analogous to a refractive index which would depend on the energy of the ion and its alterations.

Small changes in the angle at which the incident rays hit the crystal produce a regular series of changes in the directions of the deflected rays. At nearly grazing incidence on one of the calcite crystals with the rays parallel to an edge of the cleavage rhomb there was a fan-shaped arrangement of the reflected rays in eight or more radial lines of different intensities. As the angle was made steeper the lines formed by the reflected rays of various velocities shifted towards the normal to the crystal surface and became curved the intensities altered and new curved lines appeared at the sides making the patterns more complex and more symmetrical. This change was produced by an increase of only one degree. With a second calcite crystal which was turned so that at grazing incidence the rays made an angle of about fifteen degrees with an edge of the cleavage rhomb clear patterns were obtained which had an unsymmetrical character. These patterns as well as those from the diamond also changed in a regular manner with small increases in the angle of incidence. The dependence of the angles of reflection on the angle of incidence and on the velocity of the rays suggests very strongly that a theory of the phenomenon will have to contain other elements besides particles and the forces exerted on them by electric and magnetic fields.

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April, 1930.

High-Voltage Tubes

We have found that the internal shattering and puncturing of Pyrex high voltage tubes of the cascade type described in the Physical Review of January 1 is entirely eliminated if the glass is "heat-worked" throughout. Since last autumn we have been using tubes made by blowing a series of "bubbles" which comprise the cascade sections at proper intervals along a piece of Pyrex tubing using a glass lathe for holding the work. In other respects the tube construction and shielding have been similar to that previously described except that tungsten instead of wax seals were used and the electrodes were shorter. Shattering and puncture finally occurred with most of our tubes in the necks between bulbs ("bubbles") although such tubes were operated to over 1600 kilovolts by careful "seasoning" and by short-circuiting sections which shattered before these had progressed to actual puncture. It was then found that if the glass tubing was first worked at all points (by heating and alternately blowing and contracting as in working a glass seal or joint) and then formed into bubbles and necks and the electrodes assembled no shattering took place when the tube was used. In two months of very severe tests on a series of such "heat-worked" tubes we have not been able to produce any shattering or puncturing with our Tesla coil voltages. One such tube of 14 sections, 135 cm overall, was operated up to 1950 kolovolts (at about one spark per second) where gassing set in due to slightly contaminated electrodes. This type of limitation by gas is the only one we experience with these tubes and our vacuum technique can be improved considerably when higher voltages are desired. An ionization-gauge near the pumps usually reads about 10^{-5} mm Hg equivalent air-pressure. We find that every tube which is assembled using reasonable precautions against contamination expecially by water-vapor, can be relied on to go to voltages of 1,000 to 2,000 kilovolts, depending on the number of sections, the ground-point, and the success in avoiding contamination, which usually shows up as a discoloration of the out-gassed electrodes.

These tubes have been operated as high as 1500 kilovolts without a potentiometer, that is, with all except the end-electrodes electrically floating. We made the accidental discovery on several occasions that some of our potentiometer units had been broken while we were running a tube, without our knowing of their failure until afterwards, no trouble having been noted with the tube. When all of the potentiometer units were removed, the tube still operated without severe flashing, although the voltage-distribution was obviously very non-uniform. Brasch and Lange (Naturwiss. January 3, 1930) have already reported the successful operation of a somewhat similar "floating-electrode" tube. Whether or not a filament is used in a tube makes no detectable difference in its behavior or flashing, at least up to 1500 kilovolts at one spark per second, nor has any effect of the filament

been noted with 120 sparks per second up to 800 kilovolts, which voltage has happened to be the maximum available with 60-cycle excitation of the condenser at the time of these tests, due to temporary power-limitations.

We are now using tubes of 12 sections placed inside of a Tesla coil 6 inches in diameter and 38 inches long, each electrode being connected to a tap on the winding of the coil. The coil itself shields the tube from ground, and distributes the voltage. A tube of this type, *with one end grounded,* has been operated to 1900 kilovolts at one spark per second, and to 1600 kilovolts at 120 sparks per second, at which voltage the tube operated perfectly; primary power was again the limitation. Insulation difficulties are also serious at these voltages above ground. Experiments are in progress on direct measurements of the output from these tubes of the expected radiations and "rays" of radioactive energy-equivalents, the results of which we hope to report shortly.

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Photoelectric Effect and the *J* Phenomenon

In the issue of the Physical Review for May 1, 1930, appears a paper by E. Marx describing "A new photoelectric effect in alkali cells" wherein that author investigates changes produced in the limiting potential acquired by an insulated alkali electrode, by varying the composition of the incident radiation. Although these experiments constitute the first systematic study of the phenomenon in the optical region, an analogous investigation was carried out with x-rays some years ago by C. G. Barkla. I quote from one of the latter's notices (Nature, March 27, 1926, p. 448)—"The ionization produced by a heterogeneous beam of x-rays in a gas, or the electronic emission from a metal plate, (measured by ionization outside the plate) may be abruptly and enormously increased either by (*a*) superposing on that beam a very feeble radiation of slightly shorter wave-lengths, or (*b*) by taking away from the complex radiation a very small amount of the radiation of longer wave-lengths, as by filtering; that is, either by adding higher frequency radiations to or eliminating lower frequency radiations from the beam, the same effect is produced; namely, a sudden large increase in the ionization. The magnitude of a sudden increase may be from 100 to 150 percent of the original magnitude. This is the *J* ionization produced by the *J* photoelectric emission accompanying the *J* absorption."

Since the independent variable (composition of the incident radiation) is the same for both cases, they deal presumably with the same effect, and it should be legitimate to compare the results, although an extrapolation from the optical to the x-ray region must be made with caution. This comparison is difficult, since it is unlikely that the experimental arrangements were the same for both. In Marx's work, the alkali electrode was insulated, and the removal of some of the red from an incident beam of white light caused an increase in the limiting potential acquired. On the other hand, in Barkla's experiment, the photoelectric plate was probably kept at a constant potential, and he observed that the removal of some of the long wave-length radiations from the beam of x-rays caused an increase in the ionization due to photoelectrons. Barkla interprets his result as a manifestation of some unexplained interaction between the component radiations in the incident beam, which causes a fundamental change in the amount or in the nature of the photoelectric emission. This is not necessarily inconsistent with the experiments of Marx, but it is not one of the assumptions of the tentative theory which he offers. Other possible suppositions as to Barkla's experimental arrangement lead also to conclusions which are at variance with the theory of Marx. At present all that can be deduced is that the four items (*a*) the experiments, (*b*) the theory of Marx, (*c*) the experiments, (*d*) the theory of Barkla, are not consistent.

I am not aware that Barkla's observation has ever been verified. It is possible that a series of varied experiments of this nature might throw some light on the elusive *J* phenomenon.

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