electrons and positrons that are formed. Also, any normal electrons and normal positrons mutually annihilate to feed energy back into the muon formation process, which only stops when all the energy has been used up. The hypothesis that spin and non-spin energies are separately conserved, as applied to the merging of the residual electrons and positrons, will endow the muon with a g-factor given by (191). Its resonant cavity radius will be much smaller than that of the electron and its resonant frequency very much higher than that of the space medium. However, albeit with recourse to hypothesis, we have obtained extremely good quantitative results and this encourages further enquiry into the nature of these processes, guided by the theory here suggested.

The author has already drawn attention to the curious fact that the g-factor for the point charge given by (189) is almost identically the average of the measured g-factors of the electron and the muon.* The discrepancy appears to be the gravitational potential factor φ/c^2 or $1{\cdot}06\ 10^{-8}$.

Thus the average of the measured values given in (192) and (127) is:

$$g = 1{\cdot}001162776 \qquad (193)$$

Putting α^{-1} as 137·036 gives, in (189):

$$g = 1{\cdot}001162760 \qquad (194)$$

An increase in α by one part in a million will increase g by 1·16 parts in 10^9 and since α is known to this order of accuracy the last digit in (194) could only be increased by 1 on this account. Also, experimental error makes the last digit in (193) uncertain to about 3 in all probability. Hence there is a discrepancy suggesting that the mass in spin is less than that in normal motion by an anomalous factor a little over 1 in 10^8, suggesting the gravitational potential explanation.

The point charge concept seems, therefore, to play a role in the g-factor anomaly. The gravitational potential argument has support. Therefore, whatever view one has about conventional quantum electrodynamics as providing the true explanation of the anomalous g-factor, these issues bear consideration. Also, it is mentioned that in the author's paper just referenced, attention is drawn to the work of Sachs in explaining the Lamb shift by methods not relying upon conventional quantum electrodynamics. This is important because

* H. Aspden, *International Journal of Theoretical Physics*, **16**, 401 (1977).

the Lamb shift is usually taken along with the anomalous g-factor theory as the main support for quantum electrodynamic theory.

The theory, as so far developed, has not yielded an understanding of the intrinsic spin properties of particles, particularly their magnetic spin moments. In an earlier version of this work (the author's book *Physics without Einstein*) some progress in this regard was claimed. However, these early ideas do not warrant inclusion in this present work. A result which is worth mentioning is the newly-discovered technique for deriving the proton spin magnetic moment. Until similar methods can be applied to other particles this approach must be regarded as tentative. It is of special interest owing to the extremely accurate result obtained.

The gyromagnetic properties of a simple charge are known to be given by the formula:

$$\frac{(MM)}{(AM)}=\frac{e}{mc} \tag{195}$$

At the end of Chapter 2 we showed that this arose from a half-field reaction effect, as in normal theory we would expect the ratio of magnetic moment (MM) to angular momentum (AM) to be $e/2mc$, where e/m is the charge-mass ratio of the particle under study.

The half-field reaction will now be applied to a complex of protons and muons in which the protons are reacting to the muon fields in spin. Thus:

$$(AM)=(m_\mu c/e)(MM)-(m_p c/e)\tfrac{1}{2}(MM) \tag{196}$$

Here m_μ is the muon mass and m_p the proton mass. This gives the angular momentum of the complex per muon, it being the muon angular momentum $h/4\pi$ offset by that of the reacting proton system. Thus (196) can be written as:

$$(AM)=(h/4\pi)(1-m_p/2m_\mu) \tag{197}$$

Now this is a non-integral angular momentum quantum. Ideally, it should be exactly balanced by something in counter-spin. Also, although we have spoken of a proton reacting in the muon complex, we may just as well have referred to H particles. The same formula (197) would follow because the H particles have the same mass as the proton. Looking then for a system to set in counter-spin, let us take the proton form as presented in Fig. 27. Divide the angular momentum between its H particle and the electron-positron pair in proportion to their masses. Then assume a slight separation so that the H particle spins about its own central axis x–x but the electron-positron pair reacts to an applied magnetic field and also spins in the manner shown in Fig. 31. The electron and positron rotate

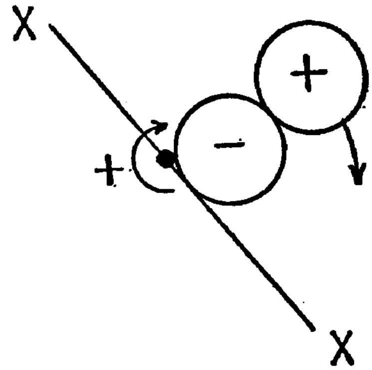

Fig. 31

together about the spin axis and this axis touches the innermost member of the pair.

The muon complex is not shown but it has shed angular momentum given by (197) to the system shown. The H particle in Fig. 31 asserts no magnetic moment. Its angular momentum has no contribution to the resonance state in spin. It may have its own spin angular momentum $h/4\pi$ in addition to that added by this interaction. The electron-positron charge pair will assert a magnetic moment related to the angular momentum added. This magnetic moment is moderated by a form factor f. The outermost charge contributes 3^2 times as much magnetic moment and angular momentum as the innermost, because it is at three times the radius. However, the charges are opposite in polarity. Thus their magnetic effects offset each other and their angular momenta add. f becomes 3^2-1 divided by 3^2+1, or 0·8. The magnetic moment of the charge pair is then 0·8 times $e/2m_ec$ times their combined angular momentum. The $2m_e$ factor is the mass of the electron plus positron. Their angular momentum is $2m_e/m_p$ times the expression given by (197). Therefore the measured spin magnetic moment should be:

$$(MM)_p = (eh/4\pi m_p c)(0{\cdot}8)(m_p/2m_\mu - 1) \qquad (198)$$

The actual measurement of proton spin magnetic moment is based upon a frequency observation and referenced on the nuclear magneton $eh/4\pi m_p c$. Bearing in mind the result we obtained in expression (115), there is cause for wondering whether the basic angular momentum quantum of $h/4\pi$ assigned to fundamental particles is offset by the factor 2α in experiments referenced on atomic behaviour. Experimental data could, conceivably, have overestimated the spin magnetic moment of the proton by the factor $1/(1-2\alpha)$. If this were so, then, in nuclear magnetons (198) would need to be changed for comparison with experiment to become:

$$\frac{0{\cdot}8}{1-2\alpha}(m_p/2m_\mu - 1) \tag{199}$$

This is such a simple formula, though its derivation is naturally unlikely to be accepted without considerable reservation. The point of interest is that we have found values for both α and m_μ/m_p in very accurate accord with experiment and so (199) should be determined with equal accuracy. With α^{-1} as 137·0359, m_p as 1836·152, m_μ as 206·7689 we obtain a value of (199) of 2·792846, which compares with an experimental value of 2·7928456. The last digit of the muon mass is critical to this agreement. Yet, in (193) we saw that the theory gave a figure of 206·7688 for this muon quantity. This is accord to within one part in two million.

Before leaving the subject of the muon, we will next deduce its lifetime. We find that this depends upon the migration of the virtual muons around the space cell. We also need to digress a little to discuss the nature of electric charge.

There is good reason for attributing a spherical form to electric charge. The difference between the positive and negative character of charge can be depicted as in Fig. 32. The arrows represent the directions of an electric field. Equally they could depict a state of

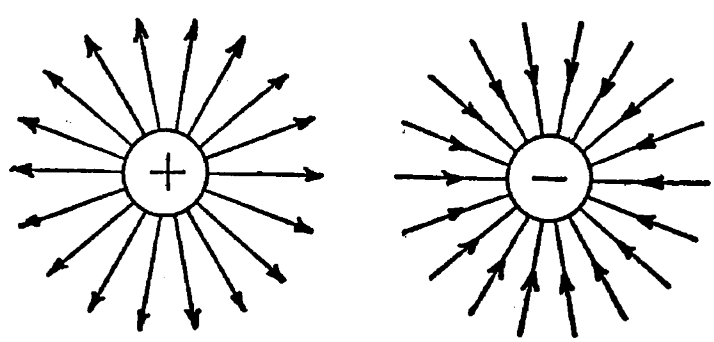

Fig. 32

motion. Presume, for example, that all charges of one polarity are expanding at any moment of time and all charges of opposite polarity are contracting. This is a workable hypothesis on the basis of the theory presented because the space medium has a universal frequency. If the charges are stable then there must be such a harmonic oscillation in their processes of expansion and contraction. Positive and negative then really signify a phase relationship, a difference of 180°.

The interaction between two charges of opposite polarity is then a mutual oscillation, depicted in Fig. 33 by imagining that the arrows reverse cyclically.

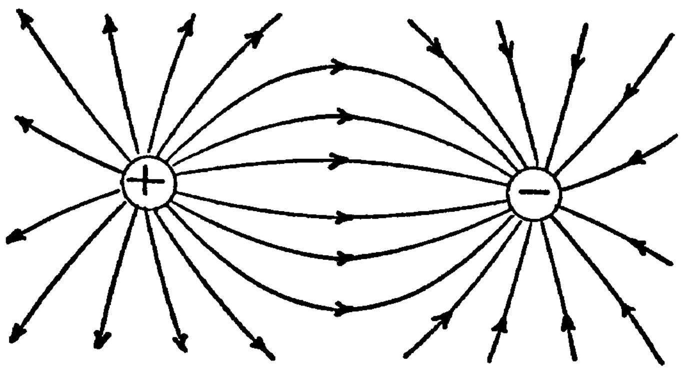

Fig. 33

We have noted that the size of the sphere containing the unit charge *e* is a measure of the energy of the particle. The number of flow lines radiating from a sphere is a measure of its charge. Beyond the resonant radius from each charge the field intensity in its interaction with the intensity of other fields determines the probability of energy quanta existing locally in the form of virtual electrons and positrons. These are themselves charge pairs as depicted in Fig. 33.

Imagine this pair of charges to become unstable, meaning that the contraction process fails to reverse in keeping with the phase of the oscillation. Then one charge will collapse to a point. The other will develop into a sphere of twice the normal volume, assuming that the interacting charges are of like size. This is illustrated in Fig. 34. The system is without character. The lines are devoid of meaning. They bear no arrows and do not symbolize motion. What has happened to the energy? Has the charge pair lost all its intrinsic character?

The residual spherical void will, by its volume, have some significance, provided we declare that the medium between the charge sphere is 'incompressible'. It retains the latent capacity to contract and, in so doing, it can nucleate a point source of motion elsewhere in the field. The point action is momentary only as the new charge is induced, its polarity being determined by the timing of its creation. Thus mutual annihilation of electron and positron means that they stop 'breathing' in and out, one ending in a point and the other in

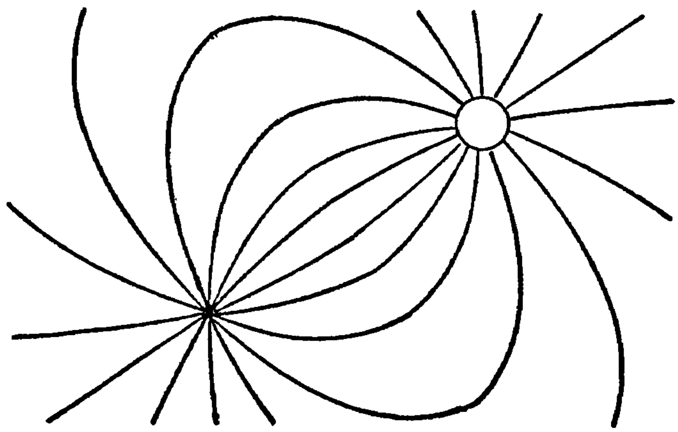

Fig. 34

an enlarged void. Their polarities are lost with this stoppage. However, the enlarged void is the seat of creation of a new electron or positron depending purely on the phase of the rebirth and the paired charge can appear from a point anywhere in the near vicinity. Thus these events of creation and annihilation can occur constantly as virtual pairs migrate all over the field. The real mystery is the nature of the energy quanta. The energy of the electron or positron is presumably the standard quantum. However, the smaller the residual voids associated with charge, the greater the energy quanta directly linked with charge. For our purposes, the energy formula $2e^2/3x$ used throughout this work need only be valid for charge in its stable state. Energy could be characteristically constant for any pair of charges and could be shared equally between them if they operate as 'virtual' pairs.

From this speculative exercise we are led to the proposition that space is permeated by charges which migrate at random by a process of annihilation and recreation proceeding at the natural oscillation frequency of the universe. A point charge arising from one of the two virtual systems, the electron-positron system or the muon system, can appear anywhere. A point charge from the electron-positron virtual field system will essentially develop into a stable charge for a short period anywhere in the field outside the resonant charge cavities. An electron point charge might appear anywhere, even inside another electron. We need, however, only consider the entry of the virtual muon into the charge of the real muon.

The line intensity within any charge sphere is uniform. This allows us to calculate the total energy. A charge of radius x has a field line intensity at its surface of e/x^2. This applies throughout its volume $4\pi x^3/3$. It corresponds to an energy term $e^2/6x$, which, when added to the energy outside the radius x of $e^2/2x$, gives $2e^2/3x$.

If a point charge e of opposite polarity appears within x at radius y then the energy becomes:

$$E' + e^2y/x^2 - 4e^2/3x \tag{200}$$

where E' is the energy of the point charge. To verify this note that the uniform energy density means that the base charge within a radius y is proportional to y^2. It asserts a steady force on a charge displaced from the centre outwards. Hence the term e^2y/x^2. Also each shell of basic charge of unit thickness contains charge $2ey/x$ and so has an interaction energy $-2e^2/x$ with the point charge if central. To this we must add $2e^2/3x$ for the base charge alone to obtain the last term in (200).

We now imagine the condition for decay to be set by the above energy falling below a certain threshold. This is set at the energy zE, where E is the energy of the real muon. Thus (200) can be expressed as:

$$E' + (3/2)E(y/x) - 2E < zE \tag{201}$$

The space frequency m_ec^2/h or $1{\cdot}2356\ 10^{20}\ s^{-1}$ is the migration frequency of the point charge muon pairs of energy $E' = \frac{1}{2}E_0$, where E_0 is given by (160). The value of E has been given in (193) in terms of m_ec^2. The volume of a sphere of radius y within which the point charge of the correct polarity must come to trigger decay is $(y/x)^3(m_ec^2/E)^3$ times the electron volume. In a unit space cell there are $(E_0/m_ec^2)(1843)^{4/3}$ electron volumes from the analysis leading to (160). From (160) this latter quantity is 9,324,644. Substituting E from (193) gives a lifetime T of:

$$T=\frac{(9{,}324{,}644)(206{\cdot}7688)^3(x/y)^3}{1{\cdot}2356}10^{-20}\text{ seconds} \qquad (202)$$

From (160) E' is 206·3329 m_ec^2 and this is $(1-0{\cdot}002108)E$. Therefore (201) becomes:

$$(3/2)(y/x)=(z+1{\cdot}002108) \qquad (203)$$

If we simply wrote $(3/2)(y/x)$ as unity then (202) would give $T=2{\cdot}25$ 10^{-6} seconds, which is close to the measured muon lifetime in its rest state.

If, however, we recognize the need to salvage the charge annihilated and say that an electron and positron are ejected in touching relationship, the value of zE is 1·25 m_ec^2. This follows from (166). Then z has the value 0·0060453. Then, using this in (203) and (202), we obtain:

$$T=2{\cdot}1973\ 10^{-6}\text{s}$$

The observed value* is $2{\cdot}197134\pm0{\cdot}000077\ 10^{-6}$s.

The decay can be depicted thus:

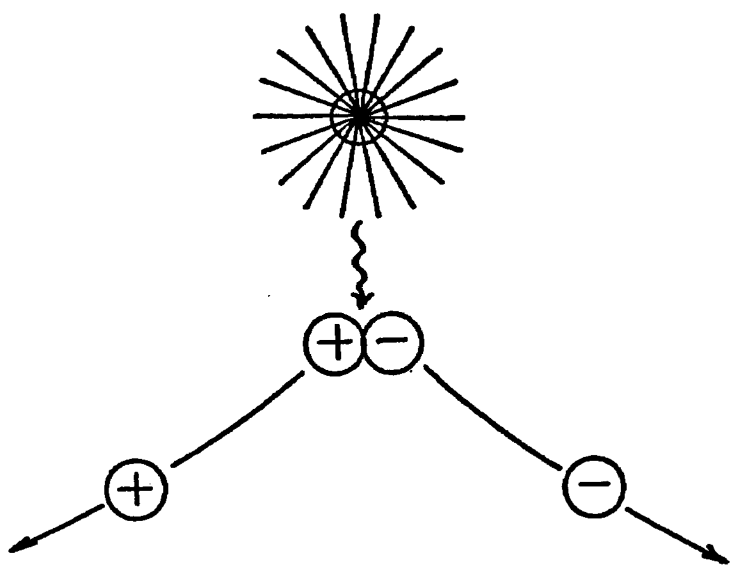

Fig. 35

Having given reason for the decay of the muon at rest, it becomes now feasible to explain how this decay is affected at high speeds.

In discussing Fig. 33 it was shown how the field interaction is always closed between two equal and opposite charges, regardless of their respective energies. These energies determine the individual

* *Review of Modern Physics*, **48**, 2, Part II, April, 1976.

stable-value radii x_1 and x_2 of two such charges, which collectively share a total energy E and a total space volume V given by:

$$E=(2e^2/3)(1/x_1+1/x_2) \quad (204)$$

$$V=(4\pi/3)(x_1^3+x_2^3) \quad (205)$$

Now imagine a situation close to the fully degenerate state depicted in Fig. 34. One charge can thus exist transiently as a point charge if the oscillations remain in phase for a short period before the field energy needs to restore equilibrium. The basic character of the two interacting particles remains in the unique determination of x_1 and x_2 from (204) and (205), bearing in mind the constancy of E and V throughout this disturbance.

Take now the muon moving at speed and having x_1 determined by its total energy βM_0c^2, where β denotes the expression $(1-v^2/c^2)^{-\frac{1}{2}}$ of equation (65) in Chapter 4. With x_1 fixed it becomes possible to imagine that the muon in motion could exist in point charge form for short periods of association with other charge of opposite polarity encountered in its progress and regardless of the nature of such other charge. In the intervening periods the muon would have different form, its full spherical form of radius x_0, as determined by its rest-mass energy:

$$M_0c^2=2e^2/3x_0 \quad (206)$$

In contrast:

$$\beta M_0c^2=2e^2/3x_1 \quad (207)$$

The hypothesis is that during these intervening periods the muon is in company with pairs of virtual muons, which account for the remainder of the energy. This is necessary, as will now be shown, because we need to conserve charge, energy and space throughout the successive quantum electrodynamic transitions of the muon when in motion. In Fig. 36 the muon is shown to change from state A to

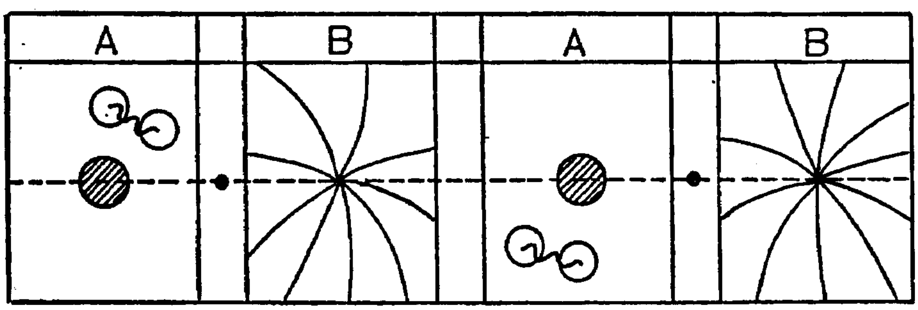

Fig. 36

state B and back again as it progresses from left to right. The trajectory of the muon is shown by the broken line.

In state A we have the basic muon of charge radius determined by its rest mass. It shares its total dynamic energy with virtual muon pairs of the same standard size. In transition from A to B the whole energy is carried by a single muon charge contracted now to the radius x_1. This transition is very short-lived. In state B the muon has gone into a degenerate form in association with a nearby charge of opposite polarity. Only the field lines from the point muon signify the locality of this nearby charge. The reverse process occurs in reverting back to state A, and so we have a constant alternation between states. Throughout, it is necessary to have a statistical conservation of energy, as between numerous muons in state A in any system at any moment of time. Also it is necessary to have a statistical conservation of space for each individual muon over periods including both states. This sets the further condition that state A will endure for $1/\beta$ of any time interval and state B for the remainder of that time interval. Note then that $1/\beta$ times the volume of the β muons of rest-mass size in state A gives the mean muon volume over a period of time as that of a single muon. Owing to the point charge character of the muon in periods of state B, the decay mechanism is restricted to the periods of state A. This results because y in (202) is effectively zero in state B. The decay in state A requires the migrant space charges to enter the basic muon. It is irrelevant if decay of one of the virtual muons is triggered, because these are in a constant state of annihilation and creation. The event would only trigger a transition back to state B. The muon would still exist. Note, however, that the virtual muons in a pair, if created at the separation distance of the C and G frames of the space medium, are much closer together than their distance from the basic muon, since they must lie outside the resonant field cavity radius. This precludes the muon from getting involved in the annihilation and creation processes of the virtual muons.

It follows from the above account that the lifetime of the muon is constant as measured only in time spent in the state A. Since this is $1/\beta$ of real time, the lifetime appears to be extended in proportion to the parameter β. This is what is observed, though the experimental results are traditionally regarded as confirming relativistic time dilation. It is submitted that the observation is rather a confirmation of the quantum electrodynamic properties of the muon.

The hypothetical picture of the step migration of a charged particle presented in Fig. 28 has a variant which should be mentioned. Suppose there is space conservation all the time, rather than on a mere statistical basis. Then, depending upon the energy of the particle, there will be voids having a volume equal to double an integral multiple of that of the particle at rest. For particle speeds up to 0·943c, the speed at which the relativistic mass is three times the rest mass, there will be a single double-volume void as in state A in Fig. 36. However, whereas in Fig. 36 this void is occupied by a virtual charge pair, we regard this occupancy by charge to be governed by probability factors to assure that, on average, the energy of the base particle plus that of the charge-primed voids is equal to the energy of the charge in motion. To complete this alternative picture, we retain the point charge in state B to cater for migration of the particle, but the void, now three times the volume of the rest particle, migrates with the charge. Thus there is space and net charge conservation on a constant basis and energy conservation on a statistical basis. As applied to the muon, the lifetime dilation remains proportional to the energy.

This alternative quantum process avoids the idea that a stable charge may store energy by contraction and accepts that all charges, in their stable form, belong to families and have a standard unit size characteristic of a particular family. This may seem to invalidate the gravitation formula (54), but it does not, because the graviton together with its associated basic void displaces three times the usual $4\pi x^3/3$ volume of continuum. This means that (54) applies, but with dE equal to the whole energy quantum of the graviton.

As applied to the electrons in an atom, the migration of the point charges may well occur statistically without the voids following the track of the electron too closely. The virtual electron-positron pairs are induced in the field adjacent the electron and so may well manifest their presence indirectly rather than as a close coupling with the charge.

Quarks

We return now to the quantum characteristics of particles in high energy environments. The object is to examine possible processes by which fundamental components of elementary particles are produced.

There is some evidence, as we shall see by reference to quark theory, indicating the existence of positive and negative quarks which carry double the unit electron charge e. Multiple charge quanta can be imagined to exist, especially as the point charge migration of virtual electrons or muons requires charge to appear within the space occupied by charge of the same polarity. This presents unlimited scope for particle creation. Nature, no doubt admits a myriad of creation processes, but only shows us the very few which rely upon basic quantum probabilities and determine the existence of the most stable particle forms. Therefore, we will restrict attention to one single process involving the quantum cluster of 1843 electrons and positrons discussed when we derived the graviton mass empirically. Under natural circumstances, outside the accelerators of high energy particle physicists, it may be that this energy quantum of 1843 electron units (942 Mev) is the maximum energy fluctuation possible.

Let us see how it governs the creation of Nature's largest natural elementary particle. The process involved is one we will term 'half-synthesis'. Two particles A and B of opposite charges $+e$ and $-e$ come together from a relatively high separation distance and create a particle C of energy equal to A + B combined, in close paired relationship with one of half this energy. This process is readily understood from (166), with E as the combined energy of the two colliding particles. The particles of energy P and Q are formed and (166) shows that Q can adopt the value E and that if it does $P=\frac{1}{2}Q$. This possibility becomes a certainty in a high energy environment in which energy fluctuations involving continuous creation and decay occur constantly until a quasi-stable result is achieved. Energy fluctuations separating the Q and P particles, followed by recombination of opposite polarity P particles, regenerate the quantum $E=Q$. Indeed, such a system will synthesize particles of up to three times the magnitude of the energy fluctuations present. The actual particles produced depend upon the controls, in particular the energy quantum E_0 of (160), the 1843-quantum and the energy of the H particle.

To create Nature's largest natural particle we begin with the H particle of charge e and add an energy supplied by a particle of opposite charge. We may add an electron or a muon or a pion. Additionally we could add a neutral quantity, notably the energy E_0. Then we apply the process of half-synthesis by iteration until separation of charge would require energy fluctuations in excess of the 1843-quantum. The results are tabulated below. The various elements will be recognized from their numerical association. The H particle is 1836 electron mass units. The muon is 207. The pion 273. E_0 is 413. The electron is, of course, unity.

1836 + 1	1837	2756	4133
1836 + 207	2043	3065	4597
1836 + 273	2109	3164	4745
1836 + 413 + 1	2250	3375	5063
1836 + 413 + 207	2456	3684	5526
1836 + 413 + 273	2522	3783	—

The second column of figures gives the total initial energy in electron mass units. The third column gives the energy after the first iteration. The fourth column gives the energy after the second iteration. Since all the figures in the last column are greater than twice 1843 we cannot have any further particle synthesis. In the last example this precluded even the second iteration.

The data show that, on the assumption that the 1843-quantum has energy in excess of 1842 electron units (half 3684), the largest particle mass is 5526. On the other hand, if the energy associated with this quantum were really marginally less than this, the largest particle mass is exactly the value we found for the graviton, 5063. This mass gives the value of G exactly, when used in the gravitational formula presented in (163). It also gave excellent results for the psi particles. Hence it is reasonable to question whether 1843 signifies an energy quantum, or, at least, to question whether it accounts for the vacuum energy fluctuations. If, for example, the energy of the H particle were the governing energy fluctuation, then the 5526 value would have to be removed from the above table. The graviton would need then to be the 5063 quantum.

This puts in doubt the early empirical derivation of the graviton mass presented in Chapter 6 in relation to elementary particles produced by graviton decay. That derivation relied upon the 1843 energy quantum. However, this seems an appropriate judgement. The 5063 graviton quantum is supported by the derivation of G and the psi particle connection. Furthermore, the derivation in the above table also confirms this result exactly and is not critically dependent upon the energy fluctuation, provided it is less than 1842 and greater than 1688 (half 3375)

On reflection, the creation of 1843 electrons and positrons would not require 1843 electron mass energy units if they were produced in the near vicinity of one another. If, for example, each pair were produced together at a separation distance equal to the spacing of the G-frame and the C-frame, then the 1843 energy quantum would have to be offset by the factor $\frac{1}{2}\alpha$. This is analogous to the need to involve the fine structure constant in reaction D in Fig. 29. This reduces the 1843 energy quantum to 1836·3. This is just sufficient to create the H particle.

Reverting now to the multiple charge quark, let us make the bold speculation that charge can vary but that space and energy are conserved in a situation where the energy fluctuation quantum just discussed finds itself associated with a charge Ze confined to the charge volume of a normal electron. The simple result is that Z is $(1843)^{\frac{1}{2}}$ or $(1836)^{\frac{1}{2}}$, according to the energy quantum selected. When evaluated Z needs to be either 42·93 of 42·85, both of which are values close to the integer 43. Since Z must be integral if the charge is built up by successive point charge accumulation, we will take a Z value of 43 as the firm basis on which to develop a quark theory. It requires only a marginal spurious energy in space pervaded by high energy matter to create this very short-lived quark state.

The total energy involved in creating the electron-sized quark of $Ze = 43e$ is 945 Mev, corresponding to the 1849 electron mass energy units required. The quark will decay rapidly in search of a stable form. First, bearing in mind that the energy was sourced in electron-positron clusters, we will imagine decay by expansion to a size corresponding to the volume of 43 electrons. The quark energy will then fall to $Z^{5/3}$ electron units, because Z is now proportional to x^3 and energy is proportional to Z^2/x, x being charge radius. The energy becomes about 270 Mev.

Next, let us accept that it is most improbable for a quark of charge $43e$ to form without there being an anti-quark of the same energy and charge $-43e$ formed nearby. They are bound to annihilate one another, being such misfits in the scheme of things. However, their existence is marked by the energy quanta left behind. Each such energy quantum will be deemed to create a pair of particles involving a quark of charge $+e$ or $-e$ (denoted N) which has association with one, two or three electrons or positrons. We are guided here by the systems shown in Figs. 29 and 30. There are four possible systems, as shown in Fig. 37. The polarities can be reversed on each of the four systems, making eight different possible particle aggregations. They all have about the same energy, because N is much larger in energy content than the electron or positron. Thus, if the 270 Mev energy quantum creates pairs involving the N quark and the N anti-quark we may expect each particle unit to have a mass energy of about 135 Mev. Also the creation process will assure approximately equal

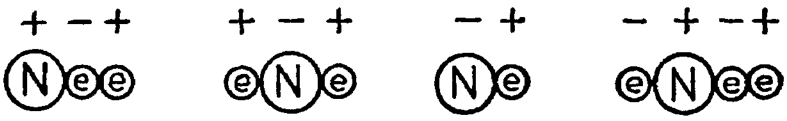

Fig. 37

production of all four of the particle forms shown. The value of N will be set by this energy apportionment. To find N we compute the mass energies of each of the four forms. Taking the electron unit as the base unit we find the following energies:

$$N+0{\cdot}25 \quad N-0{\cdot}25 \quad N-0{\cdot}5 \quad N+0{\cdot}125$$

For example, the third particle form in Fig. 37 has one N particle, one electron or positron and a negative electric interaction energy of $(3/2)N/(N+1)$ or $-3/2$. Together this gives $N-0{\cdot}5$.

The average energy of all four forms is $N-0{\cdot}09375$. It follows that the energy of the N quark is simply $\frac{1}{2}(43)^{5/3}+0{\cdot}09375$. Now, from an experimental viewpoint, the first two particle forms, being charged, will come together fairly soon and decay. The neutral particle forms will be slightly more stable, but one form, the third shown in Fig. 37, is intrinsically unstable compared with the fourth particle form. Three quark constituents are needed to enhance intrinsic stability, as we saw when we studied the proton. Thus the longest lived particle could well be the fourth shown in Fig. 37. None is likely to survive except for a very limited time, because there will not be many other stabilizing N particles around. They stem from a rather exotic creation process. We conclude that the particle most likely to be detected will be a neutral particle of mass $N+0{\cdot}125$ electron units. This is $\frac{1}{2}(43)^{5/3}+0{\cdot}21875$ or $264{\cdot}105$. This is $134{\cdot}959$ Mev. The neutral pion, an important short-lived particle in elementary particle decay, has a measured mass energy of $134{\cdot}9645 \pm 0{\cdot}0074$.

On such encouraging evidence, we will now take the quark of Ze equal to $43e$ seriously and examine its other consequences. In particular, we will search for evidence of stable quarks involving the energy quanta related to paired combinations of two oppositely charged quarks near Ze of $43e$. We look at the quarks in their intermediate decay stage when they occupy the volume corresponding to Z electrons. Thus the formula (166) for Ze interacting with $(Z-1)e$ becomes:

$$E=Z^{5/3}+(Z-1)^{5/3}-\frac{3Z(Z-1)/2}{Z^{1/3}+(Z-1)^{1/3}} \qquad (208)$$

E is here expressed in electron mass units or units of 0·511 Mev.

(208) can be simplified as follows:

$$E=Z^{5/3}(5/4-25/24Z) \qquad (209)$$

for large Z. Had the formula related to interaction between charges of equal Z, its simplified version would become:

$$E=Z^{5/3}(5/4) \qquad (210)$$

Had the formula related to interaction between charges of Ze and $(Z-2)e$, its simplified version would have become:

$$E=Z^{5/3}(5/4-25/12Z) \qquad (211)$$

Below we tabulate the energies of various charge combinations. The middle column shows the charge symbol of the aggregation, which may denote a neutral particle or one of unit or double unit electron charge of either polarity. The energies in the last column are in Mev and are deduced from the formulae (209) and (211).

43:42	±	330·6
43:43	o	337·1
44:42	± ±	336·9
44:43	±	343·6

When these particles collapse by mutual annihilation of charge we may expect to lose the neutral particle. Of the single charged particles only the first in the list can be expected to survive because it has lower energy. Thus we may expect to find two quarks of $(330{\cdot}6)^{\pm}$ and $(336{\cdot}9)^{\pm\pm}$ form, respectively.

The numbers give only approximate indications of likely energy but should hold to within about 0·1%.

Is there any evidence that such quarks may exist? The answer is very affirmative, as we see from the empirical studies of MacGregor.* MacGregor was able to show that the masses of all of the fundamental narrow-width hadron resonances could be calculated to an average accuracy of 0·1% using four mass values for quarks. His analysis also included exhaustive treatment of spins, charge splittings, magnetic moments and strangeness quantum numbers. His four quark masses were:

$$M^{o} = 70{\cdot}0 \text{ Mev}$$
$$M^{\pm} = 74{\cdot}6 \text{ Mev}$$
$$S^{\pm} = 330{\cdot}6 \text{ Mev}$$
$$S^{\pm\pm} = 336{\cdot}9 \text{ Mev}$$

This encourages belief in the quark process described above, because the two heavier quarks have emerged directly from the theory. As to the two other quarks of MacGregor's analysis, it seems probable, MacGregor implies, that the mass difference between M^{o} and $M^{\pm}$ stems from the mass difference 4·6 Mev between the charged pion and the neutral pion. For example, the M^{o} quark could combine with a charged pion to produce a neutral pion plus the quark at 74·6 Mev. Alternatively, the 74·6 Mev quark could combine with the neutral pion and produce the charged pion, leaving the 70·0 Mev neutral quark.

How may the 74·6 quark be produced? Possibly it comes from a paired association with 330·6 Mev in the minimization of formula (166). (167) shows that Q is 74·3 Mev when P is 330·6 Mev. Alternatively, how may the 70·0 Mev quark be produced? It is neutral and could come from the collision of a charged pion and an electron or positron. If the pion energy is denoted P and the electron energy is unity, then $P+1$ can develop a charged pair of energy $(P+1)$ comprising energy quanta $(P+1)$ and $\frac{1}{2}(P+1)$, as we explained in discussing 'half-synthesis' earlier in this chapter. Upon separation and recombination involving the separation energy $\frac{1}{2}(P+1)$, this latter energy could form a neutral quark. It corresponds to a mass of $\frac{1}{2}(273{\cdot}126+1)$ electron mass units, or 137·063, which is 70·0 Mev.

* M. H. MacGregor, *Physical Review*, **D10**, 850 (1974).