

On the quantum kinematics of the electron and chemical periodicity

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Abstract: The application of quantum mechanics to chemistry has not led naturally to an explanation of the well known periodicity of reactivity among the natural elements. Here an analysis of the oscillation of the Dirac electron, in a discrete framework, coupled with the Aristotelian distinction between potential and actual leads to a description of electron kinematics that is quantum mechanical and dependent upon the rules of special relativity with respect to mass, the speed of light and the mass–energy transformation relation; Lorentz symmetry is also preserved. Upon extension of the analysis to the component particles of the atom, it is found that the single-atom electron collectivities of the noble gases are uniquely complete and chemically inert; they lack the potential to donate, share or engage the electrons of other atoms. Electron collectivities mirror orbital configurations for the noble gases helium to krypton.

Keywords: *oscillation of the Dirac electron, actualization of potential, chemical periodicity, quantum mechanics and special relativity, noble gases*

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Introduction

The application of quantum mechanics to the study of the atom, has not led naturally to an explanation of the well-known periodicity of chemical reactivity among the natural elements. Numerous non-classical, often counterintuitive features of the behaviour of electrons and nucleons have been revealed by quantum physics and confirmed experimentally, but the underlying principles of chemical reactivity remain obscure. At the centre of quantum chemistry is the Hamiltonian and its associated wave function. Quantum chemistry and spectroscopy have revealed much about the chemical energies of atomic charged-particle states. The mutually supportive relationship of those two chemistry tools have helped to engender confidence in the quantitative approach to quantum chemistry, but Mendeleev's periodic law still lacks a natural explanation.

At a deeper level, the description of individual quantum events remains outside the scope of the quantum formalism (Home 1997). The question of the completeness of quantum theory and just what it is a theory of (t'Hooft 2006) are not settled. And it may be the case that the quantum analogues of the mathematical categories of classical physics are yet to be found (Butterfield et al. 2001). The limitations of quantum chemistry have aided the retention of classical concepts in both chemical practice and the search for underlying principles. This situation suggests that neither classical dynamics nor the Schrödinger formulation of quantum mechanics are able to illuminate the kinematics of quantum systems. The theory developed here focuses on the quantum kinematics of the ideal electron and is extended to the other components of the atom.

The present approach is minimalist and makes no assumptions in relation to the usual classical concepts used in chemistry. For example, electron shells, continuous trajectories, charge screening and particle individuation are not included. The Schrödinger formulation of dynamics and the wave function are also omitted. Our starting point is the introduction of two postulates: (i) the Aristotelian principle of the actualization of immaterial potential is relevant to the kinematics of the charged particles of the atom and (ii) the oscillation of the Dirac electron extends naturally to the nucleon and photon. These two postulates are sufficient for the development of a simple and consistent theory of the kinematics of the electron, whose central elements include the counterintuitive physical consequences of the Dirac equation for the electron.¹ The theory leads naturally to an explanation of the unique inertness of the noble gases.

We describe a model of discrete, direct, inter-particle action among electrons, nucleons and photons. In it, individual elementary particles oscillate between actual and potential states, out of which arises the electromagnetic interaction among the charged-particle components of the atom. The oscillation is quantum mechanical and terminates with the emergence of the classical particle. All of which complies with the rules of special relativity that relate to the speed of light, mass and the mass–energy transformation relation, which provide the special relativistic constraint on the theory.

The charged-particle ensemble of a single atom of some elements are found to form complete global electromagnetic interactions in which each electron is equally and fully engaged. Those interactions leave no tendency to donate electrons to, or engage additional electrons from other atoms—they are chemically inert.

Charged particles and the photon are analysed as elementary particles acting directly, without

¹These include electron energies of a magnitude less than zero, the motion of the electron at the speed of light and the necessity for the inclusion of time in the description of the electron. It was the inability to reconcile negative energy with physical reality, in particular, that prompted Dirac to extend the mathematics of the equation for the electron by a symmetry transformation that changed negative energies into positive energies with opposite electric charge.

a need of physically real fields or waves. The theory is fully discrete; for the individual quantum particle there is no continuity of space, time, particle motion or observable particle properties.

The electron oscillation

The oscillation of the isolated electron

The oscillation of the Dirac electron is here combined with the principle of the actualization of potential. Dirac adumbrated the oscillation 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.” (Dirac 1965). Subsequently, the oscillation was found to be characterised by a frequency of $\sim 2.5 \times 10^{20}$ cycles per second and Schrödinger showed the amplitude to be $\sim 1.9 \times 10^{-13}$ meters. The electron is postulated to consist of a series of oscillations, each of which divides into two phases: a potential phase and an actual phase. At the centre of the theory is the concept of the actualization of potential, of the type advanced by Aristotle, in which actual and potential states are the physical opposites of each other (Aristotle). Interestingly, the Aristotelian concept of potential was suggested by Heisenberg as an aid to understanding quantum mechanics (Heisenberg 1958).

The oscillation transforms the electron of continuous physics into a series of actual, stationary events, which are the classical aspects and associated phenomena of the system, alternating with non-local phases of pure immaterial potential. This postulate, when applied equally to the electron, nucleon and photon, has profound consequences for the conceptual framework in which the elementary particles of the atom are understood. Importantly, a number of the features of quantum mechanics naturally and harmoniously assume their appropriate role in the theory and with special relativity. In addition, the closure of chemical periods is seen to acquire a simple and consistent explanation.

The potential phase

The potential phase of the oscillation is a state of immaterial potential at zero energy; the electron is then in a vacuum state. The vacuum state of the electron is not a part of a society of elementary particles withdrawn from the phenomenal space of common experience. The vacuum state of an electron is private and belongs to just the one electron; it has no phenomenal content. Consequently, the electron is then devoid of all physical properties, i.e. electric charge, mass, angular and linear momentum and geometrical relations. The absence of geometrical relations means the electron does not occupy a locus relative to anything; it is not separated from anything by distance or duration. The potential phase of the oscillation does not occur at a locus in time or space.

The potential of the electron is motivated by a single imperative—self-actualization. This follows from the fact of the persistence of material reality.² The entire potential of an oscillating electron need not be actualised at any one of its constituents events; there always remains scope to have been otherwise, within the broader constraint of its potential, which includes its initial conditions. An allowed energy of the electron of a magnitude less than zero, consistent with the Dirac equation, is here interpreted to be the potential to achieve positive energy of that magnitude during a subsequent oscillation (Fimmel 2011).

The actual phase

The actual phase of the oscillation follows immediately upon the potential phase. It consists of the

² The persistence of material reality depends upon the continual actualization of potential, which avoids the awkward consequence for the actual world of its collapse into a permanent state of immaterial potential.

actualization of the potential of the electron; it is energetic and it takes time. Actualization begins without any physical features. The process culminates as an instantaneous, actual physical event in the life of the electron, which may possess any or all of the usual electron properties. The electron is then geometrically related to every other actual event in the universe, including the antecedent events of which it is composed. The electron, in effect, quantum mechanically tunnels between contiguous actual events of which it is composed. Tunnelling begins at the potential phase and ends at the termination of the actual phase.

All the energy of the electron performs the work of its own actualization, which terminates as the classical electron. Actualization is a non-local process of the creation of an event which arrives at a locus, having come from a non-geometrical vacuum. Its termination is a stationary, actual event which is local and classical. The classical aspect of the ideal electron consists of a series of such motionless events, each of which is separated by some distance, direction and duration from its immediate antecedent event, which, importantly, is the source of the potential it actualises.

The geometric separation of the actual event from its antecedent events, is complete at the termination of its actualization. Upon termination of the actual phase of the oscillation, the energy of the electron decays instantaneously to zero, thus precipitating the electron into the non-local phase of immaterial potential, from which it again begins to actualise. From the standpoint of the actual event there is nothing beyond its own energetic actualization; there is no continuous, uninterrupted being, or physical existence for an elementary quantum particle.

Among the properties of the electron are electric charge and mass. They, like all the properties of the oscillating electron, are the products of the energy of actualization, following which they decay to zero and then energetically re-actualise.³ Electric charge is defined to be the property of some elementary particles that enables them to exert forces on one another. Those forces are effected by the creation and annihilation of photons.

The photon

The photon is the charged-particle boson; it mediates energy transfer, electromagnetic forces, and bonds among electrically charged particles, including chemical bonds among electrons and protons. Photons may be described as real or virtual; they are created by one charged particle and annihilated by another.⁴ Like the electron, the real photon oscillates between potential and actual phases, during journeys of indefinite distance across a room or across a galaxy. The finite speed of light derives from the duration of the serial actualizations of the oscillating photon; the potential phases, which are non-local, between its motionless actualising events makes no contribution to the duration of the journey.

By contrast with the real photon, the virtual photon only exists for a single oscillation, as it tunnels between its creation by one charged particle and its annihilation by another. Consequently, it is never real; it remains virtual and never actualises as a photon. It tunnels instantaneously between the potential phase of the charged particle that created it and the actual phase of the charged particle that annihilated it (Hartman 1962; Steinberg et al. 1993; Laude et al.). It is devoid of a classical aspect and associated phenomena.⁵

³ The forms of energy of the actual electron includes its mass. During actualization, the energy of the electron performs all the work associated with the actual event. Among the consequences of actualization is the mass of the electron. At completion of actualization, the mass and massless energy of the electron decay instantaneously to zero. The special relativistic mass–energy transformation relation forms an essential element of the oscillation.

⁴ According to special relativity mass limits the rate at which a particle moves (changes its position). The mass difference between a photon and an electron is absolute. Consequently, the difference between their speeds is absolute; thus, their durations of actualization differ absolutely. An electron cannot, therefore, overtake a photon it has created. The relative–absolute distinction is an effect of the concept of mass, as understood according to the theory of special relativity.

⁵ The virtual photon presents a problem because its creation and annihilation occur simultaneously and that seemingly offends against special relativity. Special relativity depends upon the constancy of the speed of light in a vacuum, which is approximately 3×10^8 m/s. Information transfer and the principle of causality require a non-infinite speed of light. When the virtual photon is created, the electron that created it has just completed the actualization phase of an oscillation, when it is momentarily real and classical. Simultaneously, the electron that annihilates the photon is in its actualization phase, having just developed its quantum property of electric charge. The photon, its effects and any information that it brings with it do not materialise until the actualization that it joined is complete, when the second electron is then momentarily real and classical. The photon *travels*

When the space and time separations (phase relations) of an oscillating electron and an oscillating photon are propitious the two separate potentials will co-actualise as a single energised electron event (Fig. 1a). The co-actualization is mediated by the actualization of the electron property of electric charge. Upon completion of the co-actualization the energy and other properties, including mass and charge of the electron decay to zero, leaving two immaterial potentials; one of an electron in its ground state and one of a photon which, simultaneously but separately, begin to actualise. Actualization of the photon potential is complete before that of the electron and its electric charge; then the phase relations of the photon and electron do not enable their co-actualization, because they commenced to actualise simultaneously. The duration of the actualization of the photon is shorter than that of the charge of the electron.

The electron interaction

The electron pair

Photon annihilation and creation occur serially during a single oscillation of the electron (Fig. 1a). When the phases and space separation of two oscillating electrons are suitably related, a photon created by one electron in its potential phase is annihilated by the other electron in its actual phase. Figure 1b shows the instantaneous transfer of a virtual photon from a potential phase of one electron to the actual phase of another. The co-actualization of the potential of a virtual photon with the potential of an electron binds the resultant energised electron event to the two sources of the potential it actualises. It is thus bound to itself by the acquisition of its own electron potential, from its immediate antecedent event, and to the electron that created the virtual photon by the acquisition of the photon potential; which is the theory of the bond for the electron pair. One principle (bond formation with the source of the potential it actualises) underlies both the endurance of the discrete electron and its charge-mediated bond formation with other charged particles.

The recipient of the virtual photon occupies a locus in time and space which is related to the space-time loci of its own antecedent event and that of the virtual photon. The magnitude of the space and time separation of the bound pair of charged particles is related to the mass of the recipient of the virtual photon.⁶ It can be seen in Fig. 1 that the space and time separations of the electron events are essentially uniform. Where and when the event is realised derives from the influence exerted by those two antecedent events.

It can also be seen in Fig. 1 that two electrons do not couple to form a pair in isolation from other charged particles. Because the photon transfer between two electrons only occurs in one direction, the pair when considered as a unit annihilates and creates photons from beyond itself. Fig. 1 depicts interacting electron pairs whose extension among large numbers of electrons is indefinite; they are serially bound in the formation of an electron plasma. The theory explains the indefinite extent of the linear interaction as the many-electron interaction of lightning and spark discharges.

between real classical electrons whose oscillations are out of phase. The *travelled path* consists of two components. The first is the instantaneous tunneling from the position of its creation to the position of its annihilation, the second is the time taken for the annihilating charged particle to actualise. Only upon completion of actualization is the particle phenomenal. The component of the duration of actualization from the development of electric charge to the termination of particle actualization is the exact equivalent of the delay time, sometimes referred to as the dwell time, found in experimental quantum tunneling. The Hartman effect is the independence of the thickness of the barrier on the delay-time in quantum tunneling (Hartman 1966). In the present theory, the duration of the delay time is the duration from development of electric charge to complete actualization of the particle that annihilates the photon. The same rule applies to the electron; it changes its position instantaneously but does not move classically faster than light in a vacuum. The mass of the electron causes its duration from charge development to complete actualization to be absolutely longer than the duration of actualisation for a photon—they both move (changes their position) at the speed of light, according to the Dirac equation.

⁶ In the present theory, the space-time separation between two interacting charged particles is dependent upon the mass of the photon-annihilating particle. The electron of the hydrogen atom does not spiral into the proton nucleus because of the mass of either the proton or the electron. Similarly, two members of an electron pair do not merge because of the mass-dependent space-time interval that separates them. The electromagnetic bonds of the discrete theory are not simply attractive (i.e. classical), bound particles are where and when they are because of the potential they actualise. The loci that bound particles occupy is dependent upon special relativity and quantum mechanics, combined.

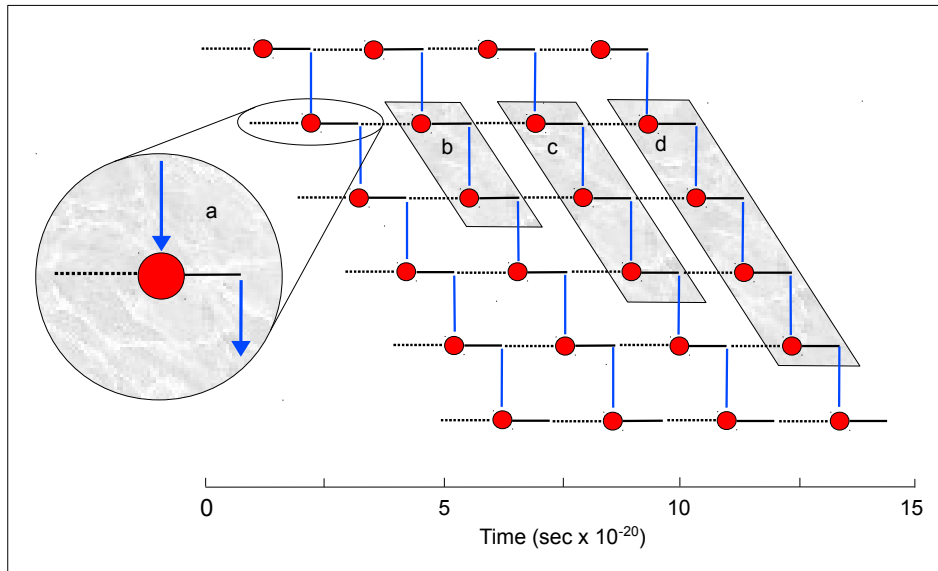


Fig. 1 The virtual photon-mediated electron interaction. Each of the six electrons consists of four serial oscillations shown horizontally. A single oscillation of the second electron is shown enlarged and circled (a) in which electric charge is represented by a large red dot close to the centre of the dotted then continuous actual phase and the blue arrows represent photons; the inward-directed arrow illustrates photon annihilation, the outward-directed arrow shows photon creation. Each electron interacts with the electron above it by annihilating a virtual photon from it, and with the electron below by creating a photon which it annihilates. Two electrons form a serial electron pair shown at (b); two interacting electron pairs are shown at (c); and two interacting electron triples are shown at (d). The three interactions shown at (b), (c) and (d) each annihilate a photon from an outside source (above) and create a photon that goes to an outside sink (below).

The anti-symmetrical two-particle ensemble

Originally, the Pauli exclusion principle was held to allow only the anti-symmetrical two-particle ensemble. Pauli expressed his disappointment at the lack of a deeper fundamental principle that explained the quantum mechanical restriction to the two-particle case (Pauli 1946). The present scheme only allows the anti-symmetrical two-particle ensemble—only two electrons can form a photon-mediated electron ensemble and they cannot occupy the same quantum state at the same time. Energy antisymmetry does for the discrete electron pair what spin (angular momentum) antisymmetry does for the continuous quantum mechanical model of electron pairing. Two-valued quantum angular momentum and two-valued total energy enable the two-particle ensemble to comply with the exclusion principle.

In the present model, Pauli compliance arises naturally. The two-particle state is formed by the shared photon, the process of which can only be anti-symmetrical—simultaneously one member

of the ensemble, in the potential state, creates the virtual photon and the other instantaneously annihilates the photon while in the actual state. The same principle that applies to bonds between pairs of electrons also applies to pairs of trebles of electrons (see below). Bonds only form between couples when one is in the potential state and the other is in the actual state.

The treble interaction

Because two electrons do not interact to form a bound pair in isolation from other charged particles, the pair has to annihilate a photon from an outside source and emit a photon to an outside sink. An electron treble is formed by the interaction of an electron pair with a third electron. The three electrons as a group are analysed as a serial pair of electron pairs (fig. 1c). At an instant, one pair is actual and the other is potential. The actual pair decays to zero as one of its members forms an actual pair with the third electron. This analysis of three electrons constituting two serial electron pairs is consonant with the Aristotelian principle: everything is potential and actual but not at the same time. The treble interaction, as distinct from the electron treble⁷ arises from the need for the electron pair to annihilate and emit photons from and to its environment (source and sink).

Provided such photons are virtual, the electron pair interacts with the two charged particles that constitute the photon source and sink, which thus forms an interaction between four charged particles.⁸ We have now reached the fundamental unit of the electromagnetic interaction situated where the logic of discrete photon creation and annihilation demands that it be: lodged in time between a photon source and sink, with which it is obliged to interact. If we assume the charged-particle source and sink are also electrons, then the interacting four electrons are analysed as a pair of serial electron trebles; importantly, they are serial in both space and time (Fig. 1d). The principle of the serial potential and actual phases of the one-electron oscillation, which extends naturally to the two-electron anti-symmetrical ensemble, extends further, and naturally, to the four-electron system. The four electrons, 'connected' serially by the one-way transfer of virtual photons is a Pauli-compliant 'two-object' anti-symmetrical ensemble, composed of an actual and potential treble which is the treble interaction. The time evolution of the interaction shows two serial trebles of which one electron pair is serially common to both. The common electron pair acts as a boson which binds the two electron trebles to form the treble-electron interaction.⁹

The bosonic electron pair is an analogue of the virtual photon which binds the members of an electron pair. The components of the treble and the pair are serially actual and bound by the one-way transfer of a boson. Pauli exclusion and the necessity for the fundamental electron pair, here considered as a unit, to annihilate a photon from a source beyond itself and emit a photon to a sink beyond itself leads naturally to the origin of the pair of interacting trebles. The treble kinematics is analogous with that of two interacting electron pairs bound by the one-way transfer of one electron, globally formed by three electrons (Fig. 1c). Importantly, like the electron pair, one of the two trebles is actual while the other is potential. The actual treble consists of three of the four electrons, the potential treble is then immaterial, it will subsequently actualise and then consist of the fourth electron plus the bosonic electron-pair. The potential treble includes just one actual electron.

⁷ An electron treble is simply three electrons. An electron-treble *interaction* consists of an actual treble of three electrons plus a potential treble of three electrons. A potential treble of three electrons consists of just a single *actual* electron which becomes a treble when it interacts with an electron pair that thereby transfers from the first actual treble to form a second treble. An electron treble interaction forms among four electrons. The same distinction between a treble and a treble interaction applies also to three electron pairs and three electron trebles.

⁸ Only virtual photons form bonds between two charged-particle events and they do so via the principle of the formation of a bond with the source of the potential actualised. Electrons also annihilate real photons, whose origin is a charged particle that might be on the far side of the galaxy or on the sun. Such pairs of electrons are not bound to one another because the actual event in the life of the distant charged particle that created the real photon is not the source of the potential actualised by the annihilating electron. For the annihilating electron the origin of the real photon potential is the last event in the life of the real photon, prior to its annihilation. Both immediate antecedent events are the sources of the potentials co-actualised.

⁹ Like the virtual photon, larger bosons are serial constituents of the pairs of objects they bind. The virtual photon is serially part of the energy of the electrons it binds, and the electron pair is serially part of the two elements of the treble electron interaction that it binds.

The basic atomic treble

The substitution of a proton for one member of an electron treble, binds a pair of electrons to the proton, which is the basic atomic treble (BAT), shown in Fig. 2B, c. The proton annihilates a virtual photon from one member of the electron pair then the second electron annihilates a virtual photon from the proton Fig. 2b. Like the electron treble, the atomic treble interacts via photons with charged particles of its environment (source and sink), but with a crucial difference.

As a consequence of the generalised Pauli principle for a bound atomic nucleus, nucleons are in a superposition of two states—the proton state and the neutron state. The nucleon oscillation occurs between potential and actual states such that serial actualizations terminate alternately in the proton and neutron states, subject to the maintenance of global charge conservation. Consequently, serial actualizations of the potential of a nucleon alternate between the two charge states of positive (proton) and zero (neutron).¹⁰ The charge-state alternation of the nucleon truncates the participation of the proton in the BAT interaction and so forfeits the linearity which characterises the many-electron interaction.

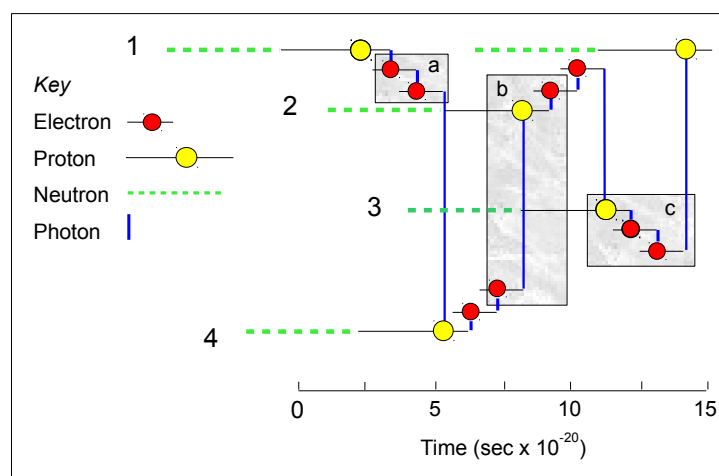


Fig. 2 The components of the basic atomic treble interaction (also the helium-4 interaction). The diagram shows four nucleons, two electrons (shown four times) and twelve photons.. The electron pair shown at (a) reacts by the annihilation of a virtual photon from proton (1), which is the outside photon source for the electron pair, and reacts with proton (4) by creating a photon that it annihilates, which is the outside photon sink for the electron pair. Two atomic trebles are shown at (b) and (c). The treble at (b) shows the mass-dependent extended space separation between the electron and proton events prior to the proton event, which contrasts with the short space separation following the proton event. In contrast to the geometry of the treble at (b), the treble at (c) shows two short space separations.

The principle of the atomic electromagnetic interaction

The quantum state of the nucleon is of central importance for the theory of the atomic treble interaction. Because of the oscillation between charge states, during the actualization of a proton

¹⁰Generalised Pauli exclusion and charge conservation are satisfied by a switch to the proton state from the neutron state by one nucleon that is matched by a switch in the opposite direction by another nucleon. Neutron-rich and neutron-proton even nuclei accommodate the switch to the neutron state by each nucleon at the termination of each proton actualization. Proton-rich nuclei behave differently. Only two stable proton-rich nuclei are found in nature—light hydrogen and helium-3. Because the generalised Pauli principle only applies to bound nuclei, light hydrogen is exempt. In the case of helium-3, the nucleus consists of two protons and one neutron. Consequently, each of the three nucleons in turn will actualise in the proton state twice in succession, (Fimmel 2009) which has consequences for the global electron interaction of He-3. The electron pair will annihilate a photon from a proton and then create a photon which the same proton will annihilate. Because the proton mass is some 1,836 times the electron mass the duration of actualization of the proton well exceeds that of the two members of the electron pair. Consequently, the global electron interaction of He-3 will be stretched in time and space by the absence of the truncation of the BAT interaction. The volume of the two-electron cloud of He-3 will exceed that of He-4. It is relevant that density measurements have shown that the volume of the He-3 atom exceeds that of He-4 by 28% (Ifft et al. 1967). The volume of the H-1 atom also exceeds that of He-4 by ~27%. Both He-3 and H-1 have the same electron-kinematic limitation.

event the development of electric charge enables the annihilation of a virtual photon created by one of the two electrons; the ensuing potential phase of the proton creates a photon. That nucleon then ceases its participation in the BAT because it next actualises as a neutron with zero electric charge. For an electron pair to continue membership of a BAT and to maintain global charge-neutrality a second nucleon needs to actualise as a proton.

While the electron pair forms a treble with the first proton, a following treble, yet to be formed, by the electron pair and a second nucleon occupies a state of pure immaterial potential. As with the pure electron interaction, two interacting trebles serially share an electron pair. The one-way transfer of the electron pair from an actual BAT to a potential BAT is the atomic treble interaction¹¹. The continuation of the non-linear interaction depends upon the availability of a second nucleon, which by itself is a potential atomic treble, being deficient of an electron pair.

The two imperatives: (a) the need of the electron pair for a photon source and sink and (b) the actual–potential oscillation as it extends to interacting trebles, are only realised by the charged-particle ensemble of a single atom by a minority of the naturally occurring elements. Those elements whose exact single-atom charged-particle ensembles do satisfy the imperatives have no tendency to engage the electrons of other atoms in the electromagnetic interaction, by donating, sharing or accepting electrons—they are inert; they have no autochthonous chemical reactivity—they are the noble gases. However, their inertness does not preclude their being bound by other highly reactive species.

The electron kinematics of the noble gases

The helium-4 interaction

The helium-4 interaction is the BAT interaction. The electron pair serially bonds with individual nucleons, one at a time, when they are in the proton state (Fig. 2). The two electrons bond to form the electron pair with the same frequency that an electron–proton bond is formed. The mass difference between the electron and proton is the cause of the two different space separations between the electron pair and the proton to which it is bound (Fig. 2).

For clarity, Table 1 and those that follow omit protons from the tabulated treble interactions; thus, an electron pair (| 2 |) denotes a BAT and the potential BAT of Table 1 is therefore empty. Actual and potential trebles are bracketed by ||.

Table 1. The interacting trebles of the helium interaction

Atom	Electron collectivity	Boson	Orbital configuration
He	2	2	1s ²

The carbon treble

Moving up the mass scale of the natural elements from helium, the charged-particle ensemble of the carbon atom is the next element to form an actual treble. One electron pair forms a single treble, with a proton; three electron pairs form a treble of BATs, with three protons. The carbon treble marks the first mass transition of the atomic treble; the electron unit of the treble has evolved from the single electron to the electron pair. The trebling imperative and the principle of the bond formed between potential and actual trebles is unchanged. Accordingly, a single carbon atom does not form a treble *interaction* on its own. The actual carbon treble needs a potential carbon treble in order to

¹¹ The atomic treble interaction maintains charge neutrality, naturally. The electron pair and its source and sink, comprised of two protons, are bound by the one-way transfer of virtual photons. Because the atomic electromagnetic interaction does not transfer photons between protons, the Coulomb component of the nucleon potential, which is known to be small, is supplied by the serial bonds formed by electron pairs between nucleons in the proton state. The boson for the Coulomb component of the nucleon interaction is the electron pair.

form a treble interaction. Its three electron pairs, subject to the interaction imperative, therefore tend to interact with two electron pairs from an outside source—as it does in the formation, for example, of the methane gas molecule.

Table 2. The carbon treble

Atom	Electron collectivity	Boson	Orbital configuration
C	2,2,2	2	1s ² , 2s ² , 2p ²

The carbon treble, like the electron treble, has to acquire bosons from external sources and transfer them to external sinks. The boson for the carbon treble is the same as the boson for the BAT interaction—the electron pair. The carbon treble is an analogue of the pure electron treble because each is a treble of equal-mass components. By contrast, the BAT, being two electrons plus a proton, is a treble of one high-mass component and two equal low-mass components. As shown in Table 2, the discrete electron collectivity and the orbital configuration for carbon are the same. The charged-particle ensemble for the carbon atom is crucial for the atomic electromagnetic interaction among the natural elements, generally.

The neon interaction

The first single-atom treble interaction beyond the helium atom consists of one actual carbon treble and one potential carbon treble. Like the potential BAT, the potential carbon treble lacks an electron pair. Table 3 shows the discrete collectivity of a single neon atom to consist of an actual carbon treble, abbreviated to six electrons, and two BATs which constitute a potential carbon treble. Analogous with the pure electron treble interaction, one electron pair of the carbon treble forms a treble with the two electron pairs of the potential carbon treble. Thereby the electron pair is the boson that binds the two trebles by its one-way transfer between them.

Table 3. The interacting trebles of the neon interaction

Atom	Electron collectivity	Boson	Orbital configuration
Ne	2,2,2 2,2	2	1s ² , 2s ² , 2p ⁶

The neon global interaction also forms an actual treble, closely analogous to the BAT in terms of the mass distribution among its components. Both consist of one high-mass component and two equal low-mass components. Neon differs from the BAT in being a treble of trebles. Like single trebles generally, it is not the basis of the single-atom interaction; that arises from its decomposition into the actual and potential carbon trebles. The neon interaction is also a mass analogue of the helium interaction. In addition, the electron collectivity mirrors the orbital configuration, as shown in Table 3.

The argon interaction

Like the evolution of the carbon treble into the neon interaction, the addition of a potential neon treble, which, like the potential helium and carbon trebles, is deficient of an electron pair, to an actual neon treble forms a complete global interaction for a single atom, which is the argon interaction. None of the elements whose complement of charged-particles lie between those of neon and argon forms a complete single-atom interaction. Like the carbon atom, argon forms a single equal-mass treble of trebles. But unlike carbon it satisfies the imperative of the interaction by its

decomposition into an actual and a potential neon treble, as shown in Table 4, where it can also be seen that the electron collectivity of the global interaction closely resembles the orbital configuration.

Table 4. The interacting trebles of the argon interaction

Atom	Discrete collectivity	Boson	Orbital configuration
Ar	6,2,2 6,2	2	1s ² , 2s ² , 2p ⁶ , 3s ² , 3p ⁶

The argon interaction represents the evolution of the form of the atomic interaction, back to its origin, which is the pure electron interaction. Each BAT is analogous with an electron in the interaction of an electron plasma. The constraint on the argon interaction is that, unlike the pure electron interaction, it has to remain cyclic. Whereas the kinematics of the pure electron interaction conforms to the principle of the bond without the cyclical constraint, the interaction among actual and potential carbon trebles of the argon interaction is so constrained by one member of each BAT being a bound component of the atomic nucleus. The similarity of the orbital configuration and discrete collectivity can be seen in Table 4.

The krypton interaction

The addition of one or two carbon trebles to the argon interaction fails to enable the interaction imperative among the charged-particle ensemble of a single atom. The addition of three carbon trebles results in a double argon interaction. It can be seen from Table 5 that the mass equality of the two actual neon trebles and the two potential neon trebles enables two serial argon interactions, arranged cyclically. The seriality gives them the form of a two-particle (two-component) ensemble. Thus, the krypton interaction (a pair of argon interactions) complies with the Pauli exclusion principle, since each member of the pair individually meets the requirements of the exclusion principle; they are able to interact as a single quantum system.

Table 5. The interacting trebles of the krypton interaction

Atom	Discrete collectivity	Boson	Orbital configuration
Kr	6,2,2 6,2 6,2,2 6,2	2,2	1s ² , 2s ² , 2p ⁶ , 3s ² , 3p ⁶ , 3d ^{2, 2, 6} , 4s ² , 4p ⁶

The electron burden of the double interaction is halved by having two electron-pair bosons to form the global bond. The two bosons are independent of one another. Table 5 shows the similarity of the orbital configuration and discrete collectivity, with the 3d orbital decomposed. The form of the krypton interaction is reminiscent of the benzene molecule.

The xenon interaction

The coupling of the ensembles of charged particles of argon and krypton forms the next equal-mass treble that decomposes so as to satisfy the interaction imperative and the cyclical constraint. The xenon treble marks the second mass transition of the interaction among the natural elements. It can be seen from Table 6 that the xenon interaction is a high-mass analogue of the argon interaction, in the form of an actual and potential zinc treble. The binding unit (boson) of the xenon interaction is

the carbon treble, which represents an evolution from the electron pair for helium, neon and argon, in the low-mass sector, to their analogue of the high-mass sector, via the double electron-pair bosons of the krypton interaction.

Table 6. The interacting trebles of the xenon interaction

Atom	Discrete collectivity	Boson	Orbital configuration
Xe	6, 6, 6 6, 6 6, 6, 6 6	6	[Kr] 4d ² , 2, 6, 5s ² , 5p ⁶

The boson for the xenon treble interaction (the carbon treble) undergoes a one-way transfer between actual and potential trebles of the neon and argon form (the zinc treble). The argon treble is the high-mass analogue of the carbon treble. The electron collectivity, shown in Table 6, embraces the underlying BATs and carbon trebles as depicted in Tables 1 to 5. The orbital configuration and discrete collectivity begin to diverge with the onset of the high mass sector.

The radon interaction

The charged particle ensembles of krypton and xenon are respectively double and triple that of argon. The next multiples of the argon ensemble are hafnium and thorium. However, they do not form single-atom interactions and neither do they comply with the Pauli exclusion principle¹². The addition of a silicon treble to the hafnium ensemble gives the next single-atom ensemble to satisfy the interaction imperative, in the high-mass sector—the radon interaction. The radon ensemble shows a unique mass evolution among its interacting components. Its two trebles, one actual and one potential, are composed of two high-mass trebles and one low-mass treble, giving the interaction itself a more massive form than the lower-mass noble gases. The silicon treble takes the same form—one low-mass component and two equal high-mass components.

Among the lower-mass noble gases, the trebles are composed of either three equal-mass trebles or one high-mass and two equal low-mass trebles. The radon interaction occurs between an actual treble and a potential treble that differ by a carbon treble, which is the boson of the interactions of the high-mass sector and as such is the high-mass analogue of the low-mass boson. Table 7 shows the interaction for the radon atom. Unlike the orbital configuration, here the radon ensemble decomposes into an actual and potential palladium treble.

Table 7. The interacting trebles of the radon interaction

Atom	Discrete collectivity	Boson	Orbital configuration
Rn	6,2,2 6,6,6 6,6,6 6,2,2 6,6,6 6,6	6	[Xe] 4f ¹⁴ , 5d ¹⁰ , 6s ² , 6p ⁶

Conclusions

The theory is pre-atomic—its postulates do not derive from the atomic sector and it makes no use of chemical phenomena. By the argument here advanced, we arrive by the evolution of the kinematics of the electron pair, according to a single principle, at the periodicity of chemical inertness among

¹² The Pauli exclusion principle applies to compound systems in which the principle also holds for its constituents. The constituents of the hafnium ensemble that comply with the exclusion principle are each of the four argon trebles, which, being four, do not constitute a two-component ensemble.

the natural elements. There are no physically real waves, shells, orbitals or fields, and electric charge remains a quantum property of some fermions. The scheme is of discrete, direct, inter-particle action.

The physical analysis employed here permits greater freedom than that allowed by the formalism of mathematics. However, it does not provide an escape from the precepts of logic and internal consistency. The analysis is not isolated entirely from mathematics—it simply avoids its formalism while building on some of its consequences. The Dirac equation for the electron remains one of the high points in the development of quantum mechanics. And the equation marks the beginning of the present analysis; the physical consequences of the equation—the oscillation—are the initial conditions for the theory.

Dirac was initially dissatisfied with some of the physical consequences of his equation, notably energies of magnitude less than zero, and so he extended the mathematics and introduced a symmetry transformation which removed negative electron energies and replaced them with positive electric charge. That manoeuvre had the effect of rendering the electron physically less problematic from the classical standpoint, but somewhat diminished as a quantum object.

The quantum electron changes its position at the speed of light, its description places equal reliance upon time and space and its positive and negative energy states emphasise the distinction between the concepts of actual and potential. Lorentz symmetry is preserved by the theory; the energy of the classical aspect of the electron, and all other elementary particles, is zero; consequently its space-time relations are flat, and despite instantaneous tunnelling its kinematics is not superluminal. The Heisenberg time–energy uncertainty relation is a natural part of the oscillation; a precise energy value for the electron can only relate to a duration; the energy of the system at an instant is meaningless. The theory is minimalist—for the individual electron there is no need of pre-existing space or time; the energetic actualization of each event forges anew, from a vacuum state, the distance, direction and duration that separates it from each contemporary and past event of the universe.

In contrast to the theory of quantum numbers and the orbital scheme of atomic electrons, the discrete model does not distinguish between or apportion rôles to individual electrons. Consequently, electrons do not belong at loci and neither do they interact differentially. There are neither valency electrons nor inner-shell inert electrons; the chemical propensity of an atom is a consequence of its entire electron ensemble. Electron collectivity is largely congruent with the electron configurations represented by quantum orbitals in the low-mass sector.

The theory is the extension of a single principle to the behaviour of all the components of the atom together with their properties, thereby simplifying and clarifying the description. The principle, advanced by Aristotle, that everything is both potential and actual, but not at the same time, is all that is needed to render the counterintuitive consequences of the Dirac equation for the electron both quantum mechanical and reliant upon special relativity. The results of the theory—the apparent evolution of the discrete electron into the well-known periodicity of chemical reactivity—may be regarded as providing support for the theory of the kinematics of the electron.

Acknowledgements I am grateful to Vincent Powell for helpful discussions.

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