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ELECTRICAL EVAPORATION.[1]

IT is well known that when a vacuum tube is furnished with internal platinum electrodes, the adjacent glass, especially near the negative pole, speedily becomes blackened, owing to the deposition of metallic platinum. The passage of the induction current greatly stimulates the motion of the residual gaseous molecules; those condensed upon and in the immediate neighborhood of the negative pole are shot away at an immense speed in almost straight lines, the speed varying with the degree of exhaustion and with the intensity of the induced current. Platinum being used for the negative pole, not only are the gaseous molecules shot away from the electrode, but the passage of the current so affects the normal molecular motions of the metal as to remove some of the molecules from the sphere of attraction of the mass, causing them to fly off with the stream of gaseous molecules proceeding from the negative pole, and to adhere to any object near it. This property was, I believe, first pointed out by Dr. Wright of Yale College, and some interesting experiments are described by him in the *American Journal of Science and Art* (Third Series, xii. 49, xiv. 169). The process has been much used for the production of small mirrors for physical apparatus.

This electrical volatilization or evaporation is very similar to ordinary evaporation by the agency of heat. Cohesion in solids varies according to physical and chemical constitution; thus every kind of solid matter requires to be raised to a certain temperature before the molecules lose their fixity of position and are rendered liquid, a result which is reached at widely different temperatures. If we consider a liquid at atmospheric pressure,—say, for instance, a basin of water in an open room,—at molecular distances the boundary surface between the liquid and the superincumbent gas will not be a plane, but turbulent like a stormy ocean. The molecules at the surface of the liquid dart to and fro, rebound from their neighbors, and fly off in every direction. Their initial velocity may be either accelerated or retarded, according to the direction of impact. The result of a collision may drive a molecule in such a direction that it remains part and parcel of the liquid; on the other hand, it may be sent upwards without any diminution of speed, and it will then be carried beyond the range of attraction of neighboring molecules, and fly off into and mingle with the superincumbent gas. If a molecule of the liquid has been driven at an angle with a velocity not sufficient to carry it beyond the range of molecular attraction of the liquid, it may still escape, since, in its excursion upwards, a gaseous molecule may strike it in the right direction, and its temporary visit may be converted into permanent residence.

The intrinsic velocity of the molecules is intensified by heat and diminished by cold. If, therefore, we raise the temperature of the water without materially increasing that of the surrounding air, the excursions of the molecules of the liquid are rendered longer and the force of impact greater, and thus the escape of molecules into the upper region of gas is increased, and we say that evaporation is augmented.

If the initial velocities of the liquid molecules can be increased by any other means than by raising the temperature, so that their escape into the gas is rendered more rapid, the result may be called "evaporation" just as well as if heat had been applied.

Hitherto I have spoken of a liquid evaporating into a gas; but the same reasoning applies equally to a solid body. But whilst a solid body like platinum requires an intense heat to enable its upper stratum of molecules to pass beyond the sphere of attraction of the neighboring molecules, experiment shows that a very moderate amount of negative electrification super-adds sufficient energy to enable the upper stratum of metallic molecules to fly beyond the attractive power of the rest of the metal.

If a gaseous medium exists above the liquid or solid, it prevents to some degree the molecules from flying off. Thus both ordinary and electrical evaporation are more rapid in a vacuum than at the ordinary atmospheric pressure.

I have recently made some experiments upon the evaporation of different subjects under the electric stress.

Evaporation of Cadmium. — A U-shaped tube was made, having a bulb in each limb. The platinum poles were at the extremities of each limb, and in each bulb was suspended from a small platinum hook a small lump of cadmium, the metal having been cast on to the wire. The wires were each weighed with and without the cadmium. The tube was exhausted, and the lower half of the tube was inclosed in a metal pot containing paraffine wax, the temperature being kept at 230° C. during the continuance of the experiment. A deposit around the negative pole took place almost immediately, and in five minutes the bulb surrounding it was opaque with deposited metal. The positive pole with its surrounding luminosity could be easily seen the whole time. In thirty minutes the experiment was stopped, and after all was cold the tube was opened and the wires weighed again. The results were as follows:—

	Positive pole.	Negative pole.
Original weight of cadmium....................	9.34 grains.	9.38 grains.
Weight after experiment......................	9.25 "	1.86 "
Cadmium volatilized in 30 minutes............	0.09 "	7.52 "

Finding that cadmium volatilized so readily under the action of the induction current, a large quantity, about 350 grains, of the pure metal was sealed up in a tube, and the end of the tube containing the metal was heated to a little

[1] Abstract of a paper read by Professor William Crookes, F.R.S., before the Royal Society, London, on June 11; from Nature of July 2.

above the melting-point. The molten metal being made the negative pole, in a few hours the whole quantity had volatilized and condensed in a thick layer on the far end of the tube, near, but not touching, the positive pole.

Volatilization of Silver. — Silver was the next metal experimented upon. The apparatus was similar to that used for the cadmium experiments. Small lumps of pure silver were cast on the ends of platinum wires, and suspended to the inner ends of platinum terminals passing through the glass bulb. The platinum wires were protected by glass, so that only the silver balls were exposed. The whole apparatus was inclosed in a metal box lined with mica, and the temperature was kept as high as the glass would allow without softening. The apparatus was exhausted to a dark space of three millimetres, and the current was kept on for $1\frac{1}{2}$ hours. The weights of silver, before and after the experiment, were as follows: —

	Positive pole.	Negative pole.
Original weight of silver	18.14 grains.	24.63 grains.
Weight after the experiment	18.13 "	24.44 "
Silver volatilized in $1\frac{1}{2}$ hours	0.01 "	0.19 "

In this tube it was not easy to observe the spectrum of the negative pole, owing to the rapid manner in which the deposit obscured the glass. A special tube was therefore devised, of the following character. A silver rod was attached to the platinum pole at one end of the tube, and the aluminum positive pole was at the side. The end of the tube opposite the silver pole was rounded, and the spectroscope was arranged to observe the light of the volatilizing silver "end on." In this way the deposit of silver offered no obstruction to the light, as none was deposited except on the sides of the tube surrounding the silver. At a vacuum giving a dark space of about three millimetres from the silver, a greenish-white glow was seen to surround the metal. This glow gave a very brilliant spectrum. The spark from silver poles in air was brought into the same field of view as the vacuum glow, by means of a right-angled prism attached to the spectroscope, and the two spectra were compared. The two strong green lines of silver were visible in each spectrum. The measurements taken of their wave-lengths were 3,344 and 3,675, numbers which are so close to Thalen's numbers as to leave no doubt that they are silver lines. At a pressure giving a dark space of two millimetres the spectrum was very bright, and consisted chiefly of the two green lines and the red and green hydrogen lines. The intercalation of a Leyden jar into the circuit does not materially increase the brilliancy of the lines, but it brings out the well-known air lines. At this pressure not much silver flies off from the pole. At a higher vacuum the luminosity round the silver pole gets less and the green lines vanish. At an exhaustion of about one-millionth of an atmosphere the luminosity is feeble, the silver pole has exactly the appearance of being red-hot, and the volatilization of the metal proceeds rapidly.

Like the action producing volatilization, the "red heat" is confined to the superficial layers of molecules only. The metal instantly assumes, or loses, the appearance of red heat the moment the current is turned on or off, showing that, if the appearance is really due to a rise in temperature, it does not penetrate much below the surface. The extra activity of the metallic molecules necessary to volatilize them is, in these experiments, confined to the surface only, or the whole mass would evaporate at once, as when a metallic wire is deflagrated by the discharge of a powerful Leyden jar. When this extra activity is produced by artificial heat, one of the effects is the emission of red light; so it is not unreasonable to imagine that when the extra activity is produced by electricity the emission of red light should also accompany the separation of molecules from the mass. In comparison with electricity, heat is a wasteful agent for promoting volatilization, as the whole mass must be raised to the requisite temperature to produce a surface action merely; whereas the action of electrification does not appear to penetrate much below the surface.

If, for the negative electrode, instead of a pure metal such as cadmium or silver, an alloy was used, the different components might be shot off to differen distances, and in this way make an electrical separation — a sort of fractional distillation. A negative terminal was formed of clean brass, and submitted to the electrical discharge *in vacuo*. The deposit obtained was of the color of brass throughout, and on treating the deposit chemically I could detect no separation of its component metals, copper and zinc.

A remarkable alloy of gold and aluminum, of a rich purple color, has been kindly sent me by Professor Roberts-Austen. Gold being very volatile in the vacuum tube, and aluminum almost fixed, this alloy was likely to give different results from those yielded by brass, where both constituents fly off with almost equal readiness. The Au-Al alloy had been cast in a clay tube, in the form of a rod two centimetres long and about two millimetres in diameter. It was sealed in a vacuum tube as the negative pole, an aluminum pole being at the other side. Part of the alloy, where it joined the platinum wire passing through the glass, was closely surrounded with a narrow glass tube. A clean glass plate was supported about three millimetres from the rod of alloy. After good exhaustion the induction current was passed, the alloy being kept negative. Volatilization was very slight, but at the end of half an hour a faint purple deposit was seen both on the glass plate and on the walls of the tube. On removing the rod from the apparatus it was seen that the portion which had been covered by the small glass tube retained its original purple appearance, while the part that had been exposed to electrical action had changed to the dull white color of aluminum. Examined under the microscope, the whitened surface of the Austen alloy was seen to be pitted irregularly, with no trace of crystalline appearance.

This experiment shows that, from an alloy of gold and aluminum, the gold is the first to volatilize under electrical influence, the aluminum being left behind. The purple color of the deposit on glass is probably due to finely-divided metallic gold. The first deposit from a negative pole of pure gold is pink; this changes to purple as the thickness increases. The purple then turns to green, which gets darker and darker until the metallic lustre of polished gold appears.

If we take several liquids of different boiling-points, put them under the same pressure, and apply the same amount of heat to each, the quantity passing from the liquid to the gaseous state will differ widely in each case.

It was interesting to try a parallel experiment with metals, to find their comparative volatility under the same conditions of temperature, pressure, and electrical influence. It was necessary to fix upon one metal as a standard of comparison, and for this purpose I selected gold, its electrical volatility being great, and it being easy to prepare in a pure state.

An apparatus was made that was practically a vacuum tube with four negative poles at one end and one positive pole at the other. By a revolving commutator I was able to make electrical connection with each of the four negative poles in succession for exactly the same length of time (about six seconds); by this means the variations in the strength of the current, the experiment lasting some hours, affected each metal alike.

The exposed surface of the various metals used as negative poles was kept uniform by taking them in the form of wires that had all been drawn through the same standard hole in the drawplate, and cutting them by gauge to a uniform length; the actual size used was 0.8 of a millimeter in diameter and twenty millimetres long.

The comparison metal, gold, had to be used in each experiment; the apparatus thus enabled me to compare three different metals each time. The length of time that the current was kept on the revolving commutator in each experiment was eight hours, making two hours of electrification for each of the four negative electrodes; the pressure was such as to give a dark space of six millimetres.

The fusible metals, tin, cadmium, and lead, when put into the apparatus in the form of wires, very quickly melted. To avoid this difficulty a special form of pole was devised. Some small circular porcelain basins were made, nine millimetres in diameter; through a small hole in the bottom a short length of iron wire, 0.8 of a millimetre in diameter, was passed, projecting downwards about five millimetres; the basin was then filled to the brim with the metal to be tested, and was fitted into the apparatus exactly in the same way as the wires. The internal diameter of the basin at the brim was seven millimetres, and the negative metal filed flat was thus formed of a circular disk seven millimetres in diameter. The standard gold pole being treated in the same way, the numbers obtained for the fusible metals can be compared with gold, and take their place in the table.

The following table of the comparative volatilities was in this way obtained, taking gold as 100: —

Palladium	108.00	Platinum	44.00
Gold	100.00	Copper	40.24
Silver	82.68	Cadmium	31.99
Lead	75.04	Nickel	10.99
Tin	56.96	Iridium	10.49
Brass	51.58	Iron	5.50

In this experiment equal surfaces of each metal were exposed to the current. By dividing the numbers so obtained by the specific gravity of the metal, the following order is found: —

Palladium	9.00	Copper	2.52
Silver	7.88	Platinum	2.02
Tin	7.76	Nickel	1.29
Lead	6.61	Iron	0.71
Gold	5.18	Iridium	0.47
Cadmium	3.72		

Aluminum and magnesium appear to be practically non-volatile under these circumstances.

The order of metals in the table shows at once that the electrical volatility in the solid state does not correspond with the order of melting-points, of atomic weights, or of any other well-known constant. The experiment with some of the typical metals was repeated, and the numbers obtained did not vary materially from those given above, showing that the order is not likely to be far wrong.

It is seen in the above table that the electrical volatility of silver is high, while that of cadmium is low. In the two earlier experiments, where cadmium and silver were taken, the cadmium negative electrode in thirty minutes lost 7.52 grains, whist the silver negative electrode in 1½ hours only lost 0.19 of a grain. This apparent discrepancy is easily explained by the fact (already noted in the case of cadmium) that the maximum evaporation effect, due to electrical disturbance, takes place when the metal is at or near the point of liquefaction. If it were possible to form a negative pole *in vacuo* of molten silver, then the quantity volatilized in a given time would be probably more than that of cadmium.

Gold having proved to be readily volatile under the electric current, an experiment was tried with a view to producing a larger quantity of the volatilized metal. A tube was made having at one end a negative pole composed of a weighed brush of fine wires of pure gold, and an aluminum pole at the other end.

The tube was exhausted and the current from the induction coil put on, making the gold brush negative. The resistance of the tube was found to increase considerably as the walls became coated with metal, so much so that, to enable the current to pass through, air had to be let in after a while, depressing the gauge one-half of a millimetre.

The weight of the brush before experiment was 35.494 grains. The induction current was kept on the tube for 14½ hours; at the end of this time the tube was opened and the brush removed. It now weighed 32.5613 grains, showing a loss of 2.9327 grains. When heated below redness the deposited film of gold was easily removed from the walls of the tube in the form of very brilliant foil.

After having been subjected to electrical volatilization, the appearance of the residual piece of gold under the microscope, using a quarter-inch object-glass, was very like that of electrolytically deposited metal, pitted all over with minute hollows.

This experiment on the volatilization of gold having produced good coherent films of that metal, a similar experiment was tried, using a brush of platinum as a negative electrode. On referring to the table it will be seen that the electric volatility of platinum is much lower than that of gold, but it was thought that by taking longer time a sufficient quantity might be volatilized to enable it to be removed from the tube.

The vacuum tube was exhausted to such a point as to give a dark space of six millimetres, and it was found, as in the case of gold, that as a coating of metal was deposited upon the glass the resistance rapidly increased, but in a much more marked degree, the residual gas in the tube apparently becoming absorbed as the deposition proceeded. It was necessary to let a little air into the tube about every thirty minutes, to reduce the vacuum. This appears to show that the platinum was being deposited in a porous spongy form, with great power of occluding the residual gas.

Heating the tube when it had become this way non-conducting liberated sufficient gas to depress the gauge of the pump one millimetre, and to reduce the vacuum so as to give a dark space of about three millimetres. This gas was not re-absorbed on cooling, but on passing the current for ten minutes the tube again refused to conduct, owing to absorption. The tube was again heated, with another liberation of gas, but much less than before, and this time the whole was re-absorbed on cooling.

The current was kept on this tube for twenty-five hours; it was then opened, but I could not remove the deposited metal except in small pieces, as it was brittle and porous. Weighing the brush that had formed, the negative pole gave the following results: —

	Grains.
Weight of platinum before experiment	10.1940
" " after experiment	8.1570
Loss of volatilization in 25 hours	2 0370

Another experiment was made similar to that with gold and platinum, but using silver as the negative pole, the pure metal being formed into a brush of fine wires. Less gas was occluded during the progress of this experiment than in the case of platinum. The silver behaved the same as gold, the metal deposited freely, and the vacuum was easily kept at a dark space of six millimetres by the very occasional admission of a trace of air. In twenty hours nearly three grains of silver were volatilized. The deposit of silver was detached without difficulty from the glass in the form of bright foil.

THE METEOROLOGICAL RESULTS OF THE "CHALLENGER" EXPEDITION.[1]

SEEING that water covers nearly three-fourths of the surface of the globe, and exercises an important influence on the temperature of the air above it, and, by the intervention of winds, extends that influence over the land surfaces, it was impossible to give a satisfactory account of the meteorology of the earth in the absence of records of a complete series of observations taken in the open ocean. It was, therefore, of the utmost importance that the records of the "Challenger" expedition should be thoroughly digested, and this work Dr. Buchan, after seven years' labor, brought to a conclusion rather more than a year ago. In addition to the results of the "Challenger" observations, he also made use of records of temperature, atmospheric pressure, etc., received from a large number of stations in all parts of the world. Some of the most striking points in the report are given in an address to the Royal Geographical Society, published in the Proceedings for March and accompanied by four maps, of which two show the distribution of temperature and atmospheric pressure, respectively, for the month of January, and the other two the same phenomena for July. These are reproductions of some of the fifty-two maps annexed to the report.

One important fact that the "Challenger" observations revealed is, that the daily variation of the temperature on the surface of the ocean away from land is very small, nowhere exceeding a degree between latitudes 40° north and 40° south, and falling to one-fifth of a degree in the high latitudes. The temperature of the air was found to have a range about three to four times as great as that of the water below. In the Southern Ocean, at latitude 63°, it was 0.8 of a degree, or four times as great as that of the sea in the same region. Over the open sea the humidity curve closely follows that of the temperature, falling to a minimum at four o'clock in the morning and rising to a maximum at two in the afternoon; but near land a second minimum occurs from about 10 A.M. to 2 P.M. At this time, the land being heated, a current rushes in from the sea to take the place of the hot air that rises from it, and dry air from the upper regions of the atmosphere descends over the ocean. Over the open sea the barometer, though removed from the disturbing influence of land, shows as marked oscillations as over land where the diurnal variation of temperature is great. The cause must be sought in the daily changes in the temperature and humidity of the air produced through all its height by solar and terrestrial radiation.

Another important fact is that, latitude for latitude, the amplitude of the barometric oscillations is larger in an atmosphere highly charged with aqueous vapor than in a dry one. In the anticyclonic regions of the Atlantic and Pacific, the barometer falls only about 0.025 inches from the morning maximum to the afternoon minimum. Since pressure remains high, though currents of air are constantly flowing out from these regions in all directions over the surface of the ocean, it follows that the dry air from above must descend into their centres. These anticyclonic regions play a most important part in regulating the climates of the neighboring continents. The four principal lie in the Atlantic and Pacific, at about latitudes 36° north and south, and appear in all the monthly charts, with the exception of the North Atlantic region, which is absent in the month of January only. The absolutely highest mean pressure for any month, about 30.5 inches, is to be found in central Asia in the month of January. Here, to the south of Lake Baikal, is the centre of a great anticyclone, covering a large part of Eurasia, from which south and south-west winds blow over Russia and western Siberia, raising the temperature of these countries. Their effect may be seen on the temperature chart, on which the isothermals run nearly north and south.

Another example of the effect of pressure on climate may be taken from the low-pressure system in the North Atlantic, where the lowest mean pressure of 29.5 inches occurs between Iceland and the south of Greenland. This system gives rise in winter to south westerly winds in western Europe, and north-westerly winds over North America. While, therefore, the temperature of the former is abnormally raised by winds from lower latitudes, that of the latter is lowered by cold breezes from the Arctic regions. Hence, the temperature of the coast of Labrador is only −13°, while on the same parallel in Mid-Atlantic it is 45°, or 58° higher.

The influence of other cyclonic and anticyclonic areas is discussed in Dr. Buchan's article. In reference to the drawing of isobars, the author gives a warning against the use of observations in steep and confined valleys, where descending cold currents at night and ascending warm currents in the afternoon unduly raise and depress the barometer alternately. Thus, in the Valley of Tönset. in Norway, the mean is 29.95 inches, while at Dovrê, situated at about the same elevation but separated from Tönset by a broad range of mountains, it is 29,87 inches.

Lastly, a few figures must be quoted regarding the velocity of the wind. This the "Challenger" observations showed to be greater over the open sea than near land, the mean difference being from four to five miles per hour. It is greatest over the Southern Ocean (23 miles per hour) and least over the North Pacific (15 miles). The curves on the open sea show a very slight diurnal variation, but near land they exhibit a distinct minimum between 2 and 4 A.M., and a maximum from noon to 4 P.M. The difference between the velocities on sea and land is greatest at 4 A.M., and gradually falls to a minimum at 2 P.M., demonstrating the effect of the land in reducing the velocity by friction, and the fact that this effect is, in some way or other, partially counteracted by the heating of the surface of the land. Such are a few of the important results pointed out in Dr. Buchan's paper, which is so full of valuable information that no abstract can do it justice.

[1] From the Scottish Geographical Magazine for July.

THE NEW LAKE IN THE COLORADO DESERT.

SPEAKING of the lake recently formed in the Colorado desert, in the southern part of California, by the overflow of the Colorado River, Major J. W. Powell, director of the United States Geological Survey, recently gave a reporter of the New York *Times* some interesting facts.

"The traditions of the Indians are by no means the only evidence that this basin has been filled, wholly or partially, before," said Major Powell. "Since the delta was formed, and that portion of the Gulf of California was cut off and left to evaporate under the terrific heat of the sun, the Colorado has been playing pranks of this sort on several occasions. Along the hills which form the sides of this basin there are shoremarks which indicate that at different times the basin has been flooded to different heights, and then, when the river cut back through its old channel, evaporatian has again changed the lake to a parched desert. Along these shore-lines shells have been found which confirm this theory. The action of the Colorado in cutting new mouths for itself and then stopping them up is comparatively rapid because of the quantity of silt which the stream carries. It is not unlikely that the supposed traditions of the Indians are facts within the memory of some of the older ones of the scattering bands that live on the hillsides along the basin, for indications are that the valley has been inundated within fifty years, and certainly it has been at least once or twice since this continent was discovered.

"There is no immediate danger of the basin being filled, because it requires a large volume of water to fill it to the river level, and the evaporation is something wonderful. At the present time, according to reports, only a fraction of the water in the Colorado is flowing through this new outlet. It is possible that the channel may be enlarged as the stream continues to flow through it, so that all the water in the river will pour into the basin. Even if that were to happen the evaporation is great