jump. The concept of the quantum jump is usually employed to explain transitions between different energy levels. Here the jump occurs between successive stationary states of any values because there can be no intermediates. Successive fermionizations are bound to each other by the intermediate bosonic phase, in the formation of the enduring electron, “which appears to us”. The fundamental and indivisible ideal electron of classical physics is thereby divided into discrete becoming events[3]. It is a composite object with just one component. The postulated oscillation process as applied to the electron is equally applied to protons and photons.

The one-electron process is therefore analogous to a particle pair; it consists of two partners. One is the actual fermion with positive energy and negative electric charge, its partner is the potential or bosonic phase without energy or any quantum property. In combination they constitute the elements of the enduring electron which is discrete in both space and in time.

4. The process photon

4.1 Discrete photon annihilation and creation

If the space separation and phases of their oscillations are suitably related for an electron and a photon they will become together. Such a co-becoming is dependent upon electric charge, which is simply the quantum property that enables a fermion to annihilate a photon. The charge-mediated annihilation is dependent upon their being propitiously located in space and time. Electric charge is the oscillating quantum property that enables that co-becoming. The ensuing bosonic phase of such an excited actual fermionic electron consists in the double potential of a photon and an electron without any quantum properties, including charge. Each potential begins to become at the instant of the termination of the two immediately preceding fermionic phases.

The absolute difference between the mass potentials of the photon and electron in the bosonic phase obeys the laws of special relativity. Consequently, the absolute difference in the duration of their next individual becoming means that the photon potential actualizes before the actualization of the electron potential and its property of electric charge. The absolute mass

[3] An event is one complete becoming in the life of the electron.

difference means there is no temporal overlap in their actualization. Relative mass differences among co-becoming coupled potentials, which are absent from interactions among photons and charged particles, are associated with some temporal overlap.

The mass-induced consequence of the absolute difference in the rates of becoming of the photon and electron potentials is that the quantum property of electric charge of the electron cannot actualize in time to *capture* the becoming photon. The geometric relations of space and time are no longer propitious for the co-becoming of the electron and photon potentials. Consequently, in the present theory, the special relativistic absolute mass difference prevents an electron from overtaking its emitted photon. In contrast to the nineteenth-century field-theoretic concept in which fields enable self-interaction, in the discrete scheme special relativity forbids an electron self-interaction via its emitted photon. That is the discrete theory of photon creation, or emission, by an electron.

For photons and charged fermions, electric charge is the discrete quantum property which permits photon annihilation and their absolute mass difference is the physical basis for photon creation. For a single electron, the oscillating phases of photon creation and annihilation relate serially to one another, they cannot occur simultaneously[4].

4.2 The discrete virtual photon and the electromagnetic bond

In the present scheme, real photons oscillate between actual and potential phases when alone and independent of charged fermions during journeys of indefinite distance and duration, across a room or across a galaxy. The sum of the durations of the actual phases of the photon gives the finite value to the speed of light; their potential phases make zero contribution to the duration of the journey. By contrast, a virtual photon is created in the potential phase of one energised charged object and is annihilated by its co-becoming with another, without achieving photonic

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[4] A logical consequence of the distinction between the concepts of mathematical and physical opposites, as it is here applied to energy, is its application to electric charge. The physical interpretation of the concept of opposites is applied to charge in the same manner that it is applied to energy. Therefore, the opposite of the charge of the electron is the charge of the opposite of the electron, which is zero charge of the potential electron. Energy and charge are two properties of a single oscillating electron. Each actualizes and then decays to the opposite status of an immaterial potential. By contrast, the opposite of the polarity of the charge of the electron is the polarity of the charge of the proton. The concept of polarity entails a property *relation* that involves differences between charged elementary particles. Charge is simply the property, in the present case, of individual electrons and protons that enable photon annihilation. Photons do not distinguish the polarity of the charges of the electron and proton. For a photon, the opposite of the electron charge is the absence of charge because the opposite of annihilation is endurance.

actualization between the two; exchange occurs entirely during a single photonic, bosonic phase. Such a photonic, potential or bosonic phase is a virtual photon tunnelling between two charged fermions.

Because the virtual photon tunnels in association with a single bosonic phase it does so instantaneously; which is the discrete Hartman effect [7]. Change of position for the photon is a nonlocal effect, it does not move through space and it is instantaneous. There is no difference between individual potential phases of a real photon and the single bosonic phase of a virtual photon and neither is there a difference between their creation or annihilation. The relativistic space contraction and time dilation is complete in both instances.

The energy of the electron, proton and real photon perform the work of their individual becoming. When a photon and an electron co-become, some of the energy of becoming takes the form of mass. Mass is derivative of the co-becoming of more than one potential. Because real photons do not co-become (except at their annihilation) their serial actualizations are energetically massless and the rate of change of location of the enduring (real) photon is therefore absolutely faster than massive particles.[5] Photons of different energies thus change their position at the same speed. Again, the discrete scheme is fully in accord with special relativity.

In what follows, all references to photons are to virtual photons. Real photons have no role in mediating binding interactions between charged particles.

5. Discrete co-becoming

5.1 The two-electron process and discrete Pauli exclusion

When the fermionic phases of two electrons are synchronised and spatially separated within the constraint of the tunnelling distance of a virtual photon, neither can co-become with a photon emitted by the other. Such a simultaneous two-way exchange of photons is impossible without a significant change in their spacetime relations (Figure 1); which are their space and phase separations. This is a consequence of geometry, in which an electron emits a photon as a

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[5] The importance, for the present theory, of the concept of mass as derived from special relativity cannot be over emphasised. Of all the consequences of special relativity it is of the first importance. By contrast with the process scheme, the field theoretic approach to modern physics, devised in the 19th century, is primarily concerned with representations and therefore, and rightly, is focused upon questions of simultaneity and the symmetries of flat spacetime. The present theory is of the *action* of energy that manifests as mass, which precedes its representation. Einstein's view: "The most important result of a general character to which the special theory of relativity has led is concerned with the conception of mass." [8] reinforces the point.

consequence of its potential phase and absorbs a photon during its actual phase and virtual photons tunnel instantaneously between creation and annihilation [9, 10].

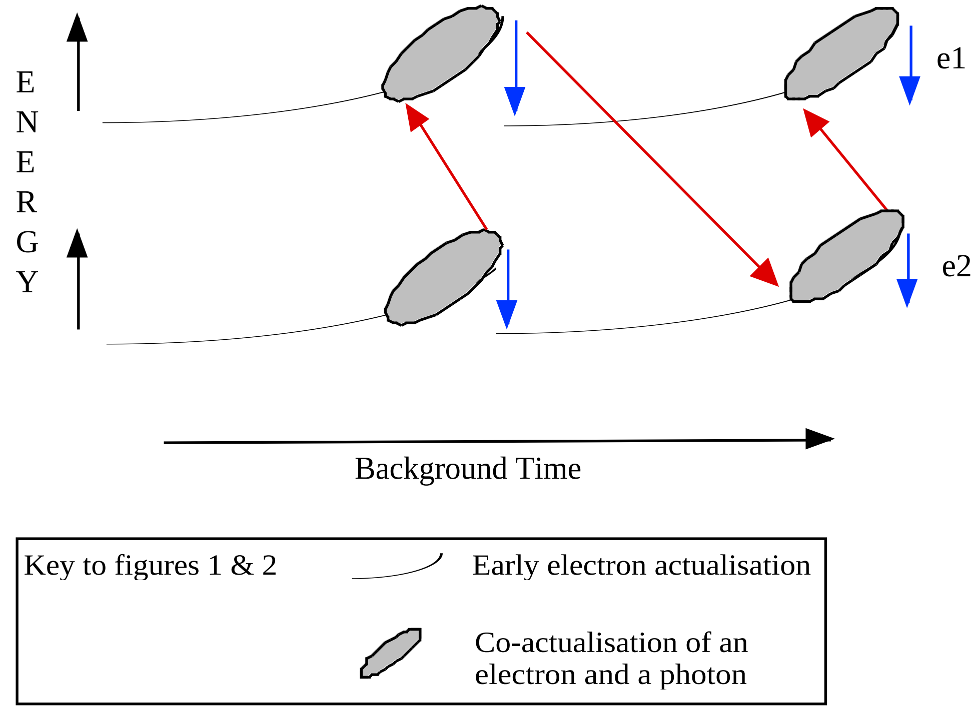

Fig. 1. Like-charge repulsion between the simultaneous actual phases of two oscillating electrons. Photon exchanges (red arrows) are shown going either backwards or forwards in time. Such a geometric impossibility results in the mutual repulsion in space and time of e1 and e2. The bosonic phase of each electron (blue arrows) is unaffected by their phase relations. The energy of becoming rises from zero (black arrows) and decays to zero (blue arrows) at its completion.

Heuristically, an attempt to simultaneously exchange photons between a pair of suitably located electrons, both in the actual phase, causes the spacetime relations between their next actual phases to be scattered—they repel one another. For one electron to absorb the photon emitted by the other, becoming of the absorber must be out of phase with that of the emitter and propitiously spatially separated. The termination of becoming of the emitter must coincide with the propitious part of the becoming of the absorber, because the photon tunnels instantaneously between them. For the actual phases of two electrons to simultaneously exchange a photon, within the spacetime constraint of the present theory, each must be the first to emit a photon—which they cannot.

If one electron of a pair is to emit a photon and the second electron absorb it, then their space and time separations must be propitious. Such a one-photon transfer occurs in one direction only, without a simultaneously returned photon in the opposite direction. No two electrons, whose oscillations are in phase, can simultaneously exchange photons for the same reason that special relativity forbids one electron from annihilating its own created virtual photon. Any two electrons engaged in the exchange of a virtual photon are members of a single quantum system. The geometry of the oscillation, which is the same for electrons and photons, prevents two photon-transferring electrons from simultaneously being actual or fermionic. The two electrons are members of the same quantum system only if one is fermionic and the other bosonic. If that relationship does not obtain they are not members of the same quantum system. Consequently, more than one fermion cannot occupy the same quantum state. Only antisymmetrical two-particle ensembles are geometrically allowed. In the present theory, that is the physical basis for discrete Pauli exclusion.

Since one electron must be potential or bosonic to emit and the other actual or fermionic to absorb the tunnelled photon, two actual fermions cannot occupy the same quantum system *at the same time*. Only the antisymmetrical class of two charged-particle ensembles is able to interact by the exchange of photons. Thus, discrete Pauli exclusion applies not only to two electrons, but to any two charged fermions capable of photon emission and absorption.

5.2 The many-electron process

If the fermionic phases of three oscillating electrons are suitably related in space and phase (time) then a one-way serial transfer of virtual photons can take place among all three; the same geometric constraint applies to more than three. If the number of electrons is suitably small and isolated such an interaction may close into a loop. By contrast with the looped configuration, the serial one-way transfer of virtual photons among indefinitely large numbers of electrons, which is a simple extension of the three-electron interaction, is postulated to be the electromagnetic interaction for an electron plasma, such as lightning and spark discharges generally. Such a large scale interaction does not form a loop because it is not limited by the number of available participating electrons. Figure 2 illustrates the interaction among three oscillating electrons.

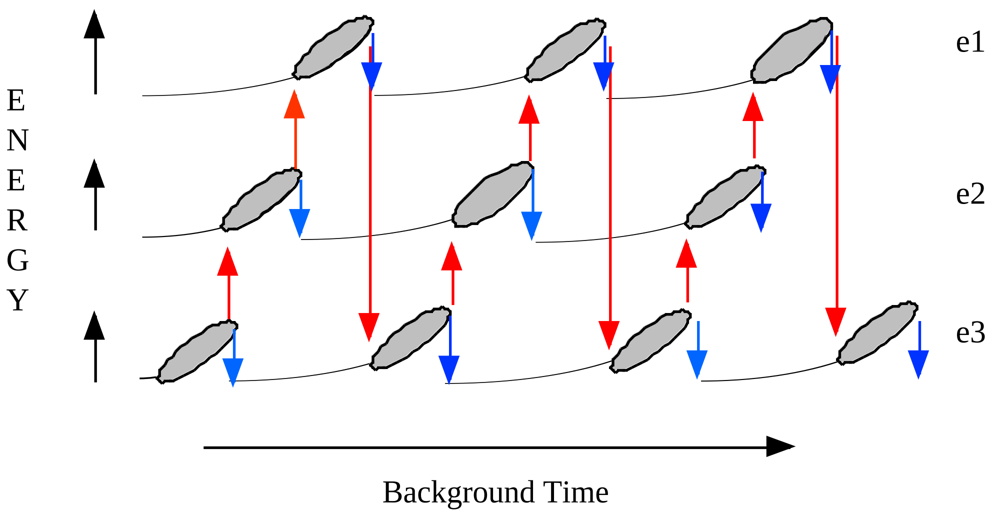

Fig. 2. The binding interaction for three oscillating electrons (e). One-way photon transfers are indicated by red arrows. Potential phases and energy decay are indicated by blue arrows. Black arrows indicate the rise of the energy of becoming for each electron.

The crucial feature of the interaction is that it engages a minimum of three electrons, because the second in the series can neither transfer a virtual photon back to the first nor overtake and annihilate its own emitted photon. If a third electron is propitiously located, it will be the recipient of the photon emitted by the second electron. The obligatory three-particle geometry of such an interaction is a consequence of the oscillation between actual and potential energies. It is manifest by the physical impossibility of any geometric alternative to the fact that an electron which receives a virtual photon from another electron can only emit it to a third and never to itself. Consequently, in contrast to the repulsion by members of an in-phase isolated pair of electrons, two electrons form a bound pair if a third oscillating charged fermion is propitiously located.

The tunnelled virtual photon between two electrons determines the spacetime interval that separates them and thereby forms the bond between them. The photon-mediated binding principle for two discrete fermions, shown by the red arrows of Figure 2, is the same as the tunnelling potential *bosonic* phase which binds two contiguous fermionic or actual phases of one enduring electron, shown by the blue arrows of Figure 2. In the treble electron interaction both bonds are simultaneously active, as shown in Figure 2.

Two features of the pure electron interaction are the absence of a mass difference between the interacting fermions and the indefinite number of electrons which can engage in the interaction. These two features are related. It is possible to envisage large numbers of interacting electrons with approximately equal duration of becoming consequent upon the fact of their equal rest mass. The extension of the interaction to larger numbers of electrons does not alter the treble imperative of the interaction. However, the membership of any treble in such an extended interaction switches with every new electron fermionization. As an electron emits a virtual photon it becomes the second member of a treble, with the electron from which it received a photon and the one to which it emits one. This switch of membership among serial trebles achieves the global interaction in which groups of three electrons are bound to each other. This feature of the spacetime geometry of the interaction is crucial in the helium atom interaction (discussed below).

From the standpoint of quantum mechanics, understood in the discrete organic framework, two electrons between which one virtual photon transfers are members of the same system for as long as they are engaged in the transfer. When the absorbing electron switches to emitting a virtual photon, which always goes to a third electron, it ceases membership of the first system and takes up membership of a new system with the third electron. In such a scheme, the constitution or membership of a quantum system is fully discrete in space and time. This is the physical basis for the antisymmetrical two-particle ensemble. The laws of Nature discovered by special relativity induce both the antisymmetry and the ensemble membership of two charged particles.

The many-electron bond may be summarised as follows: (1) virtual photon transfer is always one-way and can only occur among three electrons, (2) co-becoming in a single event of an electron and a photon forms the bond with the two antecedent fermionizations from which the two potentials tunnelled and (3) the absence of a mass difference between electrons allows the interaction to extend beyond three to an indefinite number of propitiously located treble interacting electrons.

6. The process atom

6.1 The electron–proton interaction

When a proton is substituted for one electron in a treble-electron interaction two electrons bind to the proton. A virtual photon transfers from the proton to an electron and then to the second electron, while all three oscillate between actual and potential phases. The combined large mass difference between one proton and one electron with the absence of a mass difference between the two electrons gives the treble interaction its spacetime geometry, which, from the perspective of atomic interactions, is dominated by the electron pair. Following the postulate that the mass of actualization is related to its duration, the two spacetime intervals separating two electrons and a proton are equal when the photon transfers go from the proton to the first electron, and then to the second electron. By contrast, when the photon transfers first between electrons and then to a proton, the interval separating the electrons is smaller than that separating the second electron from the proton, as shown in Figure 3.

Just as for pure electrons, the proton–electron interaction must include a minimum of three interactants and the required geometry together with the relative mass difference produce the two-electron, one-proton interaction. The electromagnetic interaction is restricted to the antisymmetrical class of two-particle ensembles no matter what the charged fermions are.

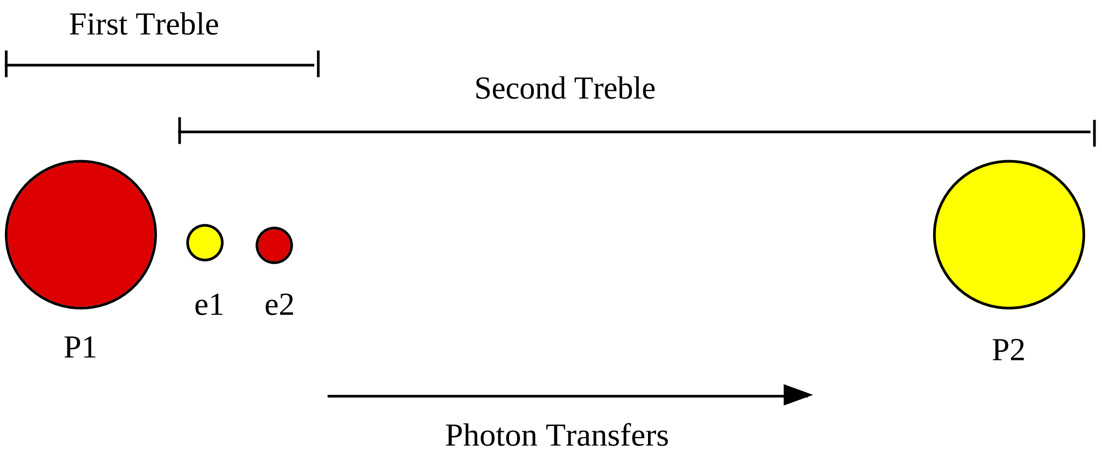

Fig. 3. The geometric relationship between the phases of the oscillations of two protons (P) and two electrons (e) of the helium atom. Red circles indicate actual phases, yellow particles potential phases. Electrons are bound to the nucleus by the two interacting trebles formed by the one-way transfer of photons from P1 to e1, e2 and P2. The electron pair couples the two trebles by their serial membership of each. P1 and P2 are shown widely separated in time but are closely bound in space.

The positive polarity of electric charge of the proton introduces a second imperative for the interaction. The first is the treble, the second is charge neutrality. Three charged fermions of which the polarity of one differs from the other two do not of themselves provide charge neutrality. Neutrality is achieved by the introduction of a second proton. For the atom, in contrast to the pure electron interaction, the treble imperative and charge neutrality operate together. Charge neutrality is a consequence of the incorporation of a second proton with the two-electron one-proton interaction. This it does in the interaction for the helium atom.

6.2. The electromagnetic interaction for the helium atom

The addition of a second proton to the interaction between an electron pair and a single proton has two consequences. One is charge neutrality and the other is the creation of a pair of coupled treble interactions. As shown in Figure 3, charge neutrality is achieved for the helium interaction by the serial actualization of the quantum property of charge for the protons and electrons; one of each is actual at the same time. When a proton (P1) *sends* a photon to an electron (e1) only the charge of the electron is actual because photon emission by the proton occurs in its potential phase when it has no quantum properties, including electric charge. Simultaneously, the charge of the second electron (e2) is potential while that of the second proton (P2) is actual, as it co-becomes with the photon emitted by the second electron. Therefore, among charge-neutral atoms and molecules generally, electric charge of one electron in each pair is actual while one is potential, and the same charge relationship obtains for the two protons. It can be seen from Figure 3 that when an electron and proton are simultaneously fermionic they are not members of the same quantum system because there is no photon transfer to physically connect them.

The helium interaction consists of serial trebling by the two electrons first with one proton and upon completion of that treble then with a second proton. The two serial trebles, of which each constitutes half the helium atom electromagnetic interaction, each consist of a one-way transfer of photons among two electrons and one proton. In one treble the photons go from the proton to the first then to the second electron, the second treble results when the photons go from the first electron to the second and then to the proton. The switch between protons, for the serial trebles, is crucial to the formation of an electron pair-mediated bond between them. Whereas three interacting (ideal) electrons may repeatedly form a loop, as shown in Figure 1, a proton in a bound nucleus cannot repeatedly participate in photon-mediated loop formation nor in successive treble interactions with an electron pair; another proton must become the third component of the second treble interaction.

According to the generalized Pauli principle as it applies to a bound nucleus, states of the nucleon fluctuate between protonic and neutronic; individual protons transform into neutrons and *vice versa*. That dynamic forms part of the theory of the discrete electromagnetic interaction for the atom. Therefore, as part of a helium nucleus, when the potential phase of a proton emits a photon its subsequent actual phase is that of a neutron. That transition is independent of the photon emitted. Consequently, because that nucleon then has no electric charge it is unable to participate in the next treble interaction with the electron pair. Having no electric charge it cannot annihilate a photon.

In the helium interaction, the proton-switch between successive trebles exerts little influence on the geometry of the disposition of the nucleons because they are bound together by the nuclear force. By contrast, in diatomic light hydrogen it is the serial discrete bond between the electron pair and two protons which maintains the molecule and determines the geometry of the spacetime relations of the two protons. The much larger spacetime separation of molecular protons by comparison with bound nucleons of the helium atom, (a factor of the order of 10^6 for the space separation) compensates for the absence of the proton–neutron mutation allowed by the generalised Pauli principle, and so accommodates the geometric constraint of the serial treble interaction for the hydrogen molecule.

7. Summary

When both the consequences of the theory of special relativity and the *unreal* aspects of the Dirac equation for the electron and are taken together the description of the behaviour of the elementary particles of the atom is congeneric with Whitehead’s doctrine of organic realism. Above all, the present theory provides a physical basis for discrete Pauli exclusion based upon an antisymmetry derivative of the oscillation of the Dirac electron.

It is concluded that a discrete interpretation of the coupled oscillation and negative energy states, which allows the energy of the electron to decay to zero, extends naturally to a description of the electromagnetic interaction for the helium atom in which like-charge repulsion, electron pairing and Pauli exclusion are physical consequences of the theory. None is put in by hand. It is an organic theory in which the well-known component particles of the atom serially become then changelessly perish. Each electron is thereby simply perpetual becoming in the absence of being.

The theory is parsimonious, it only requires particles and their well-known properties of mass and charge. There are no physically real fields and no problems of infinite energies. The rules of special relativity prevent electron self-interaction via virtual photons. The oscillation is simply an energetic fermionic becoming followed by an instantaneous termination into a zero-energy bosonic phase of pure potential which then gives rise to the next becoming phase of the oscillation.

From the perspective of special relativity the most important element of the theory is the discrete concept of mass. Mass is a manifestation of a component of the energy of becoming. Real photons are actualisations of single potentials and are massless. The mass of a fermion arises from the coupled becoming of twin potentials. The absolute difference between the massless photon and the masses of the electron and proton enables the creation of real and virtual photons. The decoupling of the double potential of a charged particle and photon is a mass effect. The analysis of mass in the discrete scheme is consistent with special relativity.

The behaviour of the electron is fully congruent with quantum theory. The discrete organic theory generalizes the quantum jump from the well-known transitions between different values of a system variable to transitions between unchanged values of a variable. The question of the system ‘knowing’ when to jump is thus redundant because it jumps at every oscillation regardless of the values of variables or whether the variables have values at all.

The non-classical character of angular momentum is also generalized to the linear case. Although the present development of the discrete theory does not touch on angular dynamics, the well-known separation of quantum angular momentum from classical motion about an axis or point is extended to the separation of linear momentum from the classical concept of rectilinear motion through fixed space. The tunnelling photons and electrons do not move through space between successive actual events.

The spacetime framework of the present theory arises from the action of the components of the atom, including photons. At the completion of the action of becoming the geometry is determinable from emitted photons of the potential phases of the interacting components. Flat spacetime relations only obtain among particles at the termination of their becoming when their energy has decayed to zero. During energetic becoming, flat zero-energy spacetime, which relates the termini of becoming of antecedent events, is in the electron’s background. The becoming electron has no external geometric relations to anything while its internal geometric relations are actualising. It is a fully background-independent process in which the differentiation of the morphology of the elementary particle is unrelated to where it turns out to be. Its morphological differentiation does not occur at a locus, but rather creates the locus of its own termination which is then spatially and temporally related to the background.

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