electrons are less likely to have the more highly energetic collisions with the conduction electrons. As a result, photons will be produced in such collisions at a lower temperature in the lighter isotope. This is mentioned because this is exactly what is found and because the recent discovery of this fact has disproved the conventional theory of superconductivity, which predicted the inverse. This was reported by Fowler *et al.* (1967), who found that uranium 235 becomes superconductive at 2·1°K and uranium 238 becomes superconductive at 2·2°K.

The Velocity-dependence of Mass

The expression $E=Mc^2$ applies to electric field energy. It follows that when we consider an electric charge in motion as having a kinetic energy, a magnetic energy and a dynamic electric field energy, as we did in explaining the problem with the Compton Effect, we are fortunate that one of these items, the magnetic energy, is negative and cancels one of the others. This really means that the dynamic electric field energy alone can be regarded as the motion energy of the charge. Since $E=Mc^2$ applies to such energy, the problem we now face is that mass must increase as the electric charge increases velocity relative to the electromagnetic reference frame. Here, it is necessary to talk about motion relative to the electromagnetic reference frame because it is in this frame that the magnetic field is induced and with it the dynamic electric field. It remains to be seen in our later discussions what physical form is to be attached to the means sustaining the magnetic field. Whatever these means are, we must assume that they have a co-operative influence in determining both the dynamic electric field and the magnetic field. It may be that very close to the electron itself there is nothing to support the magnetic field. But this does not matter as far as the analysis of the energy radiation is concerned. Nor does it matter in the earlier calculations of magnetic energy and dynamic electric field energy, because these latter quantities cancel. It does matter in calculating the mass effect of the dynamic electric field, in view of the assumed equality of the dynamic electric field energy and kinetic energy. To proceed, it is assumed that, at least over a period of time, the statistical mean value of the dynamic electric field energy is equal to the kinetic energy so that the latter can be regarded as offset by the magnetic energy, leaving the electric field energy as the only mass-containing quantity.

On this basis, from $E = Mc^2$ we can say that a mass M moving at velocity v has momentum $Mv = Ev/c^2$. Force is the rate of change of momentum and when this is multiplied by v we have rate of change of energy. Thus:

$$v \frac{d}{dt} (Ev/c^2) = \frac{dE}{dt} \tag{1.16}$$

When solved, this gives:

$$E = E_o / \sqrt{[1 - (v/c)^2]} \tag{1.17}$$

The corresponding mass relationship is:

$$M = M_o / \sqrt{[1 - (v/c)^2]} \tag{1.18}$$

This result shows that mass increases with velocity in the electromagnetic reference frame. It shows that there is a limiting velocity at which mass will become infinite. This is when v becomes equal to **c**, the speed of light. The increase of mass with velocity is well known from experiment, as already mentioned earlier in this chapter.

Fast Electron Collision

A direct experimental support for the non-radiation of energy by an accelerated electron is also afforded by collisions between fast electrons and electrons at rest. Using a Wilson cloud chamber, Champion (1932) has shown that when an electron moving at high velocity (of the order of 90% of the speed of light) collides with an electron at rest the resulting motion of the electron satisfies the formula in (1.18). On simple Newtonian mechanics the angle between the electron tracks after collision should be 90°. Using the above relation between mass and velocity and specifying *no loss of energy by radiation*, the conservation of momentum in the collision process leads to the formula:

$$\cos(\varphi + \theta) = \frac{(m/m_o - 1)\sin\theta\cos\theta}{[(m/m_o + 1)^2 \sin^2\theta + 4\cos^2\theta]^{\frac{1}{2}}} \tag{1.19}$$

where m is the mass of the incident electron as given in terms of its rest mass m_o using (1.18), and θ and φ are the angles between the electron tracks after collision and the direction of motion of the incident electron.

By measuring the velocity of the electron before collision and these two angles, Champion was able to verify equation (1.19) as taken in conjunction with (1.18). Now, although in such experiments one would expect quite significant radiation of energy by accelerated electrons using the classical formula discussed above, Champion was able to conclude as follows: "Considering the total number of collisions measured it would appear that, if any considerable amount of energy is lost by collisions during close encounters, the number of such inelastic collisions is not greater than a few per cent of the total number."

Electrons and Positrons as Nuclear Components

So far, the electron has been the topic of interest. Presently, following this chapter, we will enquire into some of the field interaction properties of the electron and its electrodynamic behaviour as a current element. Thereafter, we will study its role inside the atom and later its role in the atomic nucleus itself. However, it is appropriate at this stage to outline briefly the potential which the electron, as portrayed in this chapter, has in nuclear theory. This will be done without recourse to quantum electrodynamics or even wave mechanics. An omission, to be rectified in a later chapter, is the analysis of the spin properties of the electron and its anomalous magnetic moment. An explanation of spin is important, if only as a check on the theory offered to account for any elementary particle. For the moment, spin is ignored.

As mentioned earlier in this chapter, quark theory invites us to believe that the proton consists of three elementary particles in close aggregation. This quark theory is untenable with the theory presented in this work. Here, there is complete reliance upon the indivisibility of the charge quantum e, so far as it appears in matter. It will, however, be a contention of this theory in Chapter 7 that the proton does comprise three elementary particles as required by quark theory, but these are the electron, the positron and a heavy elementary nucleon of positive charge e. The positron was discovered in 1932. It appeared in cosmic rays and is, of course, merely a particle exactly like the electron but with a positive charge e. Positrons are ejected from radioactive substances, which suggests their existence in the atomic nucleus. It has been found that a proton can lose a positive electron, or positron, and become a neutron. Also, a neutron can lose a negative electron and become a proton. This suggests that the proton and neutron must each contain an electron and a positron. Both must contain the heavy nucleon just mentioned, and the neutron must have one electron in addition. Now, all this supposes that there are no interchanges of polarity or energy exchanges in these various transmutations. This is unlikely. Indeed, if we go on to consider the combination of the neutron and the proton, it has been suggested that they might be bound together by what is called an "exchange force" arising because they are rapidly changing their identity. The suggestion is that they are exchanging the electrons and positrons as described above, so that, according to a proposal by Fermi, the neutron and proton are really different quantum states of the same fundamental particle. Now, this may be true, but we should not blind ourselves to the other possibilities. If we know that these elementary particles are aggregations of electrons, positrons and some heavy particles, and we know the physical size of these particles, as explained earlier in this chapter, it is worth while examining what follows from this knowledge. The result contains a double surprise, and is all the more gratifying because of its simplicity.

The deuteron, the nucleus of heavy hydrogen, is the particle form to be expected when a proton and a neutron are bound together. We will assume that this deuteron, which has a mass of the order of two protons and a charge e which is positive, comprises two identical heavy particles and some electrons or positrons or a mixture of both. Then there are a number of possible configurations having electrostatic stability. For one of these the energy has a minimum value. This configuration is deemed to be that of the deuteron. Its electrostatic interaction energy is a measure of the nuclear binding energy. It is the energy needed to separate the nuclear components well apart from one another. How far apart is critical to the analysis if we wish to be exact, but for the initial study in this chapter we assume separation to infinity. The binding energy of the deuteron is known from measurements. Hence, the theory can be checked.

In Fig. 1.3 different models of possible deuteron configurations are shown. Model A depicts two heavy positively-charged particles of mass M. They have a very small radius because for a discrete charge e the electrostatic energy is inversely proportional to radius, as shown in Appendix I. In model A there is one electron located between the two heavy particles, or H particles as they will be denoted. Since the charges act from their particle centres, the radius a of the electron becomes the only significant dimension in the analysis. Then, the energy of deuteron model A is $2M+1$ electron units plus the interaction energy. It is convenient to evaluate mass quantities in terms of the electron mass as a unit. The interaction energy comprises three components. Between one H particle and the electron there is an energy $-e^2/a$. Between the other H particle and the electron there is the same energy $-e^2/a$, and between the two H particles there is the positive energy $e^2/2a$. The total interaction energy is $-1{\cdot}5e^2/a$. Now, we will put:

$$ke^2/a = mc^2 \tag{1.20}$$

where k is a constant and m is the mass of the electron. Then, in the units of mass for which m is unity we can express the total energy of model A as $2M+1-1{\cdot}5/k$.

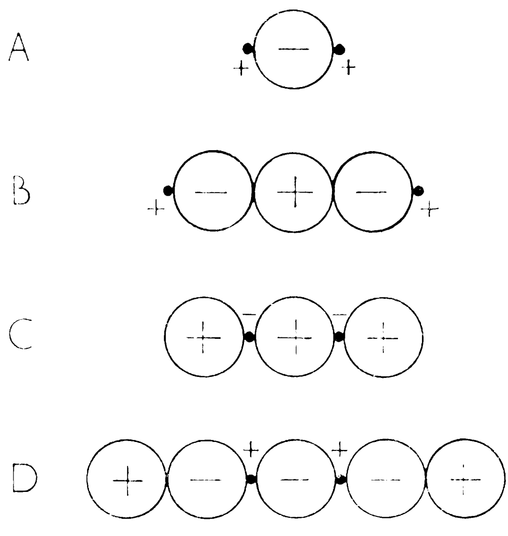

Fig. 1.3

In similar manner the other models of the deuteron presented in Fig. 1.3 can be analysed. An energy evaluation for each model shown results in the following masses:

A $2M+1-1{\cdot}5/k$
B $2M+3-2{\cdot}317/k$
C $2M+3-2{\cdot}917/k$
D $2M+5-3{\cdot}558/k$

For different values of k the deuteron could be different, since the deuteron will be the one of smallest total mass. Even so, the term involving k is the binding energy of the deuteron, and it is known from experiment that this binding energy is about 2·22 MEV or 4·35 electron mass units. Thus, proceeding from this we can derive k. Firstly, if model A is the minimum mass model, k has to be about 0·35 to assure that $1{\cdot}5/k$ is 4·35. Then we can see that model C has lower energy still, which makes us rule out model A. Model B is ruled out on direct comparison with model C. If model C is chosen, then k will be about 0·67. This gives model C slightly less overall energy than model A. It has also less energy than the other models, as may be verified by continuing this exercise. It will be found that model C is the only one able to explain the measured binding energy of the deuteron. Thus, if this theory is correct k should be 0·67, which is verification of the 2/3 factor already deduced earlier in this chapter by reference to Appendix I.

If we pause to comment on this verification that k is 2/3, we note that there are now available the following mutually-supporting points. Firstly, the magnetic field energy induced around a spherical electron of radius a in motion has a mass equivalence, if equated to kinetic energy, which puts k as 2/3. Secondly, if we assume that the constraint or binding action at the surface of the electron is such that the repulsive forces within the electron develop a uniform pressure throughout its volume, k is 2/3. This is proved in Appendix I. Thirdly, if we assume that the electric charge e of the electron is distributed throughout the body of the electron to cause the electric field or energy density to be uniform, k is 2/3. This is mentioned in Appendix I. Fourthly, it so happens that if k is 2/3 the deuteron binding energy is explained and the deuteron is identified with the model C in Fig. 1.3. It follows that there is little scope for doubt about the real nature of the electron. There have, indeed, been two surprises from this analysis. The first is that the deuteron energy is calculable on such a simple model, one which happens to be the least mass form. The second is that although the form of the electron had been deduced by separate analysis, we were able to find an empirical approach using experimental data to verify that the energy of the electron is $2e^2/3$ divided by its radius.

It is noted that a value of k of 2/3 used in connection with model C results in a binding energy of 4·375 electron units, or about 2·24 MEV. In Chapter 7 it will be shown that we can take this further to find the exact value of the deuteron binding energy. As it is, it suffices that the theoretical figure is within 1% of that measured.

Summary

In this chapter the reader has been shown that there is purpose and merit in regarding the electron as a spherical ball of charge. The quantitative analysis has drawn attention to the need to regard magnetic energy as a negative quantity, a feature which is compatible with other physical theory, and this has led to an understanding of the mass properties of the electron. In previous textbooks the dynamic component of the electric field energy has not be considered. Another omission in the past has been an inclusion of the field needed to accelerate the electron when studying its radiation effects. By rectifying these omissions, a new insight into physics has become available, with consequent benefits. It is incredible to the author that the classical formula for the energy radiated by the accelerated electron could have been accepted when it has no dependence upon the mass or size of the electron, but, be that as it may, it has been proved that non-radiation leads us to understand the nature of mass and the derivation of the relation $E=Mc^2$. The increase in mass with velocity follows from this relation, as is well known. Accordingly, although the law $E=Mc^2$ and the velocity dependence of mass are regularly ascribed to Einstein's theory, their existence in no way makes Einstein's theory an essential part of physics. They do not depend upon Einstein's Principle of Relativity. The chapter has been concluded by showing that the deuteron binding energy can be calculated to provide a result highly compatible with the model of the electron presented. This demonstrates one of the potential applications of this theory of the electron. The analysis of the atomic nucleus is an important subject in this work, as will be seen later in Chapter 7. Meanwhile, it is hoped that the reader may be beginning to realize that Nature is not quite as complicated in the realm of truly fundamental physics as might appear from modern mathematical treatments.

END OF SECTION NOTE

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