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Fractional Charge Concept Opened Gates for New Ideas on Composition of Matter

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Abstract

Before the concept of quarks with fractional electric charges was introduced, the electron charge magnitude *e* was considered as the smallest amount of charge in nature so the charge of any object could be only an integer number of ± e. Then it was suggested that the proton and neutrons are composed of quarks with the fractional charges, combined in such a way that the total charge of a proton occurred to be that same known charge +e, and the charge of a neutron was zero. We suggest expanding that fruitful concept of fractional charges to build structural models of known particles as combinations of basic elementary particles with the charges of +e/3 and -e/3. Different structures made of particles with positive and negative fractional charges can have a positive or negative or zero net charge depending on the balance between the positive and negative fractional charges. Presenting the known “elementary” particles such as quarks and an electron as the composite structures made of basic elementary charges -e/3 and +e/3, it is possible to explain the intrinsic angular momentum (spin) and the intrinsic magnetic moment of the composite particles as resulting from the rotational motion of the basic elementary charges. We suggest that in nuclear reactions that include composite particles made of the basic elementary fractional charges, the total numbers of negative and positive basic elementary charges are conserved. The basic charges present in the reagents re-arrange but are in the same numbers in the products of the reaction as they are in the reagents.

Quarks are very essential building blocks of matter. The concept of quarks as particles with fractional charges was introduced independently by Murray Gell-Mann and George Zweig [see, for example, ref. 1]. The quarks are considered elementary particles with charge, spin, and magnetic moment. A detailed review of the history of quarks as particles with a fractional charge was presented by George Zweig [2]. Before introducing the concept of quarks with fractional electric charges, the electron charge magnitude *e* was considered as the smallest amount of charge in nature so the charge of any object could be only an integer multiple of ± e, and a proton and a neutron were considered as elementary particles. When the concept of quarks was introduced, it was suggested that quarks were elementary particles that had fractional charges (-e/3) and (+2e/3). In that model, protons and neutrons are composed of quarks with fractional charges, combined in such a way that the total charge of a proton is that same known integer charge +e, and the charge of a neutron is zero. It was suggested that not only protons and neutrons but some other particles such as mesons were composed of quarks with fractional charges of magnitude e/3 and 2e/3.

In view of the success of the new concept of particles with fractional charges, it seemed logical to us to expand the concept of fractional charges and suggest that quarks themselves and an electron are not elementary but composite particles made of basic elementary particles with fractional charges of magnitude e/3. The fact that the particles with an integer magnitude of charge (like a proton with charge +e) are compositions of positive and negative fractional charges with magnitude of e/3 and 2e/3, logically lead us to an idea that an electron, a particle with an integer charge -e, could also be a composition of fractional charges in such a combination that the total charge of the combination was -e. It was obvious that that composition could not be just 3 charges, each being -e/3, or two charges, -e/3 and -2e/3, because they would repel each other, and it would be needed to introduce another fundamental force that would “glue” the like charges, the same way as the strong nuclear force was introduced initially as a “glue” for holding multiple positive charges (protons) in nuclei.

The idea that quarks and leptons are not elementary but composite particles as some combinations of preons was reviewed in [3]. In our work [4], we suggested that the up and down quarks and some other “elementary” particles could be compositions of the basic elementary charges with fractional charges -e/3 and +e/3, composed in such a way that the total charge of a composite particle is the accepted fractional or integer charge value of that composite particle, such as (-e/3) for down-quarks , +2e/3 for up-quarks, and -e for an electron. This way there would be only two elementary particles (the basic elementary charges -e/3 and +e/3, and most, if not all, other particles would be composites made of these two elementary particles.

The spin of “elementary” particles such as quark or electron, was considered as an intrinsic property of elementary particles that had no explanation based on other known mechanisms. Assuming that the particles are built of elementary basic charges that have charge and mass but no other intrinsic properties like spin, it was natural to try to explain the intrinsic angular momentum (spin) of a composite particle being a result of some internal motion in it. While different previous attempts to explain the spin of an electron as the result of spinning an electron as a single body failed, the concept of known “elementary” particles being composed of basic elementary particles with fractional charges and mass opened a gate to new attempts of explaining the spin. An intrinsic angular momentum (spin) and spin magnetic moments of different composite particles consisting of basic elementary charges with mass can be explained as the results of revolving motion of basic elementary charges about some axis of symmetry in the composite particles.

In our models [4] of composite particles built of the basic elementary charges -e/3 and +e/3, the total charge of a composite particle is determined by the difference of the numbers of positive and negative basic charges. In [4], we suggested the simplest structures for composite particles with the total charges -e/3, +2e/3, and -e. A d-quark, with the total charge of -e/3, might be a structure consisting of one positive (+e/3) in the center and two negative (-e/3) basic charges revolving about the positive charge. But other structures with the total charge of -e/3 are possible, such as made of two +e/3 and three -e/3 charges. Similarly, a u-quark, with the total charge of +2e/3, might be a structure consisting of one negative (-e/3) and three positive (+e/3) basic charges, but a structure with two negative and four positive basic charges is also possible. Similarly, a structure with the total charge of -e (like an electron) might consist of one positive (+e/3) and four negative (-e/3) basic charges, but it might be built as other compositions where the number of -e/3 charges is larger by three than the number of +e/3 charges. The simplest structure of a composite particle with a charge of -e can be the structure of one +e/3 charge and four -e/3 charges. But even for this simplest composition, different 2-D or 3-D shapes are possible. In [4], we considered the simplest shapes.

Some other (neutral) structures are also possible, each consisting of an equal number of positive (+e/3) and negative (-e/3) basic charges. In our models, all the structures made of basic elementary charges are in revolving motion about some axis of symmetry, and they are at or near an equilibrium in the rotating frame of reference. In general, rotation of any structure made of basic charges +e/3 and -e/3 results in the angular momentum and the magnetic moment. The magnetic moment might be proportional to the angular momentum (spin) of the composite particle, but this is not always the case. For example, the neutral particle made of one +e/3 and one -e/3 charges and rotating about an axis through the point midway between the particles, would have a non-zero spin (the intrinsic angular momentum) but its magnetic moment would be zero.

In our approach, d- and u-quarks, an electron, and the suggested neutral particles are quarks composed of some number of basic elementary particles -e/3 and +e/3. As summarized in [5], “all commonly observable matter is composed of up quarks, down quarks, and electrons. …. quarks are never found in isolation; they can be found only within hadrons, which include baryons (such as protons and neutrons) and mesons, or in quark-gluon plasmas”. In our models [4] of composite particles, an electron is a quark. Hence, if it is a quark, it is the only quark that has been observed as an isolated particle, and its experimentally measured parameters (such as its spin and its spin magnetic moment) can be used to determine the mass of that basic elementary particle charge. In our work [4], the mass of the basic elementary particle of charge -e/3 was predicted to be 1/6 of the electron mass. The spin and the magnetic moment of each composite structure can be calculated using our models of the composite particles.

In our models, a fractional elementary charge does not have an intrinsic angular momentum (spin) and a magnetic moment, but a structure made of such elementary particles with charge and mass revolving about some axis does have spin and might have a non-zero magnetic moment. The stability of the structures made of the basic fractional elementary charges is achieved due to electrostatic interaction between the charges and their revolving about an axis of symmetry. Some elementary charges in a composite structure might be at some distance from the axis but some charges might be on the axis of rotation. For each charge located on the axis of rotation, the net electrostatic force in equilibrium must be zero, and this condition defines the location of all other charges. For the charges located not on the axis of rotation, it is convenient to consider the structure in a rotating frame of reference. The net force on any elementary basic particle (with charge and mass) in the rotating frame of reference must be zero (the net force on each basic particle in this rotating frame is the vector sum of the Coulomb's forces and the centrifugal force).

A composite structure of several basic charges might be at equilibrium in the rotating frame of reference, but the oscillations (3-D in general) might occur near the equilibrium state. An "effective spring constant" and natural frequencies of oscillations can be calculated for each type of oscillation.

As for the shapes of the structures made of the basic elementary charges, we can use the shapes of different molecules considered in organic and inorganic chemistry [6]. Our structures, however, are simpler in view of being composed of not different but the same particles (basic elementary charges of the same magnitude), with the bonds between the particles being the electrostatic Coulomb's forces.

Using for describing our models of quarks the models of molecules shown in [6], a d-quark might be a linear structure consisting of one positive (+e/3) charge in the middle and two negative (-e/3) charges on both sides, like a linear structure shown in [6] with the bonds at 180^o. The same way, a u-quark might consist of one negative (-e/3) charge in the middle and three positive (+e/3) charges arranged in a trigonal planar structure, shown in [6] with the bonds at 120^o.

Similarly, a simple model of a composite particle with the electric charge of -e might consist of one positive (+e/3) charge and four negative (-e/3) charges. The charges can be arranged in different shapes, though. For example, they can be arranged in a tetrahedral structure shown in Fig. 1. The entire structure can be in a rotational motion about the axis through the central positive charge and one of the negative charges.

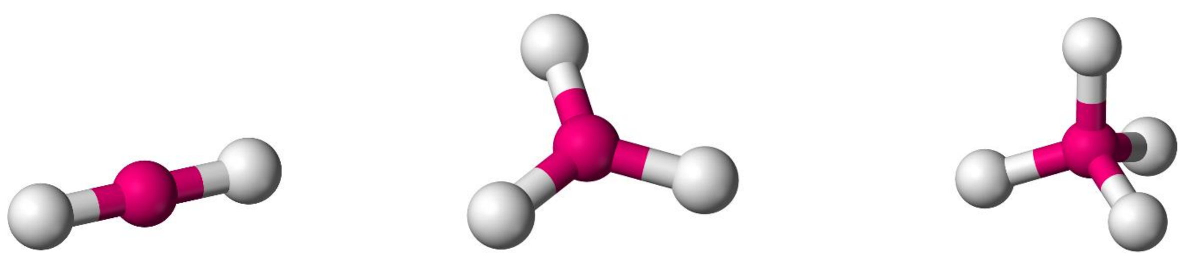
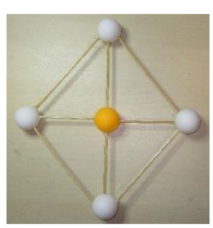


Fig. 1. The shapes of molecules shown in this images copied from [6]: left picture - a linear structure, central picture – a trigonal planar, and the right picture – a tetrahedral structure.

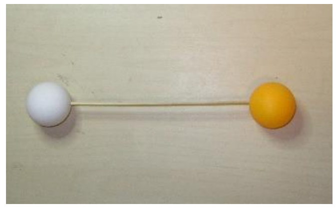
Another possible structure of a particle with the total charge of -e (like an electron) is a planar structure with one positive (+e/3) charge in the middle and four negative (-e/3) charges in the corners of a rhomboid, as suggested in [4]:



For the structure to be in equilibrium in a rotating frame of reference, it should be in rotational motion about the long axis of the rhomboid, passing through the central positive charge and two negative charges. The ratio of the long axis to the short axis in the rhomboid is about 1.04, as calculated from the condition of zero net electrostatic force on each charge located on the axis of rotation.

And one more possible shape of a composite particle with the total charge of -e (like an electron) is a square planar structure, where four -e/3 charges are located symmetrically around +e/3 charge at a 90° angle between the bonds.

For a structure made of the elementary basic charges (with mass), the revolving of each elementary basic particle contributes to the angular momentum (spin) and to the magnetic moment of the structure. If the particles revolve in the same direction about an axis, the magnitude of the spin of the composite particle equals the sum of the magnitudes of the individual angular momenta, independently on the signs of the charges. But the magnitude of the total magnetic moment, in general, is not proportional to the angular momentum of the structure – it depends on the signs of the revolving charges.



An example of a neutral structure made of the elementary basic charges is the structure of one positive (+e/3) charge and one negative -e/3) charge revolving about the axis through the point midway between the two charges as considered in [4]. Such a structure as a composite particle possesses a non-zero spin but has no electric charge, and its magnetic moment is zero.

Each composite particle (or set of composite particles) is made, in our models, of the basic elementary charges and contains definite numbers of positive and negative charges. In our models of quarks [4], d-quark consists of one positive and two negative basic charges, u-quark consists of one negative and three positive basic charges, and an electron consists of one positive and four negative basic charges.

A neutral composite particle might be a structure made of equal numbers of positive and negative basic elementary charges. For example, a π-0 pion is known to consist of d-quark and its antiquark $\bar{d}$. In our models, each of these consists of elementary basic charges: $d(1+, 2-)\ and\ \bar{d}(1-, 2+)$. Hence, a π-0 pion, in our models, contains three +e/3 charges and three -e/3 charges.

We suggest that the basic elementary particles of charges +e/3 and -e/3 cannot be created or destroyed, but they can join in different structural arrangements to form different composite particles. For example, the beta-decay reaction is described as conversion of a neutron into a proton, with emission of an electron. Notice that while protons and neutrons are parts of the nucleus, an electron is not present as a component of a nucleus but is created in the beta-minus-decay nuclear reaction. This fact hints that an electron might be not an elementary particle but a structure that consists of some other particles and can be formed as a combination of those particles. This is consistent with our models of electron. Basing on the assumption that the elementary basic charges are present in reagents of the nuclear process and just re-arrange to form other structures (the products of the nuclear process), we suggest that the total numbers of positive and negative basic elementary charges should be conserved in any nuclear reaction.

As an example, let us apply the principle of conservation of numbers of positive and negative basic elementary charges to the case of beta-decay. The beta-decay of a neutron to a proton is described as transformation of one of the d-quarks of a neutron into a u-quark, as presented in the Feynman diagrams (shown at the left of Fig. 2, a copy from [7]). A beta-plus decay includes a transformation of a proton to a neutron where one of two u-quarks of a proton converts to a d-quark as shown at the right in Fig 2. The possibility of transforming one type of quark to the other is simply postulated, without any explanation.

If our models of quarks and other composite particles correctly reflect the content of those particles, some extra basic elementary particles are needed for the beta-decay, in addition to the basic particles available in the d-quark, to form a u-quark and an electron. From the principle of conservation of the numbers of positive and negative basic elementary charges and counting them in the products of the beta-decay nuclear reaction, the equation for the neutron beta-decay process can be modified by adding a $\overline{u}$ -quark to the reactants so the combined numbers of positive and negative fractional charges of magnitude e/3 in the reactants [d-quark (one +e/3 and two -e/3) and $\overline{u}$ -quark (one +e/3 and three -e/3)] would be equal to the numbers of those fractional charges in the products of the reaction [u-quark (three +e/3 and one -e/3), electron (one +e/3 and four -e/3), and an electron antineutrino (assuming that it is composed of one +e/3 and one -e/3 charges)]:

$$d + \bar{u} \rightarrow u + e^{-} + \overline{\nu_e} \quad (1)$$

The transformation of a proton to a neutron in the beta-plus decay is assumed to be based on conversion of one of two u-quarks of a proton to a d-quark. To fulfil the condition of conservation of the numbers of positive and negative basic elementary charges, we suggest adding a $\bar{d}$-quark as a reactant. As a result, the reaction of conversion of a proton (uud) to a neutron (ddu) and a positron can be written as the result of conversion of one of the u-quarks of a proton into d-quark but with an additional $\bar{d}$-quark taking part as a reactant in the reaction:

$$u + \bar{d} \rightarrow d + e^{+} + \nu_e \quad (2)$$

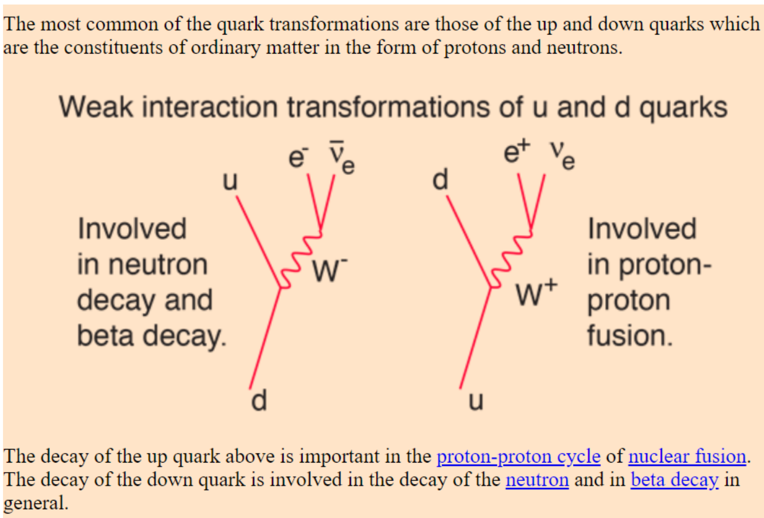


Fig 2 (a copy from [7]): Feynman diagrams for beta-minus and beta-plus transformations.

Conclusion

In our previous paper [4], we suggested expanding the fruitful concept of fractional charges to build structural models of known particles as combinations of elementary basic particles with the charges of +e/3 and -e/3. Different structures made of such basic elementary charges +e/3 and -e/3 can have a positive, negative, or zero net charge depending on the balance between the charges. Using the composite structures made of charges -e/3 and +e/3 as the structures of known "elementary" particles such as quarks and an electron, it is possible to explain the intrinsic angular momentum (spin) and the intrinsic magnetic moment as resulting from the revolving motion of the basic elementary charges. We suggest that the total numbers of negative and positive basic elementary charges are conserved in nuclear reactions. The basic charges present in the reagents can re-arrange to form other structures (products). Counting the basic elementary charges, nuclear reactions can be balanced similarly to the way the chemical reactions are balanced by counting individual atoms in the reactants and products.

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