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Robert J Buenker
Fachbereich C-Mathematik und Naturwissenschaften, Bergische Universität Wuppertal, Gaussstr. 20, D-42097 Wuppertal, Germany

Corresponding Author:
Robert J Buenker
Fachbereich C-Mathematik und Naturwissenschaften, Bergische Universität Wuppertal, Gaussstr. 20, D-42097 Wuppertal, Germany

Rebuttal of Fermi's denial of nuclear electrons: Part I: Historical background

Robert J Buenker

Abstract

The discovery of the neutron by Chadwick in 1932 is discussed in detail. Pauli pointed out that the profile for neutron decay indicates unequivocally that a third particle, in addition to the proton and electron, is involved, which has since been referred to as the anti-neutrino $\overline{\nu}$. Fermi then argued that the electron could not have been present in the neutron prior to decay. He based his conclusion on the assumption that the laws of physics must be in accord with the Lorentz transformation, which Einstein used as the cornerstone of his Special Theory of Relativity (STR). On this basis, it should be impossible for a potential to exist which is capable of binding an electron to a proton in such a small space (500 Mev would be required according to Fermi's calculation based on de Broglie's p=h/λ relation). The present work assesses this claim on the basis of recent theoretical developments which make use of the exponentially damped Breit-Pauli-Schrödinger (XPBS) equation. Calculations of this type have been successful in showing that the binding energy of an electron to a positron might be exactly equal to the energy equivalent of an electron and positron ($2m_{oe}c^2$). The possibility of a non-zero $\overline{\nu}$ charge-to-mass ratio is considered as a way to make the Breit-Pauli interactions relevant to the description of the neutron's internal structure.

Keywords: Neutron composition, neutrino properties, creation-annihilation hypothesis, exponentially-damped breit-pauli-schrödinger (XBPS) equation

1. Introduction

In preceding work [1, 2], a model for describing processes involving the interaction of electromagnetic radiation with matter has been examined whose main ingredient is the assumption of an e^+e^- "molecular" structure of the photon. Accordingly, the hypothesis of disintegrating matter is replaced with the assumption of indestructible particles, including electrons and positrons, which in a specific state of binding can lose all their mass, thereby defying experimental observation but still retaining their own existence.

The latter distinction seems subtle enough when formulated in this manner, but there is a potentially critical difference. Put simply, if particles can be created from pure energy, there is nothing fundamentally excluding the possibility that much larger objects can also be formed by this mechanism. It has been argued, [3] for example, that whole universes could be created from the "energy equivalent to just a few pounds of matter." Later in the same article it is pointed out that the key element in the author's theory 'is that quantum physics permits the spontaneous creation of something from nothing." If on the other hand, matter can never be created or destroyed by any mechanism, but instead only disappears from view under certain well-defined circumstances, the possibilities are much less fantastic. A much more sober view of the universe emerges, and consequently it behooves us to find out which of the above two hypotheses corresponds to the true facts.

It is thus important to see that the creation-annihilation concept does have definite relevance beyond the subject of the interaction of photons with other particles. In the preceding work[1] it was noted. for example, that the formation of protons and antiprotons from photon collisions demonstrates that e^+e^- systems cannot be the only mass-less particle-antiparticle binaries which must be assumed if one hopes to do without the latter hypothesis. Once one has grasped the possibility that the creation-annihilation assumption may not actually be needed to explain relatively low-energy phenomena, there is thus a challenge to follow through on such argumentation in the high-energy regime as well.

One is reminded that considerable impetus was given to the creation-annihilation concept at the time when it first became possible to carry out high-energy experiments in the laboratory. It is therefore to be expected that as the available energy from accelerators and related devices increases, the number of phenomena requiring similar explanations will tend to multiply, as has indeed been the case. New particles with non-zero rest mass have been identified over the past century, and these have provided fertile breeding ground for new theories. In the present chapter the task of surveying such high-energy experiments will be taken up, with particular emphasis on the question of how the assumption of the creation-and-annihilation of matter plays a role in the theories which are used to describe them.

2. The Neutron

After the results of Rutherford's scattering experiments were understood [4], one had the model of atoms containing a relatively massive nucleus of positive charge being orbited by a number of electrons. The simplest atom is hydrogen with a single proton and electron. The heavier nuclei have rest masses which are nearly integer multiples of that of the proton, but charges which are always a smaller (exact) multiple of the electronic charge. On this basis it was first assumed that the nucleus itself generally contains both protons and electrons. The discovery of the neutron in 1932 by Chadwick[5] caused a shift in this position, however. The neutron was found to have a slightly larger mass than the proton and to have no electric charge. It is meta-stable with a half-life of 1000 s, decaying into a proton and electron (or “β-ray” in the earlier terminology). Other unstable nuclei were also known to undergo β decay.

Several objections to the assumption of a proton-electron constitution for the nucleus quickly arose on the basis of these findings, however. The most important was based on the fact that the energy spectrum of the emitted electron is not mono-energetic, as would have to be expected from the laws of conservation of energy and momentum when a single particle decomposes into two fragments. One popular interpretation for this observation was supported by Bohr [6]. He suggested that the usual conservation laws might no longer be valid at high energies (0.8 MeV is released upon the neutron’s decay). Pauli took a different view [7], however, which has since been generally accepted, namely that the continuous spectrum observed indicates that at least one more particle must be involved in β decay. Accordingly, the energy lost in the process can be divided between several emitted particles in a continuous distribution without violating the above conservation laws. The name “neutrino” was subsequently coined by Fermi [8] for this new particle.

Other evidence was also found for the neutrino hypothesis, however. If a neutron were to consist of only a proton and an electron, it should possess integral spin and exhibit boson statistics, so that a nucleus such as [14] N (containing seven protons and seven neutrons) would behave as a fermion with half-integral nuclear spin. Since the opposite behavior is observed, it was suggested by Pauli that the neutrino (if indeed it is a single particle) is also a fermion with half-integral spin, and that its presence in the neutron thus explains this aspect of the nuclear puzzle as well. This argument eventually carried the day and the third neutron decay product was later renamed the anti-neutrino $\bar{\nu}$.

What needs to be emphasized in the present context is that in the search for a quantitative theory of β decay, confidence in the straightforward idea of the neutron being composed of a proton, electron and antineutrino was eventually lost. This development occurred primarily because of the realization that the relatively small radius of the neutron implies that an electron bound within it would have to possess an enormous amount of kinetic energy. A figure of 100-500 MeV could be computed for this quantity based on the de Broglie relation, which connects the magnitude of this radius (wavelength) with the electron’s momentum. Since the known electromagnetic and gravitational forces are far too weak to explain how the electron could enjoy a net attraction inside the nucleus under these conditions, it was clear that an impasse had been reached. In addition, the fact that the magnetic moment of the neutron was measured [9] to be much smaller than that of the electron seemed to be totally inconsistent with such a composition.

The problem was ultimately circumvented by Fermi with his suggestion that the electron might be annihilated in the presence of a strong nuclear force. It is interesting to consider Fermi's original remarks on this point, as given in translated form by Wentzel.[10] “The simplest way for the construction of a theory which permits a quantitative discussion of the phenomena involving nuclear electrons seems then to examine the hypothesis that the electrons do not exist as such in the nucleus before the ß emission occurs, but that they, so to say, acquire their existence at the very moment when they are emitted; in the same manner as a quantum of light, emitted by an atom in a quantum jump, can in no way be considered as pre-existing in the atom prior to the emission process. In this theory, then, the total number of the electrons and of the neutrinos (like the total number of light quanta in the theory of radiation) will not necessarily be constant, since there might be processes of creation or destruction of those light particles.”

In at least one sense this was a significant departure from the original hypothesis used to interpret positronium decay, because up to that point charged particles were only thought to undergo creation or annihilation pair-wise with their respective antiparticles. If one continues to doubt, as in Refs [1, 2], that electrons and positrons are really destroyed in positronium decay, however, then it is only consistent to question the very similar hypothesis made by Fermi in explaining the β decay phenomenon. Yet if one insists on the continuous existence of the electron in an alternative theory, one must face up squarely to the need for finding a potential which is strong enough to overcome the undeniably high kinetic energy the electron would possess in the small volume occupied by a nucleus. The problem is more severe than this, however, because in taking this approach one also must provide a suitable explanation for the role of the anti-neutrino itself in β decay. Before considering these points further, however, a few additional details of the experimental observations should be carefully considered.

A whole series of nuclear reactions could be found which are closely related to one another. Written in the form of reactions these are:

β decay: $n \rightarrow p^{+} + e^{-} + \bar{\nu}$

β+ decay $p^{+} \rightarrow n + e^{+} + \nu$

electron capture: $e^{-} + p^{+} \rightarrow n + \nu$ 2. 1

$\bar{\nu}$ absorption: $\bar{\nu} + p^{+} \rightarrow n + e^{+}$

ν absorption: $\nu + n \rightarrow p^{+} + e^{-}$

The notation is schematic, with p^+ and n generally denoting constituents of heavier nuc1ei actually present.

As always is the case, the classical chemist's balanced equation becomes a casualty of the assumption that matter such as electrons or neutrinos can be created or destroyed. None of the above five reactive equations is balanced in the traditional sense. In the first, an electron and antineutrino are created, while in the second, both (e^-,e^+) and $(\nu, \bar{\nu})$ pairs are created, with subsequent annihilation of e^- and $\bar{\nu}$ in the process of neutron formation. In the third, a $(\nu, \bar{\nu})$ pair is created and then the neutrino plus a captured electron from an associated atom are destroyed. Finally, an (e^-,e^+) pair is created in the fourth reaction, followed by the annihilation of e^- and $\bar{\nu}$ in the neutron formation, while in the last case the neutron decomposition produces the same two particles, only to have the antineutrino destroyed along with the neutrino which induces the reaction.

The hypothesis of mass-less particle-antiparticle binary systems is only partially successful in restoring particle balance to these equations, but strict adherence to the original definition of elements advocated by Boyle and others before him completes the process. In particular, when we surrender the idea that material particles can be created or destroyed in such interactions, we are forced to conclude that *the neutron is not an element at all.* Rather, it is a compound of its known decay products, i.e. p^+, e^- and $\bar{\nu}$, akin to a tri-atomic molecule in the usual chemical notation. The fact that the inertial mass of the neutron is greater than that of its separated constituents is perhaps surprising, but according to the Einstein mass-energy equivalence principle of his Special Theory of Relativity (STR), this is what one must expect from the fact that the dissociation energy of the neutron is negative (-0.8 MeV).

There is considerable precedent for such a situation, namely in the description of excimer complexes, which has had a great impact in the field of laser research. Excimers are bound (meta-stable) molecular states for collections of atoms with a ground state that is characterized by a repulsive potential curve and is therefore unbound. The fact that the neutron undergoes spontaneous decay is perfectly consistent with this analogy. Only the energies involved are far greater than those released in excimer lasers. In the language of scattering theory, the neutron is thus a resonance with a relatively long lifetime. The nature of the forces which hold the neutron together in this meta-stable state constitutes a major unanswered question in this model, but in this respect the situation is wholly similar to that for the e^+e^- tight-binding state which has been associated with the photon in Ref [1].

For the sake of clarity the conventional use of the term "elementary particle" for the neutron and related systems will continue to be made below [11] . Nevertheless, it is well to keep in mind that the definitions of atoms and elements that Democritus and Boyle espoused exclude the neutron from this classification because of its instability. With these preparatory remarks, we can rewrite the five β decay reactions given in eq. (II.1) in completely balanced form:

i´) $p^{+}e^{-}\nu(n) \rightarrow p^{+} + e^{-} + \bar{\nu}$

ii´) $e^{+}e^{-} + \nu\bar{\nu} + p^{+} \rightarrow p^{+}e^{-}\bar{\nu}(n) + e^{+} + \nu$

iii´) $\nu\bar{\nu} + e^{-} + p^{+} \rightarrow p^{+}e^{-}\bar{\nu}(n) + \nu$ 2.1´

iv´) $e^{+}e^{-} + \bar{\nu} + p^{+} \rightarrow p^{+}e^{-}\bar{\nu}(n) + e^{+}$

v') $\nu + p^{+}e^{-}\bar{\nu}(n) \rightarrow p^{+} + e^{-} + \nu\bar{\nu}$

In this way the number of distinct particle-antiparticle binaries has been kept to three in number, namely e^+e^- , $\nu\bar{\nu}$ and p^+p^-. The need for $n\bar{n}$ pairs is thereby avoided by virtue of the tri-atomic composition ascribed to a single neutron itself. Thus neutron-antineutron production involves the interaction of each of the three elemental binary systems, i.e.

$$p^{+}p^{-} + e^{+}e^{-} + \nu\bar{\nu} \rightarrow (p^{+} + e^{-} + \bar{\nu}) + (p^{-} + e^{+} + \nu) \rightarrow n + \bar{n} \qquad 2.2$$

The economy of the assumptions in the above model is especially desirable when one attempts to construct a quantitative theory which is capable of generating wave-functions and properties for such mass-less particle combinations. The elemental balance in the above equations also has the advantage of making the additional assumption of charge conservation unnecessary. Since charge is an intrinsic property of each particle, never to be altered in the course of physical transformations, its conservation is always ensured thereby. In addition, we must continue to assume that energy and each of the components of the net linear and angular momentum are conserved in such processes, consistent with STR and the mass-energy equivalence principle. More generally, it can be said that there is an unwritten rule in the physical sciences according to which the number of theoretical assumptions should be held to an absolute minimum. In practical terms, an irrefutable contradiction based on experimental evidence should be established before adding any new postulate to the theoretical framework in whatever form. In this sense we can take a lesson from the conservation laws of classical physics, according to which a truly remarkable variety of observations is understandable which is based on only three fundamental principles [12].

3. The Neutrino

The neutrino is associated with many puzzles that are still unresolved over 80 years after its discovery. It apparently bears no electric charge and thus is unaffected by electric fields. It also seems to be essentially mass-less, although this conclusion itself has been the subject of much controversy. During his lifetime Pauli compained[13] that the upper limit for its rest mass was set too high based on what was already know then. For a long time it was something of a bookkeeping device, merely accounting for energy otherwise missing in the β decay spectrum. In 1956 the first successful experiment involving neutrinos as reactant species was performed by Reines and Cowans [14] and this achievement allowed considerably more confidence that the particle was more than a theoretical construction. In essence, Reines and Cowan [14] carried out the first antineutrino absorption reaction [eq. II.1 (iv)] in the laboratory. Extreme sensitivity was required. The actual mode of detection was the appearance of a photon signaling the reaction of the positron product with an electron, but the time between positive events was typically 30 hours. As a result it was clear that anti-neutrinos are extremely penetrating, with a chance of one part in 10 [12] of being captured while passing through the earth along a diametric ray. The almost complete absence of ionization products observed during the experiment also led to the conclusion that the particle has virtually no magnetic moment, but this raised difficult questions about what forces actually govern the neutrino's behavior. The lack of either electric charge or a magnetic moment also left uncertain the exact relationship between ν and $\overline{\nu}$ themselves, since previously every other particle could be distinguished from its anti-particle on the basis of these properties.

An answer to this question was provided by Lee and Yang15 when they concluded that parity might not be conserved in beta decay. A decisive experiment [16] suggested by their work was carried out shortly thereafter by Wu *et al*. on the longitudinal polarization of decay electrons emitted by the ^{60}Co nucleus in the presence of a strong magnetic field at low temperature, using a method proposed earlier by Rose and Gorter [17]. As [60] Co decays into [60] Ni the nuclear spin changes by one unit from I=5 to 4, and is referred to as a Gamov-Teller transition [18], as opposed to the other possibility (Fermi transition) with ΔI=0. Because only the lowest-energy nuclear spin component is occupied in the presence of a strong magnetic field at low temperature, it was clear that the emitted electron must be ejected with its spin parallel to that of the [60] Ni nucleus. Under these conditions, a preferred direction for the departing electrons could be detected, namely opposite to that of the nuclear spin. One can summarize this result by saying that the electron behaves predominantly as a left-handed screw in β decay. In addition, subsequent studies of nuclear recoil indicated that the anti-neutrinos turn exclusively as right-handed screws [19] in the same experiment.

Out of these investigations came a new theory of the neutrino proposed independently by Lee and Yang [20], Landau [21] and Salam [22], according to which the neutrino and antineutrino could be distinguished on the basis of their respective left- and right-handedness, or alternatively their negative and positive helicities (defined as $I \cdot p/|p|$). It was referred to as the two-component theory of the neutrino because it postulated that certain spin-momentum orientations are forbidden to this particle. The idea was not entirely new to theoretical physics as Weyl had proposed something very similar [23] nearly 30 years earlier from strictly mathematical considerations based on STR. Since the parity P was not conserved in this theory, Pauli initially criticized it [24]. The observed asymmetry in the [60] Co experiments of Wu *et a1*. led him to reverse his position,25 however, although he went to some length at the time to express his amazement at this development.

Charge conjugation is also violated according to the two-component neutrino theory, but Yang noted that the product CP should still be conserved [26] i.e. by simultaneously inverting the coordinate system and changing all particles into their antiparticles, so that a left-handed ν becomes an (observable) right-handed $\overline{\nu}$. A key assumption in this theory was that the neutrinos have zero rest masses, a possibility, which, as already mentioned, has thus far not been refuted by experiment. The puzzle was later further complicated, however, by new experiments [27] also involving neutrinos, which provided strong evidence that even CP is violated in β decay.

Since a theorem by Schwinger [28] Luders [29] and Pauli [30] proved that the product of CP and the time reversal operation T should be conserved under the most general of circumstances, this observation seemed to indicate that neither T itself nor any two of these operators together are conserved in such processes.

The interpretation of the polarization phenomena discussed above has received support from a wide variety of other experimental observations, including studies on free neutron decay [31] and on muons [32, 33]. In the first instance, it was found that the proton is predominantly left-handed, which ultimately led to the convention of referring to the particle emitted in neutron decay as the antineutrino $\overline{\nu}$ rather than the neutrino ν as originally suggested by Fermi. In this way all anti-particles present in nuclei (and anti-nuclei) are right-handed, while their counterparts in charge conjugation are left-handed. Another important distinction between ν and $\overline{\nu}$ was demonstrated by the fact that anti-neutrinos do not undergo the capture reaction of eq. (II.1.v) upon interaction with neutrons [34]. Attempts to observe a double beta decay in which no anti- neutrinos are emitted [35] have also never been successful. In the present context it should be noted that this result is also consistent with the belief in a definite composition for the neutron needed to achieve particle balance in the five beta decay reactions listed in the preceding section.

Another puzzle connected with neutrinos was discovered in 1964 by Bacahl and Davis [36] as a result of their investigation of nuclear fusion processes on the sun. The fusion reaction is closely related to eq. (2.1.iii), with neutrinos being set free in the process. Detailed knowledge of the solar reaction profile enables a relatively precise calculation of the magnitude of the associated neutrino flux reaching the earth, but the above experiments have invariably indicated a large discrepancy in the computed value. Less than half the expected neutrinos are ever observed. In addition there is evidence that the neutrinos involved in the β decay of muons are not the same [37] as those associated with neutrons and heavy nuclei. One distinguishes then between electron (ν_e) and muon (ν_μ) neutrinos, and there is also theoretical evidence [38] that a third type (or flavor) also exists, namely the tau neutrino (ν_τ).

Yet the greatest puzzle of all in this connection seems to be why such charge-less, extremely penetrating particles are involved in almost every high-energy reaction ever observed. Given this situation, the question of whether neutrinos can be created or annihilated seems a secondary issue, but one that nonetheless permeates any relevant theoretical discussion of the nature of these particles, beginning with the Fermi theory of β decay put forward nearly a century ago [8].

4. Nuclear Structure and The Strong Interaction

The theory of nuclear structure relies firmly on the assumed elemental nature of the neutron [39] Any nucleus can be described as containing a definite number of protons and neutrons, thereby providing a means of discussing nuclear reactions with balanced equations along the lines foreseen by Boyle in his general theory of chemical transformations. The fact that the neutron undergoes spontaneous emission complicates this simple picture, however, suggesting an alternative interpretation according to which the real elements are the electron and neutrino, in addition to the proton. The proton itself has been theorized [40] to decay as well, but careful experiments [41] have never found any positive evidence for this expectation. By any reckoning, the proton is an extremely stable substance, with a lifetime far longer than that of the neutron.

The question of the nature of the forces which hold nuclei together is still largely open. One refers to them collectively as the strong interaction, a term which above all takes cognizance of the fact that the forces in question have properties which are far different from either the electromagnetic or gravitational type. In the time of Rutherford, three nuclear decay modes were well known, involving α-, ß- and γ-rays respectively. In the meantime, one can add at least two more decay products to this list, namely neutrons and the small nuclei which result from fission of their heavy counterparts. It is interesting to note that the creation-annihilation hypothesis is only invoked to explain two of these five possibilities, the β decay discussed in the preceding two sections, as well as the gamma or photon emission process. In the other three cases the decay products have much larger rest masses, and thus are thought to be present in the original nuclei prior to decomposition as well as subsequent to it.

As noted previously, the justification for this distinction in the case of electron (β) emission is the belief[8,10] that no potential could be sufficiently attractive to outweigh the large kinetic energy such a light particle would have in the confines of the nuclear volume. Yet the fact that the forces binding nuclei together are a matter of some uncertainty themselves lends a degree of tentativeness to this conclusion. On the other hand, if we assume that neither the electron nor anything else can be annihilated under any circumstances, we are left with no choice but to look for a potential that is capable of binding an electron so strongly. In Refs. [1, 2], a similar line of reasoning has led to the conclusion that the electron and positron form a much more tightly bound system than anything inferred from a solution of the electrostatic Schrödinger equation, which corresponds to a binding energy of 1.02 MeV. For comparison purposes, it is interesting to note that nuclei are bound together on the average by roughly 8 MeV/nucleon, a number which is somewhat larger but of the same order of magnitude as that required in the interpretation of a tightly bound electron-positron system. Moreover, it is over 200 times smaller than the p^+p^- binding energy which must be assumed on the same basis, namely 1.85 GeV.

The possibility may thus exist that in searching for a potential which binds particles with their antiparticles together with such force as to cause a total loss of mass relative to the reactant species, one is approaching the same goal as has long been sought in the context of nuclear interactions. Merely saying that the energies given off in the particle-antiparticle interactions can be computed on the basis of STR and the mass-energy equivalence relation does not after all conform to the standards physicists have adhered to in dealing with other types of elemental processes. In almost every other conceivable situation, a detailed description of the forces involved in causing systems to be either attracted or repelled by one another has become an important goal of subsequent research, and this line of approach has been rewarded with genuine scientific progress on numerous occasions in the past.

With this motivation, it is instructive to review what is known about the strong interaction from experimental studies of nuclear processes and what progress has been made in interpreting these observations theoretically. To begin with, one has a good idea from scattering experiments what the associated potential must look like. One distinguishes three types of fundamental processes, namely pp, nn and pn scattering. Especially when Coulomb repulsion effects are subtracted for proton pairs, it is found that the potential that causes nuclear binding is essentially the same in all three cases. On this basis the nuclear force is assumed to be charge-independent and, by inference, quite distinct from the electromagnetic force. Some evidence of at least a secondary role for electromagnetism is suggested by the existence of nuclear magnetic and quadrupole moments, not to mention the positive electronic charge of all nuclei, but it is felt that such effects can be dealt with separately. One also might say that the discovery of the neutrino's involvement in nuclear reactions supports the charge-independence assumption in view of this particle's lack of either electric charge or magnetic moment.

Probably the most influential conclusion based on the above experimental findings was drawn by Heisenberg [42] in 1932. He postulated that the neutron and proton were simply two different states of the same system (nucleon) which would be perfectly degenerate in the (hypothetical) absence of the electromagnetic interaction. Out of this hypothesis ultimately evolved the theory of isospin [43, 44], which has had a very great impact in both nuclear physics and the corresponding study of elementary particles.

Some of the first attempts to describe the nuclear force employed a non-relativistic Schrödinger equation[45] and an empirical potential of the type indicated by the scattering data. The most famous of these treatments employs the Yukawa exponential potential [46, 47] $V(r) = -V_0(\alpha/r)\, e^{-r/\alpha}$, where r is the distance between nucleons (protons or neutrons), V_0 characterizes the depth of the potential and α, its range. The non-relativistic kinetic energy $p^2/2M$ is deemed appropriate for this purpose in view of the relatively large rest masses of the nucleons. By varying the two parameters V_0 and α, it is possible to fit a certain number of experimental results on the basis of the corresponding solutions of the Schrödinger equation, but the Yukawa procedure has never evolved into a truly quantitative theory of nuclear binding. Nonetheless the simplicity of the model on which it is based has led to much valuable insight into the subject. In particular, it emphasizes the extremely short range of the effect through the exponential form of the corresponding potential. For $r \gg \alpha$, the potential is effectively damped to zero, whereas for $r \leq \alpha$ it varies predominantly as r^{-} [1]. In the latter respect it is similar to the Coulomb potential, but the large magnitude of

V_0 gives it a much stronger weight in the short internuclear distance region where the binding between nucleons is at its greatest. True to the creation-annihilation concept, no recognition is given to the possibility that either electrons or antineutrinos are involved directly in the nuclear binding process.

Another approach to the nuclear problem is modeled after quantum electrodynamics, focusing on the idea that the Coulomb force involves the exchange of photons between the interacting charged species. Using arguments based on the Heisenberg uncertainty principle, Yukawa postulated[47] that the particle regulating the nuclear force must have a correspondingly short range, which in turn keeps it from being directly observable under normal circumstances. By assuming a velocity close to the speed of light, Yukawa was led to predict a rest mass for the new particle which was intermediate between that of an electron and a proton (200 m_{oe} was first proposed). The Coulomb force's range is thereby thought to be infinite, consistent with the null rest mass of the photon. The theory received support from experiment a decade later when the π mesons (π^+ and π^-, with a rest mass of 273.13 m_{oe} each) were discovered [48] and shown to interact with nuclei. Attempts to construct a quantitative theory analogous to quantum electrodynamics were not generally successful, [49] however. The use of low-order perturbation theory to compute the mesonic interactions was concluded to be inadequate [50], despite the fact that a similar approach in quantum electrodynamics is found to be quite accurate. The anomalous spin magnetic moment of the electron amounts to a deviation of only one part per thousand [51] from the uncorrected value of Dirac theory, and can be predicted to an accuracy of six to seven significant figures with the perturbative inclusion of quantum electrodynamical effects. By contrast, the proton magnetic moment was measured by Stern and coworkers [9, 52] to be 2.5 times the theoretical value deduced on the basis of the respective masses of the proton and electron. Nonetheless, the π meson theory accounts for the known observations at least qualitatively, and the concept of a cloud of such (virtual) particles surrounding the proton has received broad acceptance, especially after it was found to be quite consistent with the results [53] of elastic scattering of high-energy electrons by nucleons.

Another theory which has had a great impact in this field is the nuclear shell model proposed by Goeppert Mayer [54] and Jensen. [55] This work concentrates on certain regularities in the properties of nuclei as a function of the numbers of their constituent protons and neutrons, particularly the values of the nuclear spin and of the electric quadruple and magnetic dipole moments. It is possible to predict trends in these data by assuming that protons and neutrons are added in shells according to an *Aufbau* principle similar to that used in atomic structure theory to explain observed trends in the periodic table of the elements. The shell model traces its origins to the independent-particle or Hartree model [56] and also to the Wigner coupling scheme [57], which was successful in classifying nuclear states with the aid of a spin-independent zero-order Hamiltonian. Each shell can be identified with definite angular momentum quantum numbers l and j, with their familiar degeneracy factors determining degrees of maximum occupancy in accordance with the Pauli principle. Isomorphic pairs of shells are reserved for the individual protons and neutrons, whereby the stability of the proton shells always appears to be somewhat lower, reflecting the effects of their participation in the repulsive Coulomb interaction. On the basis of these considerations it was possible to explain the occurrence of certain "magic numbers" which had been noted empirically for the atomic and mass numbers of nuclei in surveying the aforementioned properties [39, 54, 55].

For the present discussion the most interesting aspect of the shell model is the conclusion that forces are at work which are akin to the spin-orbit coupling interaction familiar in the classification of fine-structure effects observed in atomic spectra. Terms of this nature arise from a perturbative reduction of the Dirac equation, [58, 59] as shown by Breiti [60], Pauli [61] and others [62]. The origin of the spin-orbit interaction can be traced to the v x E term which appears as an adjunct to the magnetic field [63] upon application of a Lorentz transformation to the classical Maxwell equations [64]. The form of the spin-orbit interaction involved in nuclear binding is quite distinct[65] from the latter, however, because the magnitude of the effect is found to be much larger than one would expect on the basis of the small magnetic moments of nucleons.

The fact that the quantum numbers employed in such models are typical for a central potential has sometimes been remarked [66] to be inconsistent (or at least not obviously consistent) with the picture of the nucleus as a collection of protons and neutrons, i.e. without a fixed center comparable to that known for atoms. The success with which the experimental data can be ordered on this basis belies such criticism, but the *ad hoc* nature of its central potential assumption combined with its inability to obtain truly quantitative agreement with measured results have tended to prevent the nuclear shell model from being a complete triumph [67]. Nonetheless, the ability of such methods to account in an extremely detailed manner for the observed regularities in the properties of complex nuclei is a fact which must be reckoned with in trying to construct a more quantitative theory of nuclear structure in the future.

It is impossible to do justice to the progress made in theoretical nuclear physics with such a brief survey, but at least one more series of developments needs to be considered in the present context. The liquid drop model, which was proposed by Bohr [68] in 1936, points out similarities between nuclear matter and the liquid state. This model is based first and foremost on experimental measurements of radii and binding energies of a large series of nuclei, and as such is reminiscent of the theory of the chemical bond introduced into molecular physics and chemistry by Pauling [69]. Probably the most important result of an experimental nature is the finding that the magnitudes of nuclear radii are approximately proportional to the third root of the atomic mass number [70], or alternatively, that the nuclear volume increases proportionately to the number of constituent nucleons. This is a very simple result which gives the impression that, even more than in molecular systems, for which a similar model is already very successful, the components of nuclei are not at all compressible. If one knows the volume of one nucleon (or better, the volume of two nucleons that are tightly bound together), it is possible to extrapolate this result to obtain the size of the entire nucleus. This close-packing condition is another important characteristic that must be derivable from the nuclear potential. To this can be added that the interactions between nucleons in the same shell are found to be much stronger than between those in different shells.[71]

What do the theories of nuclear structure tell us about the forces involved in positronium decay? If the pervasive view that nuclear forces occur primarily between elemental protons and neutrons is correct, the answer must be that there is little or no relation. On the other hand, if the neutron is looked upon as a compound of its decay elements, the electron, proton and antineutrino, a more significant relationship can be anticipated. For one thing, it then becomes essential to account for interactions between electrons and protons inside the nucleus, in which case it is not difficult to imagine that there might be similarities between these forces and those which might conceivably cause the electron and positron to be bound together much more tightly than in positronium. *Moreover, once this path is taken, it is only consistent to assume that the antineutrino also interacts strongly with either the electron or proton or both.*

The above possibilities will be explored in subsequent sections, but for now it is worthwhile to consider how such a neutron hypothesis would affect the simple bookkeeping procedures used to describe nuclei in terms of the number of constituent protons (Z) and neutrons (N). In the first place, the number N becomes identical with the number of electrons in the nucleus, as well as the number of anti-neutrinos. The number of protons is no longer Z, but Z+N, while the total number of constituent particles is not Z+N, but Z+3N. The latter difference is 2N and thus is always even. This fact means there is no alteration in nuclear statistics as a result of such an assumption, a point used by Pauli [7] in postulating the existence of the neutrino in the first place. Otherwise, particle balance in nuclear equations is ensured in this approach (even in cases for which β-decay occurs in one form or another) if one inserts the appropriate particle-antiparticle binary systems as needed. When photons are involved, this means adding mass-less e^+e^- species as well. Conservation of energy can be handled in the usual way, in accordance with STR.

The resulting elemental balance in the description of such processes would be perfectly in line with the atomistic theories originated thousands of years before, as well as the more precise formulations proposed by Boyle and Dalton much later. What is clearly missing in the discussion to this point is a quantitative specification of the possible forces which are involved, one that would allow an accurate prediction of the differences in the masses of products and reactants in such processes. In its simplest form, this would mean the *ab initio* computation of the binding energy of the deuteron relative to its constituent proton and neutron separated to infinity, or even more fundamentally, with respect to two protons, an electron and an antineutrino at rest in their respective elemental states.

5. Metastable Particles

The hypothesis that the neutron is a tri-atomic compound composed of each of its decay elements has far-reaching consequences beyond the realm of nuclear physics. There are many other meta-stable systems which are listed among the elementary particles, the smallest of which are the two muons and the three pions. They differ from the neutron mainly in that their lifetimes are much shorter (10^{-10} - 10^{-16}s) and that their decomposition energies are far greater (over 100 MeV in the case of the muons). In addition, their decay products do not include a proton, although electrons and neutrinos are emitted. Beyond this there are a large number of other meta-stable particles known, referred to as mesons and baryons on the basis of their rest masses.

In 1964 Gell-Mann [72] and Zweig [73] suggested that all of them could be interpreted as being composed of hypothetical fermions called quarks (or aces[74]) and their antiparticles. Probably the most novel aspect regarding this suggestion is the assumption that the new particles should possess non-integral electric charges, either $\pm \frac{1}{3}e$ or $\pm \frac{2}{3}e$. In the meantime the number of quarks and anti-quarks has grown to twelve [72] and the idea has achieved wide acceptance.

Fermi and Yang [75] and Sakata [76] tried to identify a common denominator of elements in terms of the proton, neutron and lambda from which to construct all other known particles. This approach has only been partially successful, primarily because certain combinations which appear reasonable in this theory have never been observed. The quark concept is clearly consistent with the view that all matter consists of elements, but there is still some question as to whether particles of non-integral electric charge actually exist. One reads in the literature, to be sure, that individual quarks have been discovered experimentally, but the evidence is always indirect, referring to a successful prediction derived from the theoretical model.

The idea that all observed meta-stable particles might be composed of their decay products, either as elements or as other combinations thereof, is not necessarily in conflict with the quark model, although it is also not obviously consistent with it either. Just because a proton might have a quark composition, in other words, in no way precludes the possibility that a quantitative theory which employs protons as elements might not exist. The crucial test is whether the properties of the various meta-stable particles can be successfully computed with the help of any such theory. In the present context this would mean computing the rest masses of the muons and pions, for example, just as for the neutron, deuteron and other heavier nuclei, in a similar manner as one calculates binding energies and ionization potentials of atoms and molecules with the help of quantum electrodynamics.

There is a new aspect introduced by the study of the other meta-stable particles, however, namely that they exhibit multiple decay channels. Whereas the neutron is always observed to produce a proton, electron and antineutrino upon decomposition, several sets of decay products are known for most other meta-stable systems. *Does this not speak against the concept of a unique composition for them in terms of certain elements?* Not necessarily, because if mass-less particle-antiparticle binaries exist, other possibilities must be taken into account. One only has to look at a typical β decay process discussed earlier in Sect. II to see how the addition of e^+e^-, p^+p^- or $\nu\bar{\nu}$ species can result in a particle balance in reactions which are conventionally interpreted in terms of the creation-annihilation hypothesis.

The situation can be compared to that faced by the early chemists several centuries ago when a new substance was to be analyzed. A major distinction between the two cases exists, however, namely that when very large decay energies are involved, the masses of the participating systems cannot be used unambiguously to confirm a given structure. In other words, the concept of molecular weight is much less useful in elementary particle physics than it is in chemical investigations. All one knows with certainty is that if the rest mass of the combined system is less than that of its components it is a bound system, otherwise it must be meta-stable. The experimental fact that *all* the particles which decay into protons, electrons or neutrinos *have rest masses which are larger than the total for their respective fragments* again speaks clearly for the analogy with molecular excimers mentioned earlier. It remains to be seen whether a system of forces can be found which is capable of temporarily binding electrons and neutrinos together in muons and pions and the like, even though the total energy /mass in the relevant states is much higher than that for the corresponding decay particles at rest.

6. Magnetic Phenomena: Neutrino Interactions

The charge-to-mass ratios appearing in the Breit-Pauli relativistic corrections are closely related to the magnetic moments of the corresponding particles. The Bohr magneton ß of a system is defined as h/4π times the charge-to-mass ratio and the magnetic moment is usually measured in terms of this quantity. Strictly speaking, the magnetic moment is a vector proportional to the angular momentum of the particle, and in classical theory the Bohr magneton would simply be the corresponding proportionality constant. Magnetic measurements on electrons in atoms have shown that such a straightforward relationship is oversimplified, and have led to the introduction of a supplemental factor, the gyromagnetic ratio g. The discovery of spin angular momentum [77] brought with it the equally surprising result of g = 2 for the electron's spin magnetic moment [63, 78]. Later on, it was found that the correct value is actually slightly greater than this result, [51, 79, 80] however. Moreover, the corresponding value for the proton [9, 52] was measured to be several times larger than that of the electron.

The question that arises in the present context is whether the observed g values should be included explicitly in the Hamiltonian used to describe the particle-antiparticle states which have been suggested above. Since the scaling results to be discussed no longer hold if one multiplies the q/m values in the Breit-Pauli terms with a different factor for each type of particle, however, it seems clear that the measured g values should not appear in such a Hamiltonian. Moreover, this choice is also consistent with the accepted explanation[80] for the observed non-integral g values for spin magnetic moments, namely that they arise because the corresponding particle is affected by external factors (virtual photons or virtual mesons) which prevent the measurement of its properties in a pure (bare) state.

Having made this decision, it can be noted that the only experimental constants appearing in the damped Breit-Pauli Hamiltonian are the electric charges and rest masses of the interacting particles. It is therefore clear how to define a specific Hamiltonian for a system involving given numbers of electrons and protons and their respective antiparticles, particularly the e^+e^- and p^+p^- combinations of primary interest. There remains an important question, however, namely *how to deal with neutrino interactions.* The obvious approach is to simply substitute the corresponding values for the charge and rest mass of such particles and to solve the corresponding Schrödinger equation, but the observed electrical neutrality of the neutrino seems to preclude any chance of success for such a procedure. There is one possibility worth considering, however, *provided the rest mass of the neutrino is also exactly zero,* as seems possible based on experimental observations. In that case, the charge-to-mass ratio cannot simply be computed by dividing the above two quantities because the quotient of zero with itself is undefined. From a purely theoretical standpoint this eventuality would seem to invalidate the conclusion that the Breit-Pauli terms necessarily vanish for the charge-less neutrino, i.e. because $q_\nu/m_{o\nu}$ itself might still be different from zero. Such a possibility seems to clash with the experimental observations bearing on the magnetic moment of the neutrino, however, which indicate that it is also of vanishingly small magnitude [11], thereby implying that the corresponding charge-to-mass ratio is still effectively zero.

The idea that the neutrino might possess a non-zero magnetic moment which could help to explain its observed activity in nuclear reactions is not new, and was in fact proposed by Pauli [81] as a general property of mass-less neutral particles based on the Dirac theory [82]. He later stated[7] that such a hypothesis "doesn't seem to me at all well founded." The history of the relationship between the magnetic moment and the charge-to-mass ratio of a given particle has not been without its surprises, however. As already noted, the gyromagnetic ratio, for example, is an experimental quantity *invented* for the expressed purpose of accounting for discrepancies between observations and overly simplistic theoretical models. It is therefore wise to exercise some care in making conclusions about a particle's charge-to-mass ratio based on magnetic measurements alone.

In this connection it is important to recall that the Special Theory of Relativity (STR) [83] emphasizes that electric and magnetic fields are intertwined, with their respective magnitudes differing from one inertial system to another moving relative to it. Viewed from the standpoint of the affected particle, *there is never a magnetic force acting upon it,* because it is by definition stationary in its own inertial system (v = 0) [84]. Considerations of this nature led Lorentz[85] to point out that a Galilean transformation does not leave the laws[86] of electricity and magnetism invariant, and they eventually enabled Einstein [83] to formulate STR in the first place. By this reasoning, it would seem to follow [87] that since a charge-less particle *can never experience an electrical force* according to Coulomb's Law, it should consequently experience *no electromagnetic force at all in its own inertial system.* Further, because of the principle of relativity, this conclusion leads to another, namely that a charge-less particle must be unaffected by any electromagnetic field, regardless of the relative state of motion of the observer to it. If an electrically neutral system is composed of several charged particles, the analogous conclusion is negated by the possibility that its individual components move at different velocities, but for a true (charge-less) element this situation is excluded.

In order for q/m_o to be non-zero for the neutrino, however, its rest mass must be exactly zero and (for E ≠ 0; see Ref [1]) it must move with the velocity of light (v=c). In this case a Lorentz transformation to a different inertial system is no longer defined since $\gamma = (1 - v^2/c^2)^{-1/2}$ is then infinite. Consequently, the above argument based on STR does not really prove that a *charge-less, mass-less* particle is unaffected by electromagnetic fields in *all* inertial systems. It seems only prudent to note, however, that the preceding discussion has been based exclusively on classical electrodynamics. It might be anticipated that a truly definitive answer to the question of whether a mass-less neutrino can possess a non-zero charge-to-mass ratio $q_\nu/m_{o\nu}$ without exhibiting a magnetic moment in the usual sense can only be obtained on the basis of a quantum mechanical formulation of this problem.

The possibility of a non-zero charge-to-mass ratio of the neutrino is interesting in several other contexts as well, however. It provides a ready explanation for the existence of both a neutrino and an antineutrino, for example. If $q_\nu/m_{o\nu}$ is non-zero, then different signs are possible for it, just as for charged species and their antiparticles. This characteristic might then be closely related to the helicity property of neutrinos measured in longitudinal polarization experiments [16, 31-33]. It might also explain why there are apparently different types of neutrinos observed in neutron and pion-muon beta decays· [37]. Neutrinos with distinct $|q/m_o|$ ratios would be expected to exhibit different behavior, despite their mutual lack of charge and rest mass.

In the present discussion, the point of immediate interest is whether the assumption of a non-zero q/m_o value for the neutrino leads to a solution of the corresponding Schrödinger equation (with the exponentially damped Breit-Pauli interactions mentioned in Ref [2].) for a $\nu\bar{\nu}$ complex which has zero binding energy relative to its separated particles, i.e. $-2m_oc^2$ analogous to that of the e^+e^- and p^+p^- systems. Zero binding energy does not necessarily mean that a potential well does not exist. There could be a large barrier separating the two minima in this case as well as for e^+ e^-, and thus the $\nu\bar{\nu}$ system might also be characterized by a relatively small optimal inter-particle separation [86]. Calculations investigating this point will be discussed in two accompanying publications [87, 88].

7. Conclusion

Consideration of other types of observed phenomena arising in the field of modern physics is found in no way to contradict the hypothesis discussed in Ref [1-2] of ubiquitous massless photons. At the same time, this line of argumentation calls into question standard interpretations of related elementary processes which involve the creation or annihilation of individual particles. The primary example considered in this connection is that of the β decay of a neutron (Sect. 2). By following through on the proposal that no material particle is ever created or destroyed in physical transformations, one is led to conclude that a strict elemental balance must characterize any reactive equation, exactly as is assumed in ordinary chemical processes. In accordance with this view a neutron must be composed of a proton, an electron and an antineutrino *prior* to undergoing β decay, because each of these particles is present at the completion of the process. An analogy is made between the neutron (and other unstable elementary particles) and excimer systems in the field of molecular physics, which are well known to correspond to meta-stable excited states whose ground state potential energy curves are completely repulsive. The energy given off in the decay of elementary particles is so large compared to that found in the operation of an excimer laser that a significant decrease in the sum of the rest masses of the products in such reactions is observed relative to the mass of the original meta-stable system. Similar arguments can be given for a whole series of elementary particles, such as muons, pions and other heavier species, all of which are known to decay with relatively short lifetimes to a collection of fragments of smaller aggregate rest mass.

In order to give quantitative substance to the above theoretical model, it is imperative that one clearly identify the nature of the interactions responsible for high-energy processes, especially the prototype example in which an electron and a positron combine to form a tightly bound binary complex with exactly zero rest mass. Emphasis is placed thereby on the fact that no corresponding state of a proton and an electron is known, i.e. the $1s_{1/2}$ state of the hydrogen atom is perfectly stable when left in an isolated condition, whereas that of positronium has only a short lifetime. Similarly, a massless p^+p^- binary must also be assumed to exist based on the analogous experimental results for the interaction of a proton and an antiproton. The term "phanton" will be used in the following discussion in referring to such massless particle-antiparticle binary systems in general, and the special name of "prophoton" has been given to the p^+p^- member of this family, to go along with the identification of its e^+e^- counterpart as the photon.

The high energies associated with the formation of e^+e^- and p^+p^- suggest that similar short-range interactions are involved as in the binding of nuclei, in which case an exponential form for the corresponding potential has been deduced from scattering experiments. Because of the participation of electrons, positrons and photons in the electromagnetic interaction, it is suggested that a good starting point in the search for such a potential is the relativistic Dirac equation or some approximation to it. It is noted that the Breit-Pauli reduction of this equation contains short-range terms varying inversely as the cube of the interparticle distance which are of the order of α^2 (10^{-4}-10^{-5} hartree) for typical electron-proton separations in an atomic system. The unbounded character of these terms in the limit of vanishingly small separations, particularly in relation to the corresponding relativistic kinetic energy, makes it clear, however, that the desired short-range bonding of elementary particles can only be satisfactorily described by interactions of this type if they are somehow modified to become considerably less attractive at extremely small interparticle distances.

An exponential damping of the Breit-Pauli interactions has thus been suggested in Refs [1, 2]. This is in analogy to that proposed by Yukawa some eighty years earlier for the description of nuclear binding, except that in that case it was applied to an r^{-} [l] potential. The resulting set of interactions is referred to as the exponentially damped Breit-Pauli Hamiltonian and is employed in a Schrödinger equation (XBPS) of the standard $H\ \Psi = E\ \Psi$ form. The potentially crucial advantage of this Hamiltonian is that it is *bounded from below* and thus can be treated using standard variational techniques, unlike the un-damped Breit-Pauli terms themselves. The explicit form of the XBPS Hamiltonian is given in Table 1 of Ref [2].

The description of the decay of the neutron in the XBPS model also requires an explicit representation of the interaction of a third particle and its antiparticle, namely the neutrino and antineutrino. It is necessary, consistent with the above considerations to assume that a corresponding system of zero rest mass exists with a $\nu\bar{\nu}$ composition (photrino). The fact that the neutrino possesses no electric charge prevents the use of the same scaling property of the XBPS Hamiltonian as in the case of the e^+e^- and p^+p^- systems, however, because it is only valid for particles having the same absolute magnitude of charge as the electron. Examination of the coupling constants in this Hamiltonian shows that the only way that it can lead to significant interactions for neutrinos is if their charge-to-rest-mass ratios are different from zero. This condition can only be met if the rest mass of the charge-less neutrino is itself exactly zero, something which is at least consistent with all experimental investigations as yet undertaken to measure this quantity. It is also clear that the use of the rest mass instead of the relativistic mass, $m = \gamma m_0$, in the coupling constants of this Hamiltonian is essential if this possibility is to have a significant impact on the description of the neutrino interactions.

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9. References

1. Buenker RJ. Production of photons in positronium decay: Critique of the creation-annihilation hypothesis: Part I ITS Applied Physics 2021;4(1):11-34; ISSN: 2664-0821,
2. Buenker RJ. Production of photons in positronium decay: Critique of the creation-annihilation hypothesis: Part II ITS Applied Physics 2021;4(1):35-69; ISSN: 2664-0821,
3. Guth AH. International Herald Tribune 1987, 7.
4. Rutherford E. The scattering of α and β particles by matter and the structure of the atom. Phil. Mag 1911;6(21):125;669-688.
5. Chadwick J. Possible Existence of a Neutron. Nature 1932, 129, 312; The Existence of a Neutron. Proc. R. Soc. London A 1932;136:692.
6. Bohr N. Faraday Lecture. Chemistry and the quantum theory of atomic constitution, J. Chem. Soc 1932, 349-384.
7. Pauli W. in: Minutes of the Pasadena Meeting. Proceedings of the Meeting of the American Physical Society. Proceedings of Solvay Congress, Brussels 1931, 1933;38(3):324.
8. Wu CS. The Neutrino, in: Theoretical Physics in the Twentieth Century, edited by M. Fierz and V.F. Weisskopf; Interscience, New York 1960, 252.
9. Estermann I, Frisch R, Stern O. Magnetic Moment of the Proton. Nature 1933;132:169-170 Frisch R, Stern O. Magnetic Deviation of Hydrogen Molecules and the Magnetic Moment of the Proton. Z. Physik 1933;85:4.
10. Fermi E. Ric. sei. 2, No. 12, translation quoted by G. Wentzel, Quantum Theory of Fields. in: Theoretical Physics in the Twentieth Century, edited by M. Fierz and V.F. Weisskopf; Interscience, New York 1960, 69.
11. See remark by Lamb Jr., W.E. in: Weber, R.L. Pioneers of Science, edited by Lenihan, J.M.A. The Institute of Physics, Bristol 1980, 155.
12. Newton I. Philosophiae Naturalis Principia Mathematica. London, 1686; Sir Isaac Newton's Mathematical Principles of Natural Philosophy and his System of the World, Vols. 1 and 2; Motte A. Motte translation, revised and edited by Cajuri, F. University of California Press, Berkeley 1962.
13. Wu CS. The Neutrino, in: Theoretical Physics in the Twentieth Century, edited by M. Fierz and V.F. Weisskopf; Interscience, New York 1960, 250.
14. Reines F, Cowan CL. Detection of the Free Neutrino: a Confirmation. Science 1956;124:3212,103-104; Free Antineutrino Absorption Cross Section. I. Measurement of the Free Antineutrino Absorption Cross Section by Protons. Phys. Rev. 1959, 113, 273; Reines F.; Cowan, C.L.; Harrison, F.B.; McGuire, A.D.; Kruse. H.W. Detection of the Free Antineutrino. Phys. Rev 1960;117:159.
15. Lee TD, Yang CN. Question of Parity Conservation in Weak Interactions. Phys. Rev 1956, 104, 254.
16. Wu CS, Ambler E, Hayward RW, Hoppes DD, Hudson RP. Experimental Test of Parity Conservation in Beta Decay. Phys. Rev. 1957, 105, 1413.
17. Wu CS. The Neutrino, in: Theoretical Physics in the Twentieth Century, edited by M. Fierz and V.F. Weisskopf; Interscience, New York 1960, 264.
18. Sachs RG. Nuclear Theory. Addison-Wesley, Cambridge, Mass 1953, 339.
19. Goldhaber M, Grodzins L, Sunyar AW. Helicity of Neutrinos. Phys. Rev 1958;109:1015.
20. Lee TD, Yang CN. Parity Nonconservation and a Two-Component Theory of the Neutrino. Phys. Rev 1957;105:1671.
21. Landau LD. On the conservation laws for weak interactions. Nucl. Phys 1957;3:127.
22. Salam A. On parity conservation and neutrino mass. Nuovo Cimento 1957;5:299-301.
23. Weyl H. Elektron und Gravitation. I. Z. Physik 1929;56:330-352.
24. Pauli W. Handbuch der Physik. Springer, Berlin 1933;24;226-227.
25. Pauli W. Collected Scientific Papers, Vol. 1, edited by Kronig, R.; Weisskopf, V.F. Interscience, New York 1964, xii-xx.
26. Yang CN. Present Knowledge About the New Particles. Rev. Mod. Phys 1957;29:231.
27. Cristenson JH, Cronin JW, Fitch VL, Turlay R. Evidence for the 2π Decay of the K_2^0 Meson. Phys. Rev. Lett. 1964, 13, 138; Abashian, A.; Abrams, R.J.; Carpenter, D.W.; Fischer, G.P.; Nefkens, B.M.K.; Smith, J.H. Search for CP nonconservation in K_2^0 decays. Phys. Rev. Lett 1964;13:243.
28. Schwinger J. The Theory of Quantized Fields. Phys. Rev 1951, 82, 914;1953, 91, 713.
29. Lüders G. KgJ. Danske Videnskab Selskab, Mat. Fys. Medd. 1954;28(5).
30. Pauli W. in: Niels Bohr and the Development of Physics, edited by Pauli, W. McGraw-Hill, New York 1955.
31. Burgy MT, Krohn VE, Novey TB, Ringo GR, Telegdi VL. Measurements of Asymmetries in the Decay of Polarized Neutrons. Phys. Rev 1958;110:1214.
32. Backenstoss G, Hyams BD, Knop G, Marin PC, Stierlin U. Helicity of μ^- Mesons from π^- Meson Decay. Phys. Rev. Lett. 1961;**6:**415; Bardon, M.; Franzini, P. Lee, J. Helicity of μ^- Mesons: Mott Scattering of Polarized Muons. Phys. Rev. Lett 1961;7:23.
33. Garwin RL, Lederman LM, Weinrich M. Observations of the Failure of Conservation of Parity and Charge Conjugation in Meson Decays: the Magnetic Moment of the Free Muon. Phys. Rev 1957;105:1415; Friedman,

J.L.; Telegdi, V.L. Nuclear Emulsion Evidence for Parity Nonconservation in the Decay Chain $\pi^+ - \mu^+ - e^+$. Phys. Rev 1957;105:1681.

34. Davis Jr., R. Attempt to Detect the Antineutrinos from a Nuclear Reactor by the $Cl^{37}(\bar{\nu}, e^-)A^{37}$ Reaction. Phys. Rev 1955;97;766.
35. Goeppert-Mayer M. Double Beta-Disintegration, Phys. Rev. 1935, 48, 512; Furry, W.H. On Transition Probabilities in Double Beta-Disintegration. Phys. Rev. 1939, 56, 1184; Konopinski, E.J. The Experimental Clarification of the Laws of beta-Radioactivity. U.S.A.E.C. Report LAMS-1949; Primahoff, H. Angular Correlation of Electrons in Double Beta-Decay. Phys Rev 1952;85:888.
36. Davis Jr, R Harmer DS, Hoffmann KC. Search for Neutrinos from the Sun. Phys. Rev. Lett. 1968, 20, 1205; Bahcall, J.N. Solar Neutrinos. I. Theoretical. Phys. Rev. Lett. 1964, 12, 300; Davis Jr., R. Solar Neutrinos. II. Experimental. Phys. Rev. Lett. 1964;12:303.
37. Danby G, Gaillard JM, Goulianos KL, Ledermann M, Mistry N, Schwartz M *et al*. Observation of High-Energy Neutrino Reactions and the Existence of Two Kinds of Neutrinos. Phys. Rev. Lett 1962;9:36.
38. Foster B. (editor), Electron-Positron Annihilation Physics. Adam Hilger, Bristol 1990;179:206.
39. Goeppert-Mayer M, Jensen JHD. Elementary Theory of Nuclear Shell Structure, Wiley, New York 1955, 1.
40. Foster B. (editor), Electron-Positron Annihilation Physics, Adam Hilger, Bristol 1990, 171.
41. Foster B. (editor), Electron-Positron Annihilation Physics, Adam Hilger, Bristol, 1990, p. 184; Kuzmin, V.A. Proceedings of the 1985 CERN School of Physics CERN 1986.
42. Heisenberg W. Über den Bau der Atomkerne. I. Z. Physik 1932;77:1.
43. Cassen B, Condon EU. On Nuclear Forces. Phys. Rev 1936;50;846.
44. Wigner EP. On the Consequences of the Symmetry of the Nuclear Hamiltonian on the Spectroscopy of Nuclei, Phys. Rev 1937;51:106.
45. Schrödinger E. Quantisierung als Eigenwertproblem. Ann. Physik 1926;384(4):361; 384(5), .437; 384(6), 489; 384(13):109.
46. Sachs RG. Nuclear Theory, Addison-Wesley, Cambridge, Mass 1953, 28.
47. Yukawa H. On the Interaction of Elementary Particles. I. Proc. Phys. Math. Soc. Japan 1935;17:48-57.
48. Lattes CMG, Muirhead H, Occhialini GPS, Powell CF. Nature 1947;159:694-697.
49. Pauli W. Meson Theory of Nuclear Forces, Wiley, New York, 1946; Sachs, R.G. Nuclear Theory, Addison-Wesley, Cambridge, Mass 1953, 169.
50. Frauenfelder H, Henley EM. Subatomic Physics, Prentice-Hall, Englewood Cliffs, N.J 1974, 124-129.
51. Kusch P, Foley HM. Precision Measurement of the Ratio of the Atomic `g Values' in the $^2P_{3/2}$ and $^2P_{1/2}$ States of Gallium. Phys. Rev. 1947, 72, 1256; The Magnetic Moment of the Electron 1948, 74, 250.
52. Goeppert-Mayer M, Jensen JHD. Elementary Theory of Nuclear Shell Structure, Wiley, New York 1955, 11.
53. McAllister RW, Hofstadter R. Elastic Scattering of 188-Mev Electrons from the Proton and the Alpha Particle. Phys. Rev 1956;102:851.
54. Goeppert-Mayer M. On Closed Shells in Nuclei. Phys. Rev. 1948;74:1969, 235; 1949, 75; Nuclear Configurations in the Spin-Orbit Coupling Model. I. Empirical Evidence 1950;78:16.
55. Haxel O, Jensen JHD, Suess H. On the "Magic Numbers" in Nuclear Structure. Phys. Rev 1949, 75, 1766; Z. Physik. 1950;128:295.
56. Sachs RG. Nuclear Theory, Addison - Wesley, Cambridge, Mass 1953, 197.
57. Wigner EP. On the Consequences of the Symmetry of the Nuclear Hamiltonian on the Spectroscopy of Nuclei. Phys. Rev. 1937, 51, 106; Hund, F. Symmetrieeigenschaften der Kräfte in Atomkernen und Folgen für deren Zustände, insbesondere der Kerne bis zu sechzehn Teilchen. Z. Physik 1937, 105**,** 202.
58. Dirac PAM, Proc. R. Soc. London A 1931;133:80.
59. Dirac PAM. Proc. R. Soc. London A 1928;117:610.
60. Breit G. The Effect of Retardation on the Interaction of Two Electrons. Phys. Rev 1929;34:553.
61. Pauli W. Zur Quantenmechanik des magnetischen Elektrons. Z. Physik 1927;43(9, 10):601-623.
62. Bethe HA, Salpeter EE. Quantum Mechanics of One-and Two-Electron Atoms, Springer, Berlin 1957, 181.
63. Slater JC. Quantum Theory of Atomic Structure, Vol. II, McGraw-Hill, New York 1960, 166.
64. Sard RD. Relativistic Mechanics, Benjamin, New York 1970, 355-359.
65. Sachs RG. Nuclear Theory, Addison-Wesley, Cambridge, Mass 1953, 214.
66. Sachs RG. Nuclear Theory, Addison-Wesley, Cambridge, Mass 1953, 198.
67. See remark by Jensen. J.H.D. to Goeppert-Mayer, M. in: Weber, R.L. Pioneers of Science, edited by Lenihan, J.M.A., The Institute of Physics, Bristol 1980, 192.
68. Bohr N. Neutron Capture and Nuclear Constitution. Nature 1936, 137, 344; von Weizsäcker, C.F. Zur Theorie der Kernmassen. Z. Physik 1935;96:431.
69. Pauling L. The Nature of the Chemical Bond, Third edition, Corrnell University Press. Ithaca, N.Y., 1960.
70. Hofstadter R. Fechter, H.R.; McIntyre, J.A. Phys. Rev 1953;92:978.
71. Sachs RG. Nuclear Theory, Addison-Wesley, Cambridge, Mass 1953, 17.
72. Gell-Mann M. A Schematic Model of Baryons and Mesons. Phys. Lett 1964;8:214.
73. Zweig G. CERN Report 8182/Th 1964, 401
74. Foster B. (editor), Electron-Positron Annihilation Physics, Adam Hilger, Bristol 1990, 173.
75. Fermi E, Yang CN. Are Mesons Elementary Particles? Phys. Rev 1949;76:1739.
76. Sakata S. Progr. Theor. Phys 1956;16:636.
77. Goudsmit S, Uhlenbeck GE. Over Het Roteerende Electron En de Structuur der Spectra. Physica, 1925 5, 266;Uhlenbeck, G.E.; Goudsmit, S. Ersetzung der Hypothese vom unmechanischen Zwang durch eine Forderung bezüglich des inneren Verhaltens jedes einzelnen Elektrons. Naturwissenschaften 1925, 13, 953; Spinning Electrons and the Structure of Spectra. Nature 1926;117:264.
78. Thomas LH. The Motion of the Spinning Electron, Nature 1926, 117, 514; Frenkel, J. Die Elektrodynamik des rotierenden Elektrons, Z. Physik 1926;37:243.
79. Sard RD. Relativistic Mechanics, Benjamin, Reading, Mass 1970, 295-298.

80. Brodsky SJ, Drell SD. The Present Status of Quantum Electrodynamics. Ann. Rev. Nuc. Sci. 1970;20147; Levine M.J.; Wright, J. Sixth-Order Magnetic Moment of the Electron. Phys. Rev. Lett 1971;26:1351.
81. Wu CS. The Neutrino, in: Theoretical Physics in the Twentieth Century, edited by M. Fierz and V.F. Weisskopf; Interscience, New York 1960, 253.
82. Dirac PAM. Proc. R. Soc. London A 1931, 133, 60; The Theory of Magnetic Poles. Phys. Rev. 1948;74:817.
83. Einstein A. On the Electrodynamics of Moving Bodies. Ann. Physik, 1905, 322(10), 891; Lorentz, H.A.; Einstein, A.; Minkowski, H.; Weyl, H. The Principle of Relativity, Dover, New York 1952, 35.
84. Buenker RJ. Relativity Contradictions Unveiled: Kinematics, Gravity and Light Refraction, (edited by C. Roy Keys) Apeiron, Montreal 2014, 94.
85. Lorentz HA. Amsterdam Proc. 1904, 6, 809; Larmor, J. Aether and Matter, Cambridge University Press, London 1900.
86. Jackson JD. Classical Electrodynamics, Wiley, New York 1962.
87. Buenker RJ. Rebuttal of Fermi’s Denial of Nuclear Electrons: Part II Adapting the XBPS Method to the Description of the Neutron’s Internal Structure, submitted for publication.
88. Buenker RJ. Rebuttal of Fermi’s Denial of Nuclear Electrons: Part IIIXBPS Calculations of the Neutron’s Internal Structure, submitted for publication.