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Nucleations According to Barus

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NUCLEATIONS ACCORDING TO BARUS.

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No doubt all students of science have read more or less about Barus' work on condensation phenomena as produced in a specially constructed fog chamber. As is known, his work has been done under the direction of the Carnegie Institution of Washington, founded particularly for the solution of research problems, involving much time and considerable expense. The prime purpose of his work, so far as I can interpret it, is to determine the part played by various kinds of nuclei in the atmospheric condensation of vapor. This, of course, is a very interesting problem to the student of physiography, as well as to the physicist.

It is very difficult to read Barus' notes and I would not commend his style to anyone. In fact, I doubt whether anyone who has not had some experience in the experimental production of such phenomena could get much out of his writings. His literature is apparently intended for the few who have the courage to attack something exceedingly dry. In my experimental work to determine the charge of an electron I had occasion to refer to his work to help interpret my own phenomena. In the discussion of my work I have made frequent reference to Barus and it is for this reason that I present this sketch with the hope that it will make the other paper more intelligible.

Barus' fog chamber is sketched in a simple manner without detail in Fig. 1. It consisted of a cylindrical vessel made either of glass or wood and sealed air tight. The lower part of the vessel contained a layer of pure water which kept the air or gas above in a state of supersaturation. The vessel contained also a number of wet muslin partitions placed parallel to its length. The purpose of these was to prevent cross currents in the vessel when the exhaustions were made, thus keeping the clouds uniformly compact. The tube *E* leads to a vacuum chamber cut off by an intervening plug valve. By the sudden opening of the plug valve an exhaustion of the fog chamber is made, producing a consequent lowering of temperature which results under the proper conditions when nuclei are present in the formation of a cloud. A bright beam of light is admitted into the fog chambers so that when a cloud is produced a coronna, generally of a green-blue-purple type, is plainly visible. The angular diameter of the coronna is measured by a pair of goniometers suitably placed and from this the number of efficient nuclei are determined in a manner described in Barus' publication of the Smithsonian Institute, published in 1905.

Barus describes three kinds of nuclei which at given pressures are able to induce the condensation of vapor in a fog chamber by exhaustion. First, "the ordinary dust-like persistent nuclei which require the smallest degree of supersaturation to induce condensation. Ordinary air, particularly of cities, contains at all times multitudes of minute dust particles. When such air is admitted into the fog chamber saturated with vapor, the dust particles on exhaustion become the nuclei of small droplets of water which taken together constitute the cloud. As Barus states, such particles induce the condensation of vapor. These dust like nuclei are persistent. By the term "persistent" used so much by Barus, is meant that they will remain suspended in the gas of the fog chamber indefinitely until an exhaustion is made. Several successive exhaustions, however, will bring them down in droplets and thus purify the air. These persistent nuclei are particularly efficient for nucleation at a difference of pressure of 16 to 18 cm. By difference of pressure is meant the difference between the barometric pressure in the fog chamber produced by exhaustion and that of the outside atmospheric pressure.

The second class of nuclei denoted by Barus are called "fleeting nuclei." They are produced by some ionizing source, such as X-rays or radium. "They carry a charge of electrification and are called ions." These fleeting nuclei are most efficient for nucleation at a dp. of 19 cm. or higher. When a weak radium compound is brought near the fog chamber, the interior is instantly surcharged with fleeting nuclei. Barus does not attempt to describe how these are produced. The experimental work of Rutherford has abundantly proven that the Alpha and Beta rays of a radio active compound are the principal sources of its ionizing power when they are not intercepted by some intervening solid. The Alpha rays are by far the best ionizers, but unfortunately they are easily cut off by the slightest obstruction, such as a thin piece of celluloid. It is evident then that the Alpha or Beta rays are ineffective as ionizers of the interior gas of a fog chamber having such thick walls of glass or wood as that used by Barus. Barus rightly concluded that the interior of his fog chamber was ionized wholly by the Gamma rays and their secondary effects on the walls of the vessel. The Gamma rays of radium, as we know, are like the X-rays, although decidedly more penetrating and more uniform in intensity. According to modern theory, the ionization of a gas by means of X-rays or Gamma rays is due to the fact that these rays have the power of disintegrating its atomic structure. A stable atom consists of a multitude of negatively charged electrons moving with high velocities inside of a positively charged sphere, the whole in static equilibrium. The action of the Gamma rays is to set free a negative electron leaving a surplus positive charge on the atom. Such a freed electron and its corresponding positively charged atom from which it has been delivered constitute the fleeting nuclei mentioned by Barus. They are fleeting because when the ionizing source, radium or X-rays, is removed, they at once recombine and disappear in very small intervals of time.

Barus found also that persistent nuclei similar to those of a dust-like character mentioned first could be induced by X-rays even in thoroughly dust free air. These persistent nuclei varied in number with the nature of the solid material thru which the X-rays past. They are probably disintegrated particles of matter carrying one or several ions. Like the dust nuclei, they produce large droplets on exhaustion at small differences of pressure. Those who have read the account of Wilson's experiments to determine the charge of an electron by means of X-rays will remember that his clouds broke up into a succession of layers. Barus' notion of persistent nuclei evoked by X-rays gives a simple and reasonable explanation of these layers.

The third class of nuclei mentioned by Barus are the colloidal type. Stated in his words, "they are a structural part of the body of gas and are reproduced as soon as removed. They require the highest degree of supersaturation and are without electrification." To produce condensation on the colloidal nuclei, Barus carefully filtered the air thru a plug of cotton-wool before admitting it into the fog chamber so as to have it entirely free from any dust nuclei. No energizing source such as X-rays and radium was brought near the fog chamber.

With exceedingly rapid exhaustions at a dp. of 26 cm. clouds were produced consisting of exceedingly small droplets, much smaller than those induced by even the fleeting nuclei. Owing to the smallness of the droplets Barus seems to infer that the nuclei are also smaller than those of any other kind. Barus speaks of the colloidal nuclei as if they were perhaps the molecules or the normal atoms of either the gas or vapor in the fog chamber.

It is not the purpose of this article to go extensively into the vast amount of work performed by Barus and his assistants, but it might be well to mention a few of the facts determined.

Comparing X-rays and radium as sources of nucleation Barus found that the X-rays are very variable, while the radium is decidedly constant. This fact is also abundantly verified in the experimental work of radio-activity. The number of efficient nuclei induced by X-rays varies rapidly with the strength of the rays and also with the suddenness and ease of exhaustion. When the exhaust tube was enlarged to one and one-half inches in diameter, as many as 400,000 efficient nuclei per cubic centimeter were obtained.

The term "efficient nuclei" is applied only to those that induce the condensation of vapor to form the droplets of the cloud. There are no doubt many others besides those that get the moisture. In fact, it was proven that when a mixture of nuclei of different electrical magnitudes were present in the fog chamber, the larger ones on the first exhaustion received all the moisture. A second exhaustion following rapidly would bring down a greater number of nuclei than the first one. The maximum number of nuclei induced by radium was about 60,000 per cubic centimeter, increasing some on the higher differences of pressure and the enlargement of the exhaust tube. The maximum number of colloidal nuclei varied from 80,000 to 100,000 per cubic centimeter.

Barus carried on a series of experiments covering a period of two years on the nucleations of the ordinary atmosphere. Two stations were establisht, one at Providence, Rhode Island, and the other on Block Island, off the coast. Observations were taken at regular intervals each day. It was shown that the nuclei, dustlike and ionized in the atmosphere is far greater in the winter time than in the summer. The maximum is reacht in December at the winter solstice and the minimum in July at the summer solstice. It was also found that the nucleation is usually greater early in the morning, gradually diminishing during the day until the middle of the afternoon, and increasing again towards evening. Rains were always followed by a markt decrease in the number of nuclei. It was also inferred that light pressure decreast the nucleation, causing in a measure the diurnal variations. There was a markt difference in the atmospheric nucleations of Providence and Block Island. The latter place lies well out at sea, where the air is not affected by local contaminations. The number of nuclei at Providence ran as high as 60,000 to 80,000 per cubic centimeter; at Block Island 10,000 to 15,000. It is evident that the products of combustion of a large city furnish a vast number of nuclei and in this way supply the material necessary for the condensation of moisture. It might be askt why is the nucleation of the atmosphere so enormous in the winter time? The reason, of course, is that there is very little watery vapor in the air at low temperatures for condensation on the nuclei to bring them down. The result is that the nuclei gradually accumulate as the weather grows colder and colder, reaching a maximum at the winter solstice.

In his later work Barus carried on a series of experiments to determine whether or not the ionized nuclei of the atmosphere at Providence were due to local causes. To do this, the air before being admitted into the fog chamber was past thru a tubular condenser, one surface of which was charged. In this way the charge given up by the ions in a given time for a given quantity of air was accurately measured. Dividing this charge by 3.4×10^{-10}, J. J. Thomson's determination of the charge of an electron, gave the number of ions per cubic centimeter. From this work Barus concluded, quoting his own words, "that the ionization of a given region is independent of artificial local contributions, however abundant these may be." We would infer from this that the ionization of the atmosphere results from cosmical rather than local conditions.