We can generalise this three-body encounter by supposing that, before collision, one electron is moving with *any* velocity in *any* specified direction, with respect to the direction of motion of the resulting quantum. It turns out that in this case the quantum can have any energy between (1/2) $Mc^2$ as a lower limit and infinity as an upper limit. A three-body collision between *two* protons and *one* electron resulting in a quantum and one proton will also satisfy all the specified principles (*a*) . . . (*e*). In this case, the energy and momentum equations are

$$Mc^2 + Mc^2 + mc^2 = h\nu + \frac{Mc^2}{\sqrt{1-\beta^2}},$$

$$0 = \frac{h\nu}{c} + \frac{M\beta c}{\sqrt{1-\beta^2}}.$$

Solving, we get

$$h\nu = \tfrac{3}{4}Mc^2 \text{ (approx.)},$$

from which

$$\lambda = 1{\cdot}7 \times 10^{-13} \text{ cm.} = 1{\cdot}7 \times 10^{-5} \text{ Å.U.}$$

and

$$\beta = 0{\cdot}6.$$

It is very evident, therefore, that a three-body type of collision is much more satisfactory than a two-body type—as a possible explanation of the origin of the high frequency radiation.

It has been suggested that formation of the helium nucleus from four protons and two electrons will give rise to a high frequency quantum. The value of λ can be shown to be 0·0018 Å.U. It may also be shown that this process will satisfy the conservation of momentum and, moreover, that the reverse process is easily realised, being merely the break-up of a helium nucleus on the impact of the quantum.

It is evident that if we consider the possibility of collisions involving nuclei of atoms other than hydrogen, there is a wider field for further investigation and speculation.

A. Ll. Hughes.
G. E. M. Jauncey.

Washington University,
St. Louis, U.S.A.,
January 4.

### Three Fundamental Frequencies.

It is possible to equate the quantum and the relativity expressions for energy, and thus to obtain three interesting and fundamental frequencies, with their corresponding wave-lengths.

The well-known quantum expression is $h\nu$, where $h$ is Planck's constant and $\nu$ the frequency equal to $c/\lambda$, where $\lambda$ is the wave-length.

On the other hand, the relativity form of energy is $mc^2$, where $c$ is again the velocity of light and $m$ is the mass under consideration.

We have then $h\nu = mc^2$ or $hc/\lambda = mc^2$,

whence

$$\lambda = \frac{h}{mc} = \frac{6{\cdot}55 \times 10^{-27}}{3 \times 10^{10} m} = 2{\cdot}18 \times 10^{-37}/m.$$

In the first place, put $m = 9{\cdot}0 \times 10^{-28}$ gm., the mass of an electron, and we have $\lambda = 0{\cdot}0242$ Å.U., which would be the wave-length due to the complete disappearance of the mass of a slow electron when, if ever, it reappears as radiation.

If, however, $m$ is given the value of the mass of the hydrogen atom ($1{\cdot}64 \times 10^{-24}$ gm.), we find λ is $1{\cdot}33 \times 10^{-13}$ cm. This is the wave-length of the cosmic radiation to which Jeans refers (Nature, December 12, 1925, p. 861), when he contemplates the disappearance of the equal charges and of the unequal masses of the proton and electron, and their reappearance as the most penetrating radiation of which we have at present any conception.

Finally, we can give to $m$ the value derived from the congestion of four hydrogen atoms, each with atomic weight 1·008, into a single helium atom, with 4 as atomic weight. The available mass convertible into radiation is now $4 \times 0{\cdot}008 \times 1{\cdot}64 \times 10^{-24}$ gm. or $0{\cdot}032 \times 1{\cdot}64 \times 10^{-24}$ gm. This gives the wave-length λ a value of 0·0004 Å.U., or $4 \times 10^{-12}$ cm. This is the wave-length of the penetrating radiation referred to by Millikan as of cosmic origin in a recent contribution to *Science* (November 20, 1925, p. 445).

To sum up—

$\lambda = \frac{h}{mc}$ leads to three basic wave-lengths,

| | Electron. | H atom. | He from H. |
|---|---|---|---|
| $m = $ | $\frac{1}{1800}$ | 1 | 0·032 |
| $\lambda = $ | 0·024 Å.U., | 0·000013 Å.U., | 0·0004 Å.U., |

where $m$ is expressed in terms of the mass of a H atom $1{\cdot}64 \times 10^{-24}$ gm., and Å.U. denotes the Ångström unit or $10^{-8}$ cm. The reversals of such transformations, when each radiation changes into its corresponding mass, are readily conceived and may indeed occur in Nature under conditions at present unknown, for indeed such changes are not yet within our experience.

M. Home.

McGill University, Montreal,
January 5.

### New Mutations in *Gammarus chevreuxi*, Sexton.

Since the publication of the account of the first mutations in *Gammarus chevreuxi* (*Journ. Mar. Biol. Assoc.*, vol. 11, No. 3, 1917) a number of new mutations have appeared. Most of these, like the first, are connected with the eye, particularly with its colour and shape, but the most striking of all the new departures is a change in the colour of the *body*.

In the normal *G. chevreuxi* the body is pale green in colour with two bright red patches on each of the pleon-segments, and bars of brown pigment on the antennæ. The fully adult female looks much darker than the male, owing partly to a difference in the green colour, bluish in the female, yellowish in the male, and partly to the dark green, almost blackish, tint of the gonads which show through the transparent cuticle. The eggs, which are dark green when first laid, gradually change to yellow as the embryos form, and then to a deep orange colour just before the young are hatched. In the new mutation the animals are a translucent pearly-white, with no tinge of colour in the body. The gonads show as opaque white stripes, and the eggs in the brood pouch during the whole period from deposition to hatching can only be seen by transmitted light.

We have now three distinct new stocks producing mutations, the stocks having originated from three independent black-eyed pairs brought in from the wild. In all three stocks, as in the original mutating stock, red-eyes appeared which were recessive to black-eyes. We had therefore first to ascertain whether we were dealing with different and distinct mutations, or simply with re-appearances of the old form. To do this, we cross-mated the red-eyed recessives of the four stocks in as many ways as possible. Whichever way the mating was made *the offspring were black-eyed*, thus proving beyond doubt that the mutations of the new stocks are distinct from each other and from the mutations of the original stock. The reversionary blacks, as we call