(1a) $\mathbf{F} = -(8\pi/3)\mathbf{P}$ if P is perpendicular to the face of the slab,
(1b) $\mathbf{F} = (4\pi/3)\mathbf{P}$ if P is parallel to the face of the slab.

Should the wave-length be short compared to the dimensions of the slab but long compared to the lattice distance:

(2a) $\mathbf{F} = -(8\pi/3)\mathbf{P}$ for the longitudinal vibration
(2b) $\mathbf{F} = (4\pi/3)\mathbf{P}$ for the transverse vibration.

According to the conventional definition, the electric field is the electric force in a slot in the crystal with its short dimension perpendicular to the direction of the electric force. We consider a slot of dimensions short compared to the wave-length. Then $\mathbf{E}$ is obtained by subtracting from (2a) or (2b) the effect of the material that has been removed to form the slot. Since the electric force is always parallel to $\mathbf{P}$, the effect of this material is just the force (1b). Therefore

$$\mathbf{E} = -4\pi\mathbf{P} \text{ for the longitudinal vibration,}$$
$$\mathbf{E} = 0 \text{ for the transverse.}$$

The displacement, $\mathbf{D}$, is given by the electric force in the slot when its short dimension is parallel to the polarization. Therefore, subtracting (1a) as the effect of the material in the slot from (2a) and (2b)

$$\mathbf{D} = 0, \quad \mathbf{D} = 4\pi\mathbf{P}$$

for the longitudinal and transverse vibrations, respectively.

These formulae are consistent with $\mathbf{D} = \mathbf{E} + 4\pi\mathbf{P}$, and they also lead, according to (2a) and (2b), to the Lorentz-Lorenz force for both types of vibration; that is:

$$\mathbf{F} = \mathbf{E} + (4\pi/3)\mathbf{P}.$$

At first sight, the fact that the electric displacement does not vanish for the transverse vibration may appear to be inconsistent with the absence of an impressed external field. However, the polarized crystal itself gives rise to an external field which is just $4\pi\mathbf{P}$ at the surface and vanishes exponentially with distance from the surface. This may be seen by considering a charge distribution on a plane surface that is periodic in one direction with wave-length λ and constant in the perpendicular direction. Such a charge distribution gives rise to a field proportional to $\exp(-2\pi x/\lambda)$, if x is perpendicular to the surface. A transversely displaced crystal with the polarization perpendicular to the face of the slab may be considered as made up of a series of such planes, and it is apparent that there will be an exponentially decreasing external field over a distance approximately given by the wave-length of the vibration under consideration. The result obtained directly from the lattice sums by Kellerman[3] is in agreement with this qualitative argument.

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[1] R. H. Lyddane and K. F. Herzfeld, Phys. Rev. **54**, 846 (1938).
[2] H. Fröhlich and N. F. Mott, Proc. Roy. Soc. **A171**, 496 (1939).
[3] E. W. Kellerman, Phil. Trans. Roy. Soc. **A238**, 513 (1940).

The $C^{12}H_2-N^{14}$ Mass Difference

Three years ago the author, in an attempt to obtain more accurate mass values, undertook to construct a new type of mass spectrograph having a very high resolving power and dispersion. This instrument was completed last spring and reported[1] at the Washington meeting of the American Physical Society.

Its constants are given in Table I together with those of other instruments being used at the present time to study the light element doublets.

The mass scale is correction free, mass differences being obtained directly by taking the mean of the ratios of the doublet separation to the forward and backward dispersion line separations. In the case of the $C^{12}H_2-N^{14}$ doublet, this method of calculation gives the mass difference directly to 0.000015 mass unit, a figure which is several times smaller than the error introduced in making a single doublet distance measurement. In addition, exact methods have been worked out for correcting this small deviation and it is estimated that the resulting error due to the method of computation alone is approximately three to four units in the sixth decimal place. The above relation holds true regardless of the plate position within rather wide limits.

Recently a considerable number of matched as well as unmatched $C^{12}H_2-N^{14}$ doublets were obtained in a series of spectra which were photographed under different conditions and used to verify the theoretically expected relations. The values of the mass differences corresponding to these doublets are listed in Table II in order that a birdseye view of the variations may be obtained. These data result from measurements taken on three different plates, three to five measurements of the doublet distance being made in each instance. Although the difference in density between the doublet lines is not large in any case, only about half the doublets corresponding to the values listed are matched. It so happens that if the matched doublets alone are considered, the same average value is obtained, the probable error also being approximately the same.

For comparison purposes, this mass difference, together with other published values for the light element doublets is listed in Table III. Although no cross check doublets

TABLE I. *Mass-spectrograph constants.*

MASS SPECTROGRAPH	RESOLVING POWER $M/\Delta M$	DISPERSION (MM FOR 1% MASS DIFF.)
Aston	2,000	4.5
Mattauch	6,500	1.4
Asada and others	17,000	4.65
Jordan	30,000	14.6

TABLE II. *The* $C^{12}H_2-N^{14}$ *doublet mass differences.*

0.01255	0.01255	0.01257	0.01258	0.01254
0.01258	0.01254	0.01263	0.01254	0.01255
0.01256	0.01252	0.01258	0.01257	0.01251
0.01253	0.01260	0.01256	0.01265	0.01252
			0.01254	0.01256

Average 0.01256±0.000015*

* This error is three times the probable error computed from the internal consistency of the data.

TABLE III. *Mass differences in terms of 10^{-4} mass unit.*

DOUBLET	$H_2'-D^2$	$D_3^2-C^{12++}$	$C^{12}H_4'-O^{16}$	$C^{12}H_2'-N^{14}$
Aston	15.2 ±0.4	423.6 ±1.8	360.1 ±1.6	124.5 ±0.7
Bainbridge and Jordan	15.3 ±0.4	421.9 ±0.5	364.9 ±0.8	127.4 ±1.1
Mattauch	15.39 ±0.021	422.39 ±0.21	364.06 ±0.40	125.81 ±0.23
Asada and Others			364.2 ±0.9	125.7 ±0.6
Jordan				125.6 ±0.15

have been measured as yet, it seemed worth while to publish this value in view of the fact that it was obtained on an instrument which not only has extremely high constants but also differs radically from any of the others in use at the present time. Other measurements on the light element doublets are in progress.

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[1] E. B. Jordan, Phys. Rev. **57**, 1072A (1940).

Cosmic Rays and Comets

The conjecture that the comets are contraterrene bodies,[1] which accounts, if only in a rough qualitative way, for some of the more conspicuous features of comets, can be properly tested as follows: (a) by investigating its usefulness in detailed quantitative interpretation of the now known properties of comets; (b) by performing experiments, involving cosmic-ray measurements, during meteor showers known to be of cometary origin; and (c) by performing appropriate cosmic-ray experiments while a sufficiently active comet is sufficiently near to the earth. Method (a) is indirect; and since it involves detailed study of the intricacies of cometary behavior, as well as a knowledge of the distribution of meteoric material within the solar system, it is difficult. Method (b) implies the acceptance of the idea that certain meteor showers are of cometary origin, but is otherwise quite direct; and the requisite experiments can be done, for example, almost every August. Method (c) is in principle the most direct; but the occasions on which it can be tried are very rare.

One purpose of this note is to call attention to the fact that if the comet recently discovered by Cunningham proves sufficiently active, it might, within the next few weeks, provide opportunities for performing the experiments involved in method (c). Lacking the appropriate data, however, the writer is at present unable to venture an estimate whether, if comets are contraterrene, the cosmic-ray effects of Cunningham's comet would be sufficiently intense for experimental purposes.

If comets are contraterrene, their activity depends not only on the solar energy that they receive, but also on the rate at which they encounter ordinary meteoric matter. In the absence of a theory of interaction of terrene and contraterrene matter, it is impossible to say with certainty what the primary products of their mutual annihilation would be. It is reasonably safe to guess, however, that among these products there should be photons having energies of about a billion electron volts. Therefore experiments designed to determine whether any high energy photons do originate in a comet should best be performed in the upper atmosphere.

The second purpose of this note is to mention that among the products of mutual annihilation of terrene and contraterrene matter there may be free mesons. This possibility is of interest not only in view of the present conjecture concerning comets, but also in connection with cosmic rays in general; for it suggests that: (1) The continual release of mesons at the top of the earth's atmosphere may be caused by contraterrene matter coming from interstellar space and impinging upon the atmosphere, and (2) the non-ionizing particles which release mesons deeper in the atmosphere may be contraterrene neutrons, which have themselves been set free in the earlier stages of the annihilation of the impinging contraterrene atomic nuclei.[2]

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[1] V. Rojansky, Astrophys. J. **91**, 257 (1940). We call "contraterrene" a body composed of hypothetical atoms consisting of negatively charged nuclei surrounded by positrons; an ordinary body we call "terrene."

[2] The possibility of production of high energy photons in the upper atmosphere by the annihilation of negative protons arriving from interstellar space was discussed by F. Zwicky, Phys. Rev. **48**, 169 (1935). See also F. Zwicky, Proc. Nat. Acad. Sci. **22**, 266 (1936), esp. Section *F*.

Erratum: On the Angular Distribution of Fast Neutrons Scattered by Hydrogen, Deuterium and Helium

(Phys. Rev. **58**, 590 (1940))

The captions of Fig. 3 and Fig. 4 on page 592 should be interchanged.

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