SOME EXPERIMENTAL EVIDENCE SUPPORTING THE KINETIC THEORY OF GRAVITATION

CHARLES F. BRUSH

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BY

CHARLES F. BRUSH, M.E., M.S., PH.D., D.Sc., Eng.D., LL.D.,

Member of the Institute.

SOME time ago I was advised by the Secretary that The Franklin Institute had honored me with the award of the Franklin Medal. This I esteem a very great distinction, of which I beg to express my deep appreciation.

The Medal was awarded for the pioneer development of the electric arc light, and the invention of the practical storage battery. The early development of the arc light was celebrated by the Institute last month, and I shall not treat of it further. But of the early history of the storage battery very little is known to the public, so I hope I may be pardoned for giving a brief statement of it.

The Planté secondary battery had long been known. This consisted of two lead plates immersed in dilute sulphuric acid. When an electric current was passed through the combination a very thin layer of peroxide of lead was formed on the surface of one plate while hydrogen gas was evolved on the other plate. After a time the charging current was reversed, resulting in reduction of the thin coating of lead peroxide to spongy metallic lead, and peroxidation of the surface of the other plate. Many more reversals of charging current were made at increasing intervals for several weeks or months, whereby a considerable coating of peroxide of lead was formed on one plate, and an equivalent coating of spongy metallic lead on the other plate. The capacity of such a storage battery cell was small and its cost prohibitive from a commercial standpoint.

It occurred to me that larger capacity and very much quicker preparation might be secured by initially coating the plates with a paste of lead oxide and sulphuric acid, which was found to adhere fairly well. The scheme proved quite

successful. This was in 1878. Later, the plates were made cellular, to receive a larger amount of the paste and hold it more firmly. A vast amount of experimental work followed. Patents were applied for in 1881, and after several years of interference litigation in the Patent Office, the famous patent No. 337,299 was issued March 2, 1886. It claimed "mechanically-applied active material or material adapted to become active." This exceedingly broad claim was afterward fully sustained by the Federal Courts, and controlled all practicable forms of storage batteries until expiration of the patent in 1903. Unfortunately for me, no great field of usefulness for the storage battery developed until after the fundamental patent had expired.

In the early nineties I retired completely from the electrical field of effort for the express purpose of gaining more available time for research in pure science. I have always keenly enjoyed hunting for new phenomena in physics and chemistry; and occasionally I have experienced the thrill of finding one, and the joy of investigating it.

But, fortunately perhaps, my research work has always been largely mixed with business affairs. In 1893 I helped organize and finance a company for the manufacture of portland cement, and have been one of its officers ever since. The company has been highly successful and profitable. About 1905 I organized "The Lindé Air Products Company" for the commercial manufacture of oxygen from the air. I was its president for several years until its business was firmly established. Then, finding it was taking far too much of my time, I negotiated a satisfactory arrangement with the Union Carbide Company whereby the latter took over the business management of the Lindé Company while I retained my large interests. The Lindé Company has now grown to very large proportions, and I am rather proud of it as one of my children.

In 1910 I had the honor to formulate and make public "A Kinetic Theory of Gravitation." [1] This has become known as the ether-wave, or energy-shadow theory. The only new postulate required by the theory is that some, or perhaps all, of the vast instrinsic energy of the ether exists in wave form of some sort capable of motive action on par-

[1] *Science*, March 10, 1911; *Nature*, March 23, 1911.

ticles, atoms or molecules of matter, and propagated in every conceivable direction so that the wave energy is isotropic. The waves are of such frequency, or otherwise of such character, that they pass through all bodies without obstruction other than that concerned in gravitation and a slight heating effect in some substances, and perhaps other slight effects. Distribution of the ether's energy is assumed to be uniform throughout the universe except as modified by the presence of matter.

The Kinetic Theory clearly indicates that the energy acquired by falling bodies is derived from the ether; and in subsequent papers I have submitted most convincing argument that this is true.

The Secretary has honored me with an invitation to make an address on the present occasion, on any subject I may select, preferably about some phase of my own research work; and I have chosen as my text "Some Experimental Evidence Supporting the Kinetic Theory of Gravitation."

Study of the nature of gravitation is beset with unusual difficulties, because gravitation is ever with us and about us; it is the one universal phenomenon, and we cannot escape from its influence—cannot obtain any outside point of view.

From the beginning of my experimental work on the problem of gravitation, many years ago, I have largely directed my efforts toward finding some evidence of the postulated ether waves other than gravitation itself; and it has seemed quite possible that such evidence might be furnished by a continual slight generation of heat within some substances specially adapted to exhibit it. The following argument will make this conception clear:

Heat is often defined as an agitation of atoms and molecules of matter, and measured by the total kinetic energy of such agitation. The agitation consists partly in internal vibrations of the elastic atoms and molecules and spinning about their various axes, and partly in a very rapid translatory motion among themselves. Thus they are supposed to dart about in every conceivable direction, constantly colliding with each other and rebounding or glancing in new directions. The kinetic energy of this translatory motion constitutes *sensible* heat (not total heat) and is the measure of *temperature.*

Anything (such as absorbed radiation) which stimulates the internal vibration of atoms or molecules likewise increases their translatory velocities by the increased violence of rebound after collision, and thus increases their temperature; and *vice versa*.

All the above is known to be true of gases and vapors (kinetic theory of gases), and is generally believed to be true of liquids and solids.

The "*mean* free path" and the "*mean* velocity" between collisions of the molecules of many gases under stated conditions have been computed. But it has also been shown mathematically that the higher and lower velocities, and the longer and shorter paths differ greatly from the means, and may in each respect vary twenty or more times in amount. Doubtless this is true also of liquids and solids.

From the fortuitously wide variation in velocities and free paths of the billions of vibrating atoms or molecules in their heterogeneous movement, it follows that collision frequencies must also vary greatly, from instant to instant, everywhere in a body of matter.

Probably the postulated gravitation waves are not confined to one frequency, but have a wide range of frequencies as do the well-known X-rays.

With the foregoing in mind it is easily conceivable that some kinds of matter may have atoms or simple molecules or complex molecules of occasional vibration frequency corresponding with some gravitation wave frequency, whereby fortuitous resonance can, for brief instants, be established at various points. This would result in a slight increase of vibrational activity and a cumulative rise of general temperature, perhaps sufficient to be detected.

A body of such matter, with some thermal insulation, would become and remain permanently warmer than a neighboring body similarly circumstanced, but not endowed, or less endowed with the permissive heat-generating quality.

The foregoing hypothesis had been my guide in a very lengthy search for some material exhibiting continual generation of heat in observable amount.

Two quite different calorimeters, very carefully designed and constructed, have been in frequent use for many years,

testing many metals and alloys, and also rocks and minerals for some slight and continuous generation of heat. Incidentally this research long ago led to the discovery of "spontaneous generation of heat in recently hardened steel," a new phenomenon, now well recognized in the metallurgy of steel.

The calorimeter work with rocks and minerals developed the fact that some of these substances do generate heat in easily observable amount, not due to radioactivity. The Bureau of Standards, with a calorimeter of its own design, is working with some of these minerals for the purpose of checking my findings.

It is notable that the materials which appear to be endowed with persistent heat generating activity are complex silicates; and it seemed highly probable that some silicates may be very much more active than others. This now appears to be true.

Guided by this thought I prepared and tested many artificial silicates. A silicate of the protoxides of nickel and cobalt showed very large activity, larger than either silicate alone; and this activity, after nearly two years aging of the silicate, appears to be permanent.

In the absence of other explanation, it has been thought that persistent generation of heat in some rocks and minerals, not due to radioactivity, is due to isotropic ether waves of great penetration; and in the light of more recent experiments, it is now thought that these ether waves are in the same class, perhaps having a wide range of frequency, with those postulated as the cause of gravitation.

Conversion into heat of some of the energy of the gravitation ether waves, however little, might be expected to impair, to some extent, the falling velocity of a heat generating substance; *and all such substances thus far tested have clearly shown impairment.*

I have yet found no exception to this remarkable phenomenon, though I have already tested many natural and artificial minerals. Substances which have shown no generation of heat in the calorimeters show no impairment of their falling velocity when compared with lead. Substances exhibiting small, moderate or large generation of heat have shown comparatively small, moderate or large impairment of

their gravitational acceleration. I aim to continue this research until the quantitative relationship of the two phenomena is ascertained. This may open a fertile field for mathematical exploration.

In making the above indicated comparisons of falling velocities I have largely used the method and apparatus described and illustrated in my 1923 paper on "Some New Experiments in Gravitation." [2] (See also 1924 paper of same title.) [3]

Two aluminum containers are used, alike in size, shape, weight and smoothness of surface, and dropped *simultaneously*, side by side through exactly the same distance (about 122 cm.).

Each container, at the end of its journey, breaks an electric circuit. But the breaks of both containers are in series in the same circuit, so that the break which occurs first produces a bright spark, while the belated break gives no spark because its circuit is already open.

When the containers are equally loaded with the same metal, there is no visible spark at either break or a very feeble spark at one or the other indifferently. But when they are equally loaded with certain different metals, one container persistently produces a bright spark, though the containers are always reversed in position for each trial. From this it seems clear that the container giving the spark falls a little faster than the other. This sparking condition is clearly manifested when the faster container reaches the end of its free path as little as .0125 mm. (.0005 inch) in advance of its neighbor. This indicates a time difference about 1/400,000 second.

To facilitate estimation of larger falling velocity differences I am perfecting a photographic method of observation. After falling about 110 cm. the small lower ends of the containers are photographed in silhouette against a white background having many horizontal black lines, and illuminated by a bright electric spark timed by allowing the conical shoulder of one container to contact with a fine, very flexible, steel wire. Duration of the spark is so brief, probably much

[2] *Proc. Am. Phil. Soc.*, Vol. LXII, No. 3, 1923.
[3] *Proc. Am. Phil. Soc.*, Vol. LXIII, No. 1, 1924.

less than a millionth of a second, that the container tips are practically stationary while being photographed.

After each exposure the right and left position of the containers is reversed and the photographic plate is so screened that only a horizontal strip is used at once. Thus eight exposures are made on one plate by suitably moving the plate-holder after each exposure.

In a recent experiment a marked container was filled with silicate of nickel and cobalt tightly packed; while the other container was loaded with an equal weight of lead sawdust (and cork) held firmly in cylindrical shape by a tightly fitting cork.

Each of the eight photographs on the same plate clearly showed the silicate container slower than its companion. Several more similar plates made with the same loaded containers all showed the same effect.

Of course I tried exchange of loads in the containers, but without observably affecting the result; the container holding the silicate was always slow.

The observed retardation of the silicate container must be due to impaired gravitational acceleration of the silicate as compared with the lead sawdust in the other container; and as the silicate constitutes only 30.8 per cent. of the total mass undergoing acceleration, we must multiply the observed retardation by 3.25 to find the full impairment of the silicate alone.

Micrometer measurements of the photographs will be made to find the quantitative value of retardation of the silicate.

Other materials tested by the photographic method have shown similar retardation in lesser degree.

Correlation of continual generation of heat in some substances and impairment of their gravitational acceleration, is regarded as very strong evidence in support of the kinetic theory of gravitation; and we seem now well started on the way of finding out something definite about the nature of gravitation, which is by far the greatest of all outstanding physical problems.