the joint meeting of the Pittsburgh sections of the American Electrochemical Society and the American Institute of Mining and Metallurgical Engineers in January, 1925, but so far not otherwise published:

α-iron (body-centered cube) is the characteristic form of the iron crystal and can exist at all temperatures below the freezing-point.

α-iron can hold impurities such as carbon, oxygen, etc., in solution, the parasitic atoms occupying the interstitial spaces in the iron lattice, and the amount held in solution depending upon the temperature. If the amount exceeds the solubility for the particular temperature, the impurities may be precipitated, or they may cause the iron to change its modification to the γ state (face-centered cube) in which form it can hold a larger amount of impurities in solution.

The bases for this hypothesis are discussed in a paper now being prepared for publication, but they may be stated here briefly:

(1) All iron so far experimented with contains impurities to a greater or less extent, particularly carbon and oxygen. Electrolytic iron, extensively used for transformation point determinations, contains oxygen to the extent of about 0.4 per cent., and all such determinations are consequently made with iron more or less saturated with oxygen in solution. The lower the carbon content the higher is probably the oxygen content.

(2) The addition of silicon (a substitution atom in the lattice and a strong deoxidizer) to the extent of 1.5 to 2 per cent., eliminates the transformations from α- to γ-iron. This is a well-established fact. We have now found that the lower the carbon content the lower is the amount of silicon necessary to eliminate the transformations. Extrapolating to zero carbon content (or $C < 0.001$ per cent.) it seems logical to suppose that the amount of silicon necessary to eliminate the transformations should be zero in the absence of oxygen, *i.e.,* for pure Fe we should have no allotropic transformations.

Equilibrium diagrams based on the above hypothesis have been drawn and are not contradicted by present experimental evidence or by theoretical reasoning. Efforts are being made to produce samples of iron very low in carbon and oxygen that can be used in confirming or invalidating this hypothesis, and cooperation by others is invited, especially by those having first-class facilities at their disposal.

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WEATHER PREDICTION AND WEATHER CONTROL

THE recent disastrous hurricane will have made many men willing to listen to a discussion of the possibilities of weather control, and as an introductory to such discussion it is worth while, perhaps, to discuss the possibilities of greatly improved and extended weather forecasts.

Stated mathematically, the forecast problem is approximately as follows: Consider the data *a, b, c, d,* etc., which represent the state of the weather over an extended area at a given instant; these data would consist of, let us say, 10,000 separate quantities (temperatures, air pressures, velocities of wind, directions of wind and humidities; at various points on the ground and at various elevations). Consider the similar quantities *x, y, z,* etc., which represent the state of the weather after *t* hours, where *t* is of course specified. The first approximation to the actual behavior of the atmosphere is to assume that *x, y, z,* etc., are *linear* functions of *a, b, c,* etc., and *t,* and the constant coefficients are supposed to have been found for the various seasons of the year. Then the problem would be to solve the 10,000 simultaneous linear equations for the 10,000 unknowns, *x, y, z,* etc. This solution would be utterly impracticable unless Lord Kelvin's machine for solving simultaneous linear equations could be made to be practicable for 10,000 simultaneous equations, which is extremely doubtful. The "constant coefficient" could be determined by observing *x, y, z,* etc., at time *t.*

The above suggestion[1] is exactly equivalent to the laborious calculation which has recently been made by Louis F. Richardson,[2] who assumed certain linear differential equations as expressing the laws of motion of the atmosphere and found *x, y, z,* etc., by integrating these differential equations over time *t* starting from the given state *a, b, c, d,* etc. This was a labor of several months where *t* was only one day (24 hours)! That is to say, it took three or four months to calculate the weather one day in advance! Weather forecast by straightforward calculations seems to be impracticable—and it must be remembered that the straightforward calculation is based on assumed linearity.

A third method of forecast would be to let the weather be its own integrating machine! Suppose a very elaborate study of the weather over the United States were to enable us to classify general weather conditions as 1,000 type-series, each series being a succession of states extending over 20 days (the numbers 1,000 and 20 are taken for the sake of illustra-

[1] Made to the writer by Professor Norbert Wiener.

[2] "Weather Prediction by Numerical Process," Cambridge University Press, 1922.

tion). This would mean 20,000 individual and fairly distinct types. Then from the weather data on any given date we could identify the weather type on that date, and the forecast for a number of days would be the successive stages in the corresponding type-series.

This method of weather forecasting is used at present, but by no means as elaborately as it should be. This I pointed out in a paper in the U. S. *Monthly Weather Review* for October, 1918.

This same paper also contained a suggestion as to a possible method of weather control, and it seems to me to be worth while to enlarge on this suggestion, for, in my opinion, it deserves actual trial. Essentially the method is the use of the "back fire" in the fighting of a prairie or forest fire.

In the first place, the local energy of a storm is undoubtedly derived from the local potential energy of a widespread unstable state, just as the local energy of a line of standing dominoes is derived from the local potential energy of the standing dominoes when the whole line is made to collapse by touching the end domino. Let us discuss the recent Porto Rico and Florida hurricane; of course the discussion will have to be based on assumed data, and we will find that the word control is rather a strong term to use for what might conceivably be accomplished.

The energy of the storm at Palm Beach came undoubtedly from a local region fifty miles or so in radius, and the local energy was released by the progressive and somewhat systematic collapse of a widely extended unstable state of the atmosphere, this progressive collapse being the whole progress of the storm movement from far beyond Porto Rico—very much like the progressive collapse of a row of standing dominoes.

Suppose we could have known of the widespread and threatening unstable state of the atmosphere in the region near the Florida coast a short time before the actual arrival of the storm at Palm Beach, and suppose that we had "touched off" this unstable state at three or four points and at three or four times in the Bahamas and along the Florida coast. We might thus have caused the local energy of the unstable state of the atmosphere to have been frittered away in several *unrelated* storm movements, each of very moderate violence, and no energy would have remained in the neighborhood to support the great systematic collapse which constituted the actual storm.

The knowledge of the threatening state of the atmosphere could certainly have been established by observations in time for the remedial measures; but how to "touch off" the unstable state of the atmosphere—that is the question which must be answered by trial.

The most promising thing to try would be as follows: Suppose that, anticipating the need in the Florida region, we had erected twenty or thirty very large steel cones, fifteen or twenty feet in diameter at the base, forty or fifty feet in diameter at the top, one hundred feet high, and open at the top. These would be distributed thinly over southern Florida and on the Bahama Islands. A large charge of gun powder (a ton or more for a cone) exploded in the base of a cone would drive the air in the cone (60,000 cubic feet of air) upwards as a gigantic vortex ring, or "smoke ring," which would carry a very considerable upward impulse to an elevation of several thousand feet, and thus start a rising column of warm, moist air in the lower strata of the atmosphere. Would this work? Nobody can tell except by trial. Would a trial cost very much? It certainly would cost several millions of dollars. Would a trial be worth while? Ask the people of southern Florida. I am purposely making what seems to me an overestimate of the size of cones required, and perhaps also an overestimate of the number.

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A FURTHER NOTE ON THE DIFFICULTIES ENCOUNTERED BY LAND VERTEBRATES IN THEIR DEVELOPMENT[1]

IN addition to the difficulty presented by the respiratory requirements of vertebrates, in emerging from water to land, one must reckon also the changes which were necessary in the uro-genital system. Further experiment and reflection on the development of the respiratory system have brought out certain new problems with reference to the tenth cranial nerve and its peripheral afferent and central nervous endings. From the point of view of the student of the phylogenetic development of the neuro-muscular mechanisms of respiration, the pulmonary components of the vagus have changed from something which every physiologist and every anatomist thought he knew about to practically unknown territory in the amphibian and in the reptile. The chapter on the respiratory mechanism is thereby lengthened. But coincident with the development of the mechanism which brought about the adjustment of vertebrates to the free, rather than to the dissolved, atmosphere, there were changes in two other systems: one, the development of an epidermis which could survive in an atmosphere containing little water vapor, and, two, the development of a mechanism to protect the young from this atmosphere and its attendant dangers until they had reached a certain stage of development. The fertilization of the ovum floating free in the

[1] F. H. Pike, SCIENCE, 59: 402, 1924.