

THE INDUSTRIAL APPLICATIONS OF OXYGEN¹

LAVOISIER, who was the first to recognise in its widest range the importance of oxygen, was also the first who succeeded in making a practical use of it. "It is evident," he writes,² "that atmospheric air is not the best calculated means to increase the effect of fire; for, when a volume of air is conveyed through the bellows to red-hot coals, three (?) parts of noxious or at least useless gas are conveyed with every one part of the useful kind of air; consequently, if the latter could be employed for combustion in its pure state, the action of the fire would be greatly increased. Doubtless this idea has occurred to many others before me; indeed, I hear that M. Achard³ has already tried the experiment, but as yet a cheap and convenient apparatus is wanting." Lavoisier first used the bladders of animals, which were provided with cocks and tubes. "Then," continued he, "I made a hole with a knife from three to four lines deep in a large piece of charcoal and placed in it six grs. of platinum. I then ignited the charcoal through the blowpipe communicating with the enamel lamp, uncocked my apparatus, and blew the pure vital air into the cavity. The coal burnt very rapidly with detonation (such as is produced by fusing saltpetre) and with dazzling brightness; in a few moments the platinum was fused to grains, which soon united into a drop. The fusion was effected equally well when using commercial platinum as when using that, which had been deprived of its magnetic parts by the magnet. Hitherto, it is well known, platinum had been considered infusible." In the course of the same year Lavoisier⁴ improved his apparatus with the assistance of Meusnier, and soon became possessed of a gasometer consisting of two boxes greatly resembling, on a small scale, the well-known reservoirs used in gasworks for holding coal-gas. About the same time Saron had constructed two blow-pipes (*chaleurcaux*), one to furnish oxygen, and the other hydrogen gas.

By their help Lavoisier did not succeed in melting platinum.⁵ However, at that time he and Saron had conceived the idea of constructing an improved blow-pipe, in which the oxygen should surround the hydrogen, and this led to the contrivance of the oxyhydrogen blow-pipe, which has ever since been of such substantial service in the working of platinum and the soldering of lead.

No further attempts were made to fuse platinum by means of oxygen until Deville and Debray⁶ in 1857-1859 and the years following, published their excellent researches "On the platinum metals," and brought the fusion of platinum into practice. The soldering of platinum with platinum, and the manufacturing of cast bars, were carried on on a large scale, first by Messrs. Johnson, Matthey, and Co., in London, and afterwards, though on a smaller scale, by Heræus in Hanau. The experiments of Debray and Deville were attended with one especial result, the discovery of a fire-proof material for making furnaces and crucibles. This is quick-lime, which had the further advantage of retaining the heat as completely as possible. Besides, the temperature was increased by conducting the flame from above, directly, to the surface of the metal, and regulating the quantity of oxygen and hydrogen as theory and practice suggested it. To melt 2 kilogs. of platinum, theory demands 55 litres oxygen and 110 litres hydrogen, while in reality more than one kilog. is fused by these quantities, so that not 50 per cent. of the generated heat is lost (a very satisfactory result). Their experiments were of still greater importance for the history of oxygen industry, inasmuch

as they gave occasion for comparing the prices of different modes of preparing it, and stimulated inquiry after cheaper processes. These we may divide into chemical and mechanical, subdividing the former again into continuous and intermittent processes. Up to this time the following modes of preparation were in use, or had been proposed. To begin with the oldest method of Priestley, heating oxide of mercury, unquestionably the most costly and the least adapted for practical purposes; then Scheele's method, treating peroxide of manganese with sulphuric acid, which produces sulphate of manganese and oxygen. Through Berthier's researches in 1822, this process has been superseded for manufacturing purposes by heating peroxide of manganese; and, lastly, we have to mention Bertholet's method, the heating of chlorate of potassium. Notwithstanding its cost, the latter is constantly used in the laboratory, because it is easy and requires little heat, although it not unfrequently happens that a too rapid fusion causes explosions. To obviate this inconvenience, the suggestion has repeatedly been made of mixing peroxide of manganese with the chlorate of potassium.

More recent accidents, especially a fearful explosion which took place in a pharmaceutical laboratory in Paris, induced Debray and Bourgoin¹ to publish the precautions taken in Deville's laboratory: peroxide of manganese, or what is easier to obtain in a pure state, red oxide, Mn_2O_3 , is added to the chlorate of potassium in equal quantities, and the iron vessel containing it exposed to heat in a charcoal furnace, so that the fire is lighted from above. Schwartz² also gives an account of some accidents occasioned by using peroxide of manganese adulterated with lampblack, and by inadvertence, even with sulphuret of antimony; and for that reason he recommends that all mixtures for the production of oxygen be first tried by heating them on a sheet of platinum. Munck³ proposed adding oxide of iron, which is more easily recognised, instead of peroxide of manganese. Scheele's method of using peroxide of manganese and sulphuric acid had this disadvantage: the glass vessels employed were very liable to burst, through the solidifying of the sulphate of manganese. To prevent this, R. Wagner⁴ proposed to substitute bisulphate of sodium for sulphuric acid, thus forming an easily fusible double salt, which would afford no danger of breaking the retort when cooling. Pure peroxide of manganese yields 18 per cent. by this treatment, while heating it to red heat, which resolves it into sesquioxide, yields only 12 per cent. of oxygen; nevertheless, the last method is the cheapest. Deville and Debray⁵ calculates its expense in proportion to the prices of peroxide of manganese, which are as follows:—

	Per 100 kilogs.	Per 100 francs	Per 1 cb.m.
Romanèche	10	...	4.86
Spain	16	...	3.45
Pyrenees	18	...	3.85
Giessen	29	...	4.87
Italy	40	...	5.98

The trifling value of the remaining sesquioxide, which (containing iron) is of no use in the manufacture of glass, is not here considered.

The calculation dates from the time when the regeneration of peroxide of manganese was an unsolved problem. Allowing therefore the price of oxygen obtained from peroxide of manganese to vary between 3.45 and 5.98 fr., it is more than twice as cheap as that which is procured from chlorate of potassium, for which, according to Dupré,⁶ the average price is 10 fr.

As a much cheaper source, Deville and Debray now had recourse to sulphuric acid, which at a high temperature is decomposed into water, sulphurous anhydride, and oxygen.⁷ Retorts of hard glass of a capacity of 5 litres are filled partly with thin layers of platinum-foil or bits of tile and heated to a red heat, whilst a thin stream of sulphuric acid is introduced.

The escaping gases pass through a cooling contrivance to condense the sulphuric acid, and afterwards through water to remove the sulphurous acid gas. Thus, out of 2.435 kilogs. of sulphuric acid of spec. grav. 1.827, 240 litres of oxygen were obtained, and the price was calculated at 1 fr. per cb.m. By

¹ Debray and Bourgoin, Ber. Chem. Ges., 1870; 240.

² Schwartz, "Breslauer Gewerbeblatt," 1865, No. 7; Polzt Centralbl., 1865, 12.

³ Munck, Pohl's Lehrb. d. Technol., Wien, 1865; 186.

⁴ Wagner, Jahresber., 1866; 198.

⁵ Deville and Debray, Compt. Rend., li. 822; Dingl. pol. J., clix., 50.

⁶ Dupré, Compt. Rend. li. 736.

⁷ Deville and Debray, Compt. Rend. li. 822; Dingl. pol. J. clix., 50, in Ausz. Ann. Chem. Pharm. cxvii. 225.

¹ Translated, by permission of the editor, from the Report on the Development of Chemical Industry, in conjunction with friends and fellow-workers, by A. W. Hofmann.

² "Mémoire sur un moyen d'augmenter considérablement l'action du feu et de la chaleur dans les opérations chimiques" (1782). Œuvres de Lavoisier, ii., 425.

³ The above-mentioned work of Achard is to be found in the Memoirs of the Berlin Academy of 1779, under the title, "Sur un nouveau moyen de produire avec une très-petite quantité de charbons une chaleur égale à celle qu'on peut produire par des verres et des miroirs ardents d'une grandeur considérable." Achard decomposed saltpetre by heat in an earthenware retort, and introduced the "dephlogisticated air" thus obtained into a pair of bellows, from whence it was conveyed into a charcoal furnace, where some iron nails in a hessian crucible were rapidly reduced to fusion. He was also of opinion that the introduction into badly ventilated rooms of gas procured in this way would cause the air in the same to be "dephlogisticated."

⁴ Lavoisier, Œuvres ii., 430.

⁵ Lavoisier, Œuvres ii., 430.

⁶ Deville and Debray, 1859, Ann. Chim. Phys. [3] lvi. 385; Dingl. pol. J. clix., 130, 199, 287, 383; in abstract Ann. Chem. Pharm. cxiv. 78, and Debray, "Sur la production des températures élevées et sur la fusion du platine," in the "Leçons de Chimie professées en 1861." Paris, Hachette, 1862.

this process the cost of melting 1 kilog. of platinum was reduced to 20 or 30 centimes. According to a notice of Moigno,¹ the firm of José de Susini and Co., in Paris, in the year 1867 prepared oxygen in this way at the low price of 0.85 fr. per cb.m., retransforming sulphurous into sulphuric acid. Instead of the acid itself, Deville and Debray also proposed employing sulphate of zinc: 100 kg. of anhydrous salt yielded them 6.8 cb.m. of oxygen (far more therefore than the best peroxide of manganese), 22 kilogs. of sulphurous acid gas, and 51 kilogs. of oxide of zinc.

Wagner's statement² is worthy of remark, that in the year 1867 neither of these methods was in use in Deville's own laboratory; perhaps because the sulphurous acid evolved complicated the working.

We must not pass over Archereau's attempt³ to employ sulphuric acid in its cheapest combination as gypsum. He asserted that heating pulverised gypsum with sand would produce silicate of calcium, setting sulphurous acid free, which he partly condensed (as did also Susini) under a pressure of three atmospheres, and partly removed by means of a thin paste of lime. A manufactory established on these principles in Paris did not work long.⁴ Obviously the very high temperature required is an obstacle. The production of this gas from one of the oldest of all oxidising agents, saltpetre, was not employed on account of two drawbacks. In the first place, a quantity of nitrogen is mixed with it; and secondly, the temperature necessary for its decomposition greatly increases the cost. This last inconvenience was remedied by Webster's⁵ adding oxide of zinc to saltpetre: 20 lbs. of nitrate of soda and 4 lbs. of crude oxide of zinc furnished 94.676 cubic feet of a mixture of 59 p. c. of oxygen and 41 p. c. of nitrogen, while chiefly oxide of zinc and caustic soda remained. The price of the oxygen contained in this mixture, so useful for many purposes, without taking into consideration the value of the solid residue, amounts⁶ to 2.32; and allowing for the value of the remains, the price is reduced to 0.78 fr.

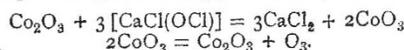
In no one of these methods appears one of the leading ideas of modern industry, viz., the regeneration of the residues.

The following plans were happier in this respect, and thereby, in part, more successful.

To combine chemically the oxygen of the air with a carrier of oxygen that would easily give off the gas, and would be always ready to take up and again to give off fresh quantities of oxygen, just as mercury does when we transform it into its oxide and retransform the oxide into the metallic state—that is the problem of which the last few years have given an economical solution. As early as 1829 Döngler jun.⁷ discovered that oxide of copper as well as peroxide of cobalt and nickel, treated with an excess of chloride of lime, generate oxygen gas, thereby transforming it into chloride of calcium. In the year 1845 Mitscherlich⁸ observed that many other metallic oxides, viz. peroxide of manganese, hydrate of ferric oxide, cupric oxide, &c., when added to a solution of chloride of lime, caused a development of pure oxygen. In 1865, Th. Fleitman⁹ renewed these observations with reference to freshly prepared sesquioxide of cobalt, the smallest trace of which was sufficient completely to reduce a concentrated solution of chloride of lime into chloride of calcium and oxygen. For practical purposes he recommended to heat to 70° or 80° a highly concentrated solution of chloride of lime (which to avoid frothing over should be previously cleared by filtration) with 0.1 to 0.5 per cent. of sesquioxide of cobalt. By applying chloride of lime containing 35 per cent. of pure hypochlorite, he obtained from twenty to thirty volumes of oxygen in a regular stream; and other observers, notably F. Varrentrapp,¹⁰ confirmed these results, and commended their industrial application. The sesquioxide of cobalt need not be added ready formed; any cobalt salt answers the same purpose, and the sesquioxide employed with or formed by it soon settles at the bottom and can be used again and again.

For that very reason a cheaper oxide—cupric oxide, for instance, as Böttger¹¹ proposed—would be of trifling advantage, because its use demands¹² a much higher temperature for decom-

position. The tedious work of preparing a clear solution of chloride of lime may be avoided by adding¹ small morsels of paraffin, a thin layer of oil on the surface preventing an overflow. There was still one evil to be grappled with. Chloride of lime requires considerable quantities of water for its solution, and consequently large vessels were necessary for the production of even a moderate quantity of oxygen. For that reason a Winkler² rejected chloride of lime, preferring to pass chlorine through a thin paste of lime mixed with a little nitrate of cobalt. By this modification a greater quantity of oxygen can be produced in the same vessel, and there is no danger of the liquid frothing over. The part which the metallic oxide plays in these methods is easy to understand. It acts as a carrier of oxygen, passing by turns into a higher and very unstable oxide, and being reproduced in its original state. The hypochlorous acid transforms sesquioxide of cobalt into cobaltic acid, which instantly separates again into oxygen and sesquioxide of cobalt.



Thus, part of our problem is solved. By the production of oxygen the carrier of oxygen is reproduced. The oxygen, however, thus obtained is not taken from the atmosphere, but from lime. The solution of chloride of calcium resulting from its preparation must be removed and replaced by fresh lime water. The process is therefore an interrupted one, and in this respect capable of economical improvements. These also have been accomplished by methods which carry us back from the wet to the dry way.

Since 1851³ Boussingault proposed baryta as a carrier of oxygen, which, heated to redness in a porcelain tube and treated with moist air previously freed from carbonic acid, became transformed into peroxide of barium. A current of steam passing over it reproduces hydrate of barium and liberates the oxygen; while an admixture of lime or magnesia prevents the fusing together of the mass, and thus 75 gr. of baryta yield 4 to 5 lit. of oxygen at every operation.

In 1868 Gondolo⁴ improved on this method by employing iron tubes protected by an outside covering of asbestos and by an inside layer of magnesia, and placed in suitable furnaces, the temperature of which could be easily regulated. He further added to the baryta a little manganate of potassium as well as lime and magnesia. In this manner 122 alternate oxidations and reductions were carried on in the same tube. Whether it be the high temperature or other obstacles which have prevented this method from being generally adopted, it has certainly made no way as yet into practice, although it has paved the way to final success.⁵ Looking for carriers of oxygen of a more useful sort than baryta, the chlorides of copper were the first to strike the attention of chemists. The facility with which they pass into oxychlorides of various compositions when exposed to the air, is the base of the manufacture of a well-known painter's colour, Brunswick green. In 1855 Vogel proposed the action of muriatic acid on cupric oxychlorides as a means of obtaining chlorine.⁶ Mallet⁷ studied these substances more closely, and founded on them a process of obtaining both chlorine and oxygen. He discovered that cupric chloride, treated with a current of steam, changes at 100° to 200° into several oxychlorides, which, by means of muriatic acid, are not only at once retransformed into the chloride and free chlorine gas, but give off all oxygen at a temperature of only 400°, 1 kilog. of cupric chloride yielding from 28 to 30 lit. of oxygen. Experiments on a large scale produced from 3 to 3½ cb.m. of oxygen, or from 6 to 7 cb.m. of chlorine, from 100 kilogs. of chloride of copper in one operation. As four or five operations can be performed in one day, from 200 kilogs. of cupric oxychloride 15 to 18 cb.m. of oxygen are producible daily.

The apparatus employed consists of revolving retorts of cast-iron lined with clay, and containing the cupric chloride mixed with ¼ of sand or kaolin to render the mass less fusible. This

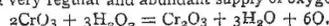
¹ Stolba, J. pr. Chem., xcvi., 309.

² A. Winkler, J. pr. Chem., xcvi., 340.

³ Boussingault, Compt. Rend. xxxii. 261 et 821; J. pr. Chem. lii. 480 u. liii. 313; Dingl. pol. J. cxx. 120 u. 416; Ann. Chim. Phys. [3] xxxv. 5.

⁴ Gondolo, Compt. Rend., lxxi., 488.

⁵ Robbin (Pogg. Ann., cxvii., 256) employed peroxide of barium in another form for laboratory use. He recommends a mixture of chromate of potassium (1 mol.) and peroxide of barium (3 mol.) with dilute sulphuric acid, to obtain a very regular and abundant supply of oxygen:—



⁶ Vogel, Wagn. Jahresber., 1861, 177.

⁷ Mallet, Compt. Rend. lxxv. 286, u. lxxvi. 349.

¹ Moigno, Mondes 1867; p. 494.

² Archereau, Dingl. pol. J. clxxviii. 57.

³ Wagner, Jahresber., 1867, 216.

⁴ Pepper, "Chemical News," 1862; 218.

⁵ Dupré, Compt. Rend. lv. 736.

⁶ Dingl. pol. J. xxvi. 231.

⁷ Mitscherlich, Pogg. Ann. lviii. 471.

⁸ Fleitman, Ann. Chem. Pharm. cxxiv. 64.

⁹ Varrentrapp, "Mittheilungen f. d. Gewerbe verein der Herzogthums," Braunschweig, 1865, 1866; 72.

¹⁰ Böttger, J. pr. Chem., xcv., 375.

¹¹ Reinsch, N. Jahrb. Pharm., xxiv., 94; Zeitschr. Chem., 1866, 31.

method was employed at Cologne in 1871.¹ A company formed in Paris for its employment had but a very brief existence,² probably owing to a similar discovery which soon supplanted the one described above.

This method, originated and perfected since 1867,³ by the inventive powers of M. Tessié du Motay, employs peroxide of manganese as the carrier of oxygen, and takes its stand upon the following reactions. Sodid hydrate exposed to dark red heat with manganese and air, yields, as Mitscherlich discovered, manganate of sodium and water, $4\text{NaOH} + 2\text{MnO}_2 + 2\text{O} = 2\text{Na}_2\text{MnO}_4 + 2\text{H}_2\text{O}$; and manganate of sodium, under the influence of a dry current of overheated steam, disengages at the same temperature sodid hydrate, manganic sesquioxide, and free oxygen, $2\text{Na}_2\text{MnO}_4 + 2\text{H}_2\text{O} = 4\text{NaOH} + \text{Mn}_2\text{O}_3 + 3\text{O}$. By previously depriving the overheated air of its carbonic acid, one may preserve the mixture in a perpetually active state. This method has been thoroughly tested and approved, and has since been employed on a large scale in Comines, near Lille; in Pantin, near Paris; in New York, in Brussels, and in Vienna. Bothe⁴ informs us that a mixture of sixty parts of dry carbonate of sodium with forty parts of 95 per cent. peroxide of manganese, when fused, contains 74.62 parts of manganate of sodium, and that 40 kilogs. of this mixture, which, according to calculation, should give 2,036 cb.m. of oxygen gas, produced in reality 1,800 cb.m., or 90 per cent. of the theoretical yield. He recommends the proceeding as a very practical one. M. Pourcel⁵ has given us the most detailed description. According to him, M. Tessié du Motay employs cast-iron ellipsoidal retorts, which lie horizontally one beside the other, and are divided by a grating parallel to their axes, into two unequal parts. Over the grating 350 kilogs. of manganate of sodium, or of the reduced mixture of manganese and soda, are so spread out that its height amounts to 0.60 m., and the empty space above and below the mass is as inconsiderable as possible. In Comines, where five of these retorts are used, the amount of oxygen produced daily is 140 cb.m. at the cost of 450 kilogs. of coals for heating the retorts, and of 150 kilogs. used for the steam-engine. The air is passed through a thin iron vessel with quick-lime by means of the bellows, under a pressure of from 3 to 4 cm. of mercury, and enters the retort from above. The temperature of the latter can be observed through a hole provided with an iron stopper. In this way the air gives off only about half of its oxygen, so that to produce 1 vol. of oxygen 10 vol. of air must be passed through, the remainder escaping into the atmosphere. Five minutes suffice for oxidising the reduced mass. The current of air is then interrupted by means of a three-way stopcock and superheated steam passed through the retorts for five minutes, while the gas, passing out below the grating, enters condensers. Here a fine rain of cold water frees the oxygen from the steam, and the gas enters the gasometer under the pressure of a column of water of from 8 to 10 cm. in height. Thus reduction and oxidation alternate at intervals of five minutes. After a lapse of six hours only, it is necessary, for a perfect regeneration of the fused mass, to admit atmospheric air for about an hour, because the quantity of oxygen obtained becomes lowered after five or six hours, down to half or even a third part of the original quantity. In Vienna the cocks are worked by an automatic apparatus. The longer the steam is forced in and the retorts freed from air before the communication with the gasometer is opened, the purer will be the oxygen; half a minute is enough to leave only 15 per cent. of nitrogen mixed with it, provided the injurious space in the retort be kept as small as possible. If the nitrogen be lowered to 4 per cent., which is easily effected, the sacrifice of oxygen will be so much the greater. To make certain that the quantity of nitrogen remains within the limits of 15 and 10 per cent., which are proved to be the most practicable, gas is taken from the gasometer or the condenser in graduated tubes, and the oxygen is absorbed by means of pyrogallate of potassium, a reaction attended by quick and sure results, even in unpractised hands.

As every cooling down of the retort below dark red heat lessens the yield, care is necessary to raise the temperature of the air, as well as of the steam, to about 300° C. In Pantin, where several groups of ten retorts are set up, two of them are filled with pumice-stone to warm the air and the steam. The composition of the fused mass corresponds to 2 mol. NaOH, 1 mol. MnO₂, and the fifth part of a mol. of cupric oxide, which serves

only to disintegrate the mass and make it more accessible to the influence of the air and steam. In Comines peroxide of manganese is reproduced from the residues of chlorine by the known methods, almost in a pure state. Its market-price, for which the Pantin works buy it, amounts to 2 fr. per kilog. The high price of this basis of the manufacture of oxygen is indifferent, as it can be used continuously, and the longer, the more carefully the air is kept free from carbonic acid. If, through some unavoidable interruption of the manufactory, the mass should have attracted carbonic acid from the atmosphere, it suffices to bring it to a red heat, and pass steam over it until the steam, on leaving the retorts, produces no precipitates in lime-water: then hot air passed over it will restore the mass to its original efficiency. On an average, a retort is said to last about a year.

M. Tessié du Motay's method produces a cubic metre of 90 per cent. of oxygen for 15 to 30 centimes,¹ or, according to the results of Herr Kuppelwieser's experiments,² 1,000 cubic feet at 3 fr., a price in accordance with the last-mentioned sum, and scarcely exceeding that of coal-gas. We may regard this method as a final and successful solution of the problem of discovering economical and rational chemical means for obtaining oxygen.

(To be continued.)

NOTES

THE Wollaston Medal of the Geological Society has been awarded to Prof. Huxley, and will be presented at the Anniversary of the Society on the 18th inst. Prof. Huxley has also been elected a Corresponding Member of the Danish Academy of Sciences.

THE *Times* of yesterday contains a summary account of what has been done so far in this and foreign countries towards organising the Loan Collection of Scientific Instruments to be opened at South Kensington in April. The invitation from the Science and Art Department has met with a hearty response both in this country and from foreign Governments. We last week gave a list of the Foreign Committees, and the *Times* publishes the list of those on the English Committees in the various departments of Mechanics, Physics, Chemistry, Geology, and Biology; and as the *Times* remarks: "By going over them not only does one get an idea of the disinterested way in which men--for the most part busy men--have come forward to help the Department, but there can be no better guarantee of the success of the Exhibition than that afforded by the list of those who are labouring to make it successful." It would indeed be difficult to mention any man of scientific eminence in this country whose name is not included in the list. Out of England, as our readers would see from last week's list, the most numerous committee is the German one. On this the *Times* says:—"The German list gives us much food for thought. It is known, for instance, that the thirty-four local committees, representing her many Universities, Polytechnic Schools, and other scientific centres, were all organised in a week, and that her Universities will, in all probability, be the richest contributors, whereas when we have mentioned Edinburgh, Glasgow, Manchester, Birmingham, Leeds, and Liverpool, and perhaps Newcastle, we have almost exhausted the localities where committees would be useful." The teaching side of the collection will be complete beyond all anticipation. The Physical Cabinet, it is stated, will be such as the world has never seen, towards the formation of which not only will British, French, German, Italian, and Austrian instrument makers lend their aid, but the collections of the Royal Institution, Glasgow University, Edinburgh University, King's College, the Conservatoire des Arts et Métiers, the College de France, the Universities of Berlin, Bonn, Heidelberg, Leipsic, Vienna, Rome, and Leyden, and the Tayler Institution at Haarlem, and the like, will be ransacked. The Chemical and Historical Collections will be of scarcely less magnitude. With regard to the last it is still doubtful whether Italy will part with Galileo's telescope and magnet, even for a month, though it is

¹ Philipps, "Der Sauerstoff," Berlin, 1871, 22.

² Wagn. Jahresber., 1867, 215.

³ Tessié du Motay, Institut 1868, 48.

⁴ Bothe, Zeitschr. d. Vereins deutsh. Ing., 1867, 334.

⁵ Pourcel, "Mémoires de la Société des Ingénieurs Civils," Paris, 1873.

¹ Philipps, "Der Sauerstoff," 18.

² Kuppelwieser, Berg-u. Hütten. Zeitung, 1873, 354.