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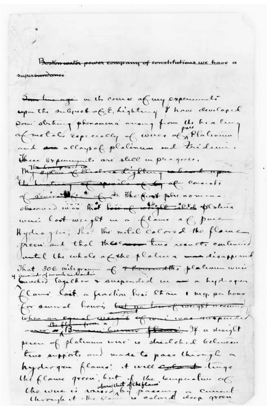
Draft Paper for the American Association for the Advancement of Science



[Saratoga, N.Y., c. August 28, 1879][1]

~~Some time ago~~ in the course of my experiments upon the subject of E. Lighting I have developed some striking phenomena arising from the heating of metals especially of wires of pure[a] Platinum and ~~on~~ alloys of platinum and Iridium. These[b] experiments are still in progress.[2]

~~The Lamp placed in   My system of Electric Lighting is based upon the heating of spirals of by of~~ consists of ~~several feet of~~   The first phenomena observed was that ~~loss of weight which~~ platina wires lost weight in a flame of pure Hydrogen, that the metal colored the flame green and that these[b] [----][c] two results continued until the whole of the platina [~~was~~?][c] disappeared. That 306 miligrams of ~~4 thousandths~~ platinum wires 4 thousands of an inch in diameter[d] bunched together & suspended in [~~an~~?][c] a hydrogen flame lost a fraction less than 1 m.g. per hour for several hours, ~~but no loss of weight occurred~~

w~~hen an equal weight amount[a] of wire was suspended over the flame from a[e] Bunson burner flame~~. If a straight peice of platinum wire is stretched between two supports and made to pass through a hydrogen flame, it will ~~color it~~ tinge the flame green, but if the temperature of the wire is raised above that of the flame[f] by passing a current through it the flame is colored deep green to ascertain the ~~loss of~~ diminution in the[g] weight of a platinum wire when heated by the electric current, I streatched between two clamping posts a wire five thousandth of an inch diameter weighing 2~~96~~66[h] m.g. This wire[i] after being brought to[j] incandescent for [-][c] 20[a] minutes by the electric current[k] its weight was ~~293~~ 265[a] mg showing a loss of [-][c] one[a] m.g.— The same wire was then raised to incandescence for 20 more[a] minutes its[b] weight was[a] 262 m.g. shewing a further loss of weight of 3 mg ~~or a total~~ after 10 minutes additional its weight was 260 mg—in 20 minutes more 258 mg ~~or a total loss of 8 mgrams in one hour and ten minutes~~. after being kept[b] incandescent for 40 minutes longer it loss [~~1~~?][c] 2[a] mg additional or a total loss of ~~7~~ 8[a] m.g. in 1 hour & 50 minutes[3] Afterwards a ~~wire~~ strip of platinum offering large surface to the air &[l] 343 mg[a] was kept [-----][c] moderately[m] incandescent by the current for ~~39~~ hours after which time[a] it weighed ~~310 m.g~~. 301 mg[n] shewing a loss of ~~33~~ 42[a] m.g. A platinum[a] wire 20 thousandths in diameter was wound in[b] [----][c] the form of a spiral ⅛ of an inch in diameter & about ½ an inch in ~~diameter~~ length.[a] This was secured in clamping posts and covered with a glass shade 2½ inches in diameter & 3 inches high. ~~upon passing the current through the spiral~~ upon bringing the spiral to incandescence by the current for 20 minutes that part of the glass globe in line with the sides of the spiral become slightly darkened in ~~4~~5 hours the deposit of platinum was so thick that the incandescent spiral could not be seen through it. This deposit was most perfect and I have no doubt but large plates of glass might be coated economically by being placed on each side of a sheet of platinum kept incandescent by a Dynamo Electric machine.

The loss of weight in[a] together with th~~e~~is deposit upon the glass became a very serious obstacle in the way of its use for producing the Electric light by ~~the~~ incandescence, but it was easily surmounted when the cause was ascertained. I coated ~~a spiral wire with~~ the wire[o] forming ~~a~~ the[a] spiral ~~p~~ by ~~passing~~ with the oxide of Magnesium by[p] dusting powdered acetate of magnesia on the wire while incandescent. The salt was decomposed by the heat and left a strongly adherent coating of the oxide ~~of magnesia~~ upon the wire. This spiral placed in the glass shade was brought to incandescence [---][c] ~~& allowed to remain in that st 20 minutes an opalescent~~ for some time but ~~no dep~~ instead of a deposit of platinum there was a deposit on the glass of the oxide of magnesia, proving that the [~~high~~?][c] effect was due entirely to the molecular[a] attrition—~~or the attrition of the rapidly circulating air in the glass receiver globe cover and produced by the rapid movement of gaseouses~~[q] ~~molecule when in proximity to the highly incandescent was washing o~~ the[r] that the loss of weight & coloration of the hydrogen flame was also due to the wearing away of the surface of the platina by the attrition produced by the impact of the stream of gases upon its highly incandescent surface, and not to volatilization as I understand it, and I venture to say although I have not tried the experiment that sodium cannot be volatilized in high vacua[b] by the heat derived from incandescent platinum, and if[a] any effects are obtained they[s] will be produced by the action of the residual gases.[4] After being satisfied[b] that the deposit & loss of weight was due to the [~~air~~?][c] attrition of the air, I placed a spiral of platinum in a glass receiver of a common air pump & arranged ~~in~~t so that the current could pass through it while[b] the receiver was exhausted, at[b] an exhaustion of 2 millimeters. ~~it look~~ the spiral was kept incandescent for over 2 hours before the deposit was sufficiently thick to become noticable.[5]

by another experiment & at a higher exhaustion it[b] required 5 hours before a tint was observed. in a sealed bulb exhausted by a sprengel mercury pump to a point where a ¼ inch ~~induction coil~~ spark from an induction coil[t] will not pass between wires 2 mm apart I have not detected any deposit whatever although the spiral contained therein had been kept incandescent for many hours, ~~and I feel certain that I shall be able to produce~~. I will now describe the most important phenomena which I have observed. If a piece of platinum wire 1 thousandth of an inch in diameter[u] be held in the flame of a bunsen burner at[b] some point it turns a sharp angle, and under the microscope shews a globule formed at the point where it is bent. in some cases the effect of the heating is to throw the wire into a zig zag shape & melting in many places. with a wire 4[b] thousandths of an inch in diameter this effect does not take place as it temperature cannot be raised to equal that of the small wire, but if th~~is~~e wire be examined under a powerful[b] microscope [~~its~~?][c] that part of its surface which has been incandescent will be found ~~to be~~ covered with innumerable cracks. If a peice of wire be streatched between clamping posts and is brought to incandescence for 20 minutes by the passage of the electric current, ~~This effect will be greatly magnified and the wire will present a~~ these cracks may be seen with the naked eye. The wire under the microscope will present the same appearance as a stick of moistened pipe clay after drying. If the current be continued for several hours[v]—the whole wire[b] will become so cracked & shrunken that it will fall to peices. This[b] disintregation[b] has been noticed by Prof.[a] John W Draper.[6] ~~and~~ It[a] was also[a] the cause of the failure of the process of lighting[w] devised by the eminent French chemist Tessie Du Motay[7] who ~~caused~~ raised platinum to incandescence by the combustion of[x] hydrogen on its surface. ~~Now I have discovered that~~ I have discovered the cause of this phenomena ~~an in eliminating this and have succeeded in bring platinum wire~~ and have suceeded in eliminating that which produces it, and in doing so have produced a metal in[b] a state hitherto unknown, a metal which ~~stands~~ is absolutely stable at ~~which~~ temperature where nearly[y] all substances melt or are disintegrated, a metal which is a homogenous as glass ~~and nearly as brittle~~, as hard as steel wire, in[b] the form of a spiral is as springy and elastic when[b] dazzling incandescent as when cold, and which cannot be annealed, by any process generally[a] known ~~to me~~[z] The ~~method~~ cause of the cracking & shrinking of the wire is ~~entirely~~ due entirely[a] to the sudden expansion of the air in the mechanical & physical pores of the platinum wire and the subsequent contraction[b] of the metal when the air has escaped. Platinum ~~wire~~ as delivered from the manufact~~ori~~ures may be compared to a piece of[aa] sandstone, it being made up of innumerable particles seperated at places by air spaces. The sandstone on being melted becomes homogenous & no air spaces exists while with the platinum the air spaces may be eliminated and the wires made homogenous by a simple process. ~~If a~~ [--][c] This process I will now describe[bb] I made a large number of platinum spirals[8] all of the same size a presenting to the air a radiating surface of 3/16 of an inch. 5 of these spirals ~~were brought to incandescence by the electric current, and~~ had[a] their temperatures slowly increased by the current[cc] until thes melted, the light~~s~~ which they gave off being measured by a photometer[dd] up to the melting point— This varied from 3 to 4 candles, the melting[b] point of the metal being determined by the ~~depth of the large crack in the wire wire~~[a] ~~due to the~~ [-][c] flaws produced ~~by~~ by sudden heating[ee] one of the same kind of spirals was then placed in the[b] receiver of an air pump and the air exhausted to two mm. a very weak current was then passed through the wire to slightly warm it. For the purpose of assisting the passage of the air ~~from in~~ from[a] the pores of the metal into the vacuum, the temperature of the[ff] wire was ~~then~~ gradually augmented at intervals of 10 minutes[9] until it became red. ~~upon~~ [~~coat~~?][c] The object of slowly increasing the temperature ~~so as to~~ [~~reduce~~?][c] was to allow the air to pass out of the metal gradually without disrupting it—[gg] afterwards the current was increased at intervals of fifteen minutes each time before increasing the current the wire was allowed to cool this expansion & contraction of the wire caused it [to melt together at the points previously containing air. In one hour and forty minutes this spiral had reached such a temperature without melting that it was giving a light of twenty-five standard candles, whereas it would undoubtedly have melted before it gave a light of five candles had it not been put through the above process. Several more spirals were afterwards tried with the same result. One spiral, which had been brought to these high temperatures more slowly, gave a light equal to thirty standard candles. In the open air this spiral gave nearly the same light, although it required more current to keep it at the same temperature.][hh]

[Upon examination of these spirals which had passed through the vacuum process, by the aid of a microscope, no cracks were visible, the wire had become as white as silver and had a polish which could not be given it by any other means. The wire had a less diameter than before treatment, and it was exceedingly difficult to melt][hh] in the oxyhydrogen blow pipe[10] as compared to untreated platinum, that it was as hard as ~~pianoforte~~ the steel wire used by pianoforte makers and could not be annealed at any temperature,[11] and my experiments with many metals treated by the process has proved to my satisfaction and I have no hesitation in stating that what is known as annealing of a wire ~~by heating~~ to make it soft and pliable is nothing but cracking of the metal as in every case when a hard wire has been annealed a powerful microscope shows myrids of cracks. ~~Since the experiments above~~, Since these experiments I have by the use of sprengel pumps produced higher[b] exhaustions, and have succeeded by consuming 5 hours in excluding the air from the wire[b] & in intermitting the current[ii] by obtaining a light of eight candles from radiating surface of 3 hundreds of an inch, which is equal to 264 candles per inch of radiating surface,[12] divided upon 33 parts The ~~utmost~~ average [~~amount~~?][c] quantity of[jj] light obtainable from a surface of 3⁄100 of an inch without passing through this process is 1 standard candle.

Thus I am enabled ~~to~~by the increased capacitity of platinum to withstand high temperatures to employ small radiating surfaces, and consequently require less energy ~~to give th~~ per candle light than if I were compelled to use a radiating[b] surface several times greater in consequence of lower melting points, and I ~~can~~ am thus enabled to[kk] obtain eight seperate[a] lights each giving a light of sixteen candles by the expenditure of 33 000 ft lbs of energy[ll] notwithstanding[mm] ~~with~~ all the losses which occur in the passage from the engine to the ~~belt~~ lamp, ~~but all that is required and and as to the impossibility of subdividing the Electric light with economy as has been asserted by some scientific men~~ a result which is quite sufficient to make the Electric Light a commercial success.[13][nn] As a matter of curiosity I have made spirals of other metals and ~~passed them~~ and excluded the air from them in the manner described. Common iron wire may be made to give a light greater than that obtainable from platinum not treated it~~s~~ becomes as hard as steel[14][oo] Nickel is far more refractory than Iron. Steel wires used in piano becomes decarbonized remains hard[pp] and ~~very~~ as[a] white as silver.[qq] Aluminum melts only at a white heat. Magnesium melts only at a bright red The color of the arc at the moment of melting an iron wire in high vacua is deep violet.[15] ~~Palladium requires a longer t~~ In conclusion it may be interesting to state that the melting points of many oxides is dependent upon the manner of applying the heat. For instance, pure ~~Z~~oxide of Zirconium does not fuse in the flame of the[rr] oxyhydrogen blow pipe, while it melts like wax on an incandescent platinum spiral, ~~at a~~ which is at a[ss] far lower temperature, on the other hand ~~alumina~~ the oxide of aluminum [--][c] easily melts in the flame of the oxyhydrogen blow pipe, while it only becomes vitrous at the melting point of platinum.[16]

ADf, NjWOE, Miller (*TAEM* 86:72; *TAED* HM790088a). [a]Interlined above. [b]Obscured overwritten text. [c]Canceled. [d]"4 . . . diameter" interlined above. [e]"~~the flame from a~~" interlined above. [f]"above that of the flame" interlined above. [g]"diminution in the" interlined above. [h]"66" interlined above. [i]"This wire" interlined above. [j]"brought to" interlined above. [k]"by the electric current" interlined above. [l]"offering . . . air &" interlined above. [m]"[-----] moderately" interlined above. [n]"301 mg" interlined above. [o]"the wire" interlined above. [p]"with the oxide of Magnesium by" interlined above. [q]"gases" overwrites "gaseous." [r]"~~produced by . . . washing o~~ the" interlined above; "~~washing o~~ the" interlined separately. [s]"are obtained they" interlined above. [t]"from an induction coil" interlined above. [u]"in diameter" interlined above. [v]"for several hours—" interlined above. [w]"of lighting" interlined above. [x]"the combustion of" interlined above. [y]"temperature where nearly" interlined above. [z]"by any . . . ~~me~~" interlined above. [aa]"piece of" interlined above. [bb]"This process . . . describe" interlined above. [cc]"by the current" interlined above. [dd]"by a photometer" interlined above. [ee]"flaws . . . heating" interlined above. [ff]"The temperature of the" interlined above. [gg]"The object . . . disrupting it—" interlined above; "was to allow" interlined above that. [hh]Page missing, text taken from published paper. [ii]"& in intermitting the current" interlined above. [jj]"average [~~amount~~?] quantity of" interlined above. [kk]"am thus enabled to" interlined above. [ll]"by the . . . energy" interlined above. [mm]Interlined below. [nn]"a result . . . success." interlined above. [oo]"it~~s~~ . . . steel" interlined above. [pp]"remains hard" interlined above. [qq]"as silver"interlined above. [rr]"flame of the" interlined above. [ss]"which is at a" interlined above.

1. In Doc. 1810 George Barker indicated that Edison wrote this paper while in Saratoga. Edison arrived there on 27 August and left on the evening of 30 August, leaving Francis Upton to "read the paper from the writer's exquisite manuscript" on 2 September ("Mr. Edison's Discoveries," *New York Tribune,* 3 Sept. 1879, Cat. 1241, item 1322, Batchelor [*TAEM* 94:511; *TAED* MBSB21322X]). This draft is essentially the same as Edison 1880a with some changes in wording and different paragraphing; text from the published version has been used to replace the text from the missing page nine of the draft. The paper was reprinted within days by three New York newspapers. One of these, the *New York Times,* also reported George Barker's enthusiastic remarks on Edison's electric light and the paper itself, which he praised "as one of the highest importance" ("Giving Metals New Properties. Some of the Wonderful Results of Prof. Edison's Experiments," *New York Times,* 3 Sept. 1879; "Mr. Edison's Experiments," *New York Sun,* 3 Sept. 1879; "Mr. Edison's Discoveries," *New York Tribune,* 3 Sept. 1879; Cat. 1241, items 1314, 1318, and 1322, Batchelor [*TAEM* 94:506, 509, 511; *TAED* MBSB21314X, MBSB21318, MBSB21322X]). The paper was also reprinted in the technical press ("On the Phenomena of heating Metals in Vacuo by means of an Electric Current," *Sci. Am. Supp.* 194:3098; "The Action of Heat in Vacuo on Metals," *Chemical News* 40:152–54; "The Action of Heat in Vacuo on Metals," *Nature* 20:545–46; "Heating Metals in Vacuo by the Electric Current," *Teleg. J. and Elec. Rev.* 7:320–21).

2. On the wire experiments described in the first part of this document see Docs. 1665, 1666, 1669, 1670, 1672, 1675, and 1678; see also Docs. 1676 and 1735.

3. Edison apparently had with him the notebook containing the notes of experiments he had conducted during the last two weeks of January as the precise weights and times given here are found in that book (Doc. 1665). The final paper has some differences. The first twenty minute loss of 1 mg. is incorrectly omitted but the total loss is correctly summed as 8 milligrams after one hour and ten minutes.

4. This statement regarding sodium is not contained in the final paper.

5. See Docs. 1679 and 1735.

6. The work in which John Draper's observation appears has not been identified.

7. Nothing is known of this particular apparatus. Cyprien Tessié du Motay was a French industrial chemist noted for inventing a system of producing pure oxygen with which he planned to modify carbureted gas

systems in Paris and New York. More recently he had experimented with incandescent lighting and, with a partner, filed for a U.S. patent in January 1879 for an electric lamp employing a "pencil formed of earthy material in combination with a metal or metallic oxide." The Patent Office declared an interference with Edison's Case 164 and rejected a related application from Edison (Case 172). The interference was decided in Edison's favor in June; Case 164 issued as U.S. Patent 218,866 and Edison subsequently abandoned the other application. "Death of a Noted Chemist," *New York Times,* 7 June 1880, 2; *Gde. Ency.*, s.v. "Oxygène"; *Ency. Brit.*, s.v. "Gas and Gas-Lighting"; Lemuel Serrell to TAE, 7 Feb., 14 Mar., 9 and 15 Apr., and 14 June 1879, DF (*TAEM* 51:407, 435, 462, 470, 507; *TAED* D7929M, D7929ZAL, D7929ZBF, D7929ZBL, D7929ZCT); TAE to Serrell, 16 Apr. 1879, Lbk. 4:283 (*TAEM* 80:74; *TAED* LB004283A); see also Doc. 1802 n. 1.

8. In the final paper Edison states that these were platinum-iridium spirals of the same quality.

9. In the final paper Edison states that the intervals were fifteen minutes.

10. See Doc. 1670 n. 3.

11. In the final version Edison noted that "it was also scarcely attacked by boiling aqua regia."

12. In the final paper Edison states that the spiral of wire had a "total radiating surface of one-thirty second of an inch, or a surface about equal to a grain of buckwheat." To the side of this statement he wrote the calculation $33 \times 8 = 264$.

13. In the final paper the discussion of economy ends after Edison states the figure of 30,000 foot pounds, which he notes is "less than one horse power"; the rest of the sentence is omitted.

14. In the final paper Edison also noted that common wire became as elastic as steel.

15. The statements about magnesium and the color of the arc when melting iron wire in vacua are omitted from the final paper.

16. See Doc. 1787.