GAS AND GAS MAKING.

I.

By L. P. GRATACAP, Ph.B.

THE average householder, partly from tradition, partly by inherited prejudice, and partly through personal grievances and misunderstanding, regards the gas company who supplies his dinner table, his parlors, and his bedrooms with light, as an exorbitant monopoly, commissioned to impose upon its consumers, and to be resisted in any way, as invention or shrewdness dictates. Gas is somehow classed with sunlight and air, a universal element upon the use of which no artificial restraints should be laid, and which belongs quite naturally to any one who can or cares to use it. When the announcement of Edison's discovery of a cheap and brilliant substitute was made, a perceptible thrill of exultation went through the community. Surely, Edison has much to answer for if he wittingly deceived his admiring audience, and, after promising them emancipation from an unnatural yoke, and luring them into a distempered glee, now permits them to return to an odious bondage and a discarded nuisance.

Much, perhaps, of this ill-natured criticism of gas companies arises from an insufficient sense of the privileges gas bestows, its delightful assistance and protective influence; from ignorance of the amount of skill and invention that has been shown in the history of its improvement, and of the advanced state its manufacture has reached through persistent experiment. It is not to satisfy any profound craving after knowledge in gas making that we offer a general sketch of this industry, but rather to temper with a little reasonable information a surprising indifference as to what gas is or how it is made.

THE MATERIAL.

Not the least interesting topic connected with this subject is the material which yields the gas, and which, in whatever relation it is discussed, chemical, geological, or botanical, is one of the most remarkable objects offered to human study. It is coal. Those black, sightless heaps of grimy stone which fill the bins of our coal yards, represent the pivotal bearings of a nation's wealth. In other words, the heat that keeps winter from our door, the motion that carries us over hill and dale, the agency by which our ores are made to yield the sinews of commerce, and the cheerful flame that renews day in the night, all proceed from coal. The half-expressed apprehension of her statesmen that in 300 or 400 years England's supply of coal will become exhausted, and with its decline her naval and industrial supremacy disappear, strikingly illustrates the pre-eminent role King Coal may yet play in history. America views her own immense coal beds with complacency, and sees in them a sort of fore-installment of means ample enough to develop her enormous mineral resources and assist in the continuous growth of that of other peoples. The coal-bearing area of the United States, as compared with the available areas of other countries, is shown in the following table, quoted from Le Conte:

United States.....	120,000 sq. miles.
British America.....	18,000 "
Great Britain.....	12,000 "
Spain.....	4,000 "
France.....	2,000 "
Germany.....	1,800 "
Belgium.....	518 "

But how directly related the industry of coal mining is to the growth and development of the nation, and how the tables of its production are in a way criteria of the country's condition, is seen from the adjoined valuable statement:

Countries.	Yield in 1855. Million tons.	Yield in 1875. Million tons.	Percentage increase.
United States.....	5	50	900
Great Britain and Ireland.....	66	132	100
Germany.....	8	50	462
France.....	7.5	17	126
Belgium.....	8	15	88
Austria.....	2.5	12	380
Russia.....	.5	1.5	200
Australia.....	.25	1.5	500
Spain.....	.25	.75	200

This increase of 900 percent. has been largely due to rapid and abnormal increase in population, to a change from wood fires to coal fires, a cause which has similarly operated in Germany and Austria, to an enlarged consumption of fuel in living, manufactures, and railroads.

What is coal? Thanks to a long series of minute investigations we are able to answer this inquiry with considerable confidence. It was plants that contributed their parts, whether branches, leaves, twigs, bark, spores, or roots, to form extended layers of vegetable matter, which, collected after many seasons of decay and growth over immense flats, barely emerged from the waters of adjacent seas, or in swampy basins, built up seams of woody fiber that, through subsequent alteration, made our coal veins. Mr. Wunsch, of the Glasgow Geological Society, says that, from personal observation on the Isle of Arran, three to four inches of coal represents twenty generations of trees, and that in one foot of coal is condensed the vegetable debris of eighteen centuries.

Four genera of plants were prominent among—indeed, almost solely composed—the vegetable life of that time, enjoying a wonderful vitality and vigor, contrasted strangely with the meager subsistence of their modern relatives. These plants were ferns, equisetæ or horse tails, sigillaria and lepidodendra. The ferns, like the low-waving forms whose fronds adorn our rock gardens, and others, whose size resembled the tree-like proportions of the tropical species, mingled together in the woods. Great numbers of their fallen sprays and delicate leaflets are preserved on the floors and roofs of the coal seams, and impressions left over slabs of stone, formerly a plastic mud, which faithfully stereotyped every detail, acquaint us with the species that then flourished.

But much above these in importance, and more remarkable in appearance, were the lycopods, the lepidodendra, and the sigillaria. These plants were closely related to each other, and were identical in functions and general type of organization. The sigillaria, or seal tree, has contributed in large part its bark, branches, and especially its cellular core, which formed a pithy axis throughout its trunk and superior divisions, to the formation of the Nova Scotia coal, as revealed by the microscope to Dr. Dawson. Dr. Dawson says: "These trees present tall pillar-like trunks, often ribbed vertically with raised bands, and marked with rows of scars left by the fallen leaves. They are sometimes branchless, or divide at top into a few thick limbs, covered with long rigid grasslike foliage.

The lepidodendra were larger, more striking, and more attractive plants. Their branches were more numerous, forked, and with slender leaves wound around them in continuous spirals. These at first clothed the trunks and limbs, but as the tree expanded and rose they shriveled from the older parts, leaving lozenge-shaped scars in a quincunx order, whose form has offered an artificial and useless indication of specific differences. Many species made according to this mistaken criterion are really parts of the same species, being frequently but outer or inner bark.

These trees, multiplying their awns by their peculiar style of division (dichotomy), waved a forest of their leaves and flexible branches through the air of the carboniferous day, rapidly absorbing the carbonic acid about them, which, decomposed by the sun, fed their increase. Noticeable among these leaves were the lepidostroba—cone-like bodies enveloped in imbricated sheathing scales—which contained the spores or seeds for new plants. When ripe their dispersion took place much as the winged seed of our pines filter out from the pine cones and shower in clouds upon the ground. These minute sacs of the lepidodendron, though only 1-20th of an inch in diameter, actually constituted the bulk of large deposits which carbonized now form some of the best English coal. Modern instances are not wanting, affording some corroboration of this remarkable assertion.

In Invernesshire a shower of fir pollen occurred which hid the ground about for miles and in places was half an inch thick. Immense palls, traveling with the wind, have hid portions of the sky to observers in Virginia and North Carolina, which proved, after investigation, to be clouds of pine seeds. A more interesting parallel is found in the tasmanite of Australia. This is a shale, six to seven feet thick, and miles in extent, highly resinous and burning readily. The microscope shows the presence of numerous spores, sacs, and their accumulation in these schists has rendered the beds bituminous and combustible.

The last important member of this carboniferous flora was the calamites or equisetæ. These were rush-like canes, growing very high, bearing whorls of leaves at regular intervals, and tapering to a narrow and acute summit, tufted with crowded clusters of smaller leaves. They are related to the scouring rush, whose silicious stytes make a cheap sapollo to the rural housewife. They grew in hedges along the margins of low levels, and arrested the invasion of drift and sand over the interior country where the sigillaria and lepidodendra were storing up in comparative purity the fuel of the future. These plants collectively have furnished a great part of the material for our coal, their contributions far preponderating over the slight additions furnished by pines and cycads. Their luxuriant vegetation was grouped in swampy and extended basins, low troughs, and estuarine flats, scarcely elevated above or insecurely separated from the sea, and subject to occasional incursions of the latter, which hid, at each successive overflow, the new accumulations, and sealed them up in recurrent strata. They heaped up mouldering and rotting trunks, leaves, branches, and spores, which afterward were compressed by a weight of sand and mud, consolidated by heat, and metamorphosed by the alembic power of chemical forces. Thus was prepared from the sodden, rank, and fermenting layers the hard and soft coals which fill our coal scuttles, blaze on our hearths, and feed, by tons, the fury of our furnaces. Along with these towering club mosses, and, probably, composing a ground tier from which they rose, enormous stretches and mires of peat bog were engaged, century by century, in preparing deposits of vegetable fiber many hundred feet deep. Lesquereux says: "In ancient peat bogs, the peat especially near the bottom becomes black, compact, intermixed by layers of crystalline, though still soft coal matter, which only wants hardness to be comparable to true coal or even undistinguishable from it." The essential importance of peat in coal making may be judged from its present utility in supplying a primitive fuel and its local extent. It is used as a substitute for coal in Ireland, Germany, Switzerland, America, and Sweden, and in Indiana covers one area three miles wide, sixty miles long, and varies from five feet to fifty feet in thickness.

It does not seem necessary to presuppose an atmosphere essentially diverse from our own, though it was once thought that carbonic acid, the food of plants, should have far exceeded its present proportions in the carboniferous age, to provide for the enormous appropriation of it by the rank vegetation. Yet, although there are but three to four parts of carbonic acid at present in 10,000 parts of air, there still rest over each square mile of the earth's surface 1,800,000 tons of this gas, containing 371,475 tons of carbon, and but the slightest increment would raise these figures astonishingly. Surely, here is reason enough to warrant our rejecting the prevalent conception of the necessity of a noxious atmosphere, crowded with this irrespirable gas, in the days of the coal measures. Moisture, however, abounded, the air was heavy with humidity, frequent and long rains watered the luxuriant forests, and hot fogs enveloped, at times, the highest trees. The climate was equable, and since we do not find in the remains of exogenous trees any rings of growth, it has been concluded that growth was continuous and not annually intercepted by cold winters.

The thickness of the coal seams varies from thin films to strata forty feet in thickness, though, in most instances, impure beds lessen the workable veins of coal by many feet. These coal beds extend over wide areas, embracing thousands of square miles, they vary throughout their extent in thickness, the same seam thinning out almost entirely and thickening again to its greatest depth, illustrating the varying surface of the land, its depressions, its margins and drier parts, and the contrasted luxuriance and poverty of the vegetation.

The formation of coal from woody tissue can be chemically expressed with sufficient clearness to allow us at least to apprehend the stages of the process and the nature of the bodies whose disappearance from the original fiber leaves the carbonaceous residue known as coal. Wood is composed in its ultimate analysis of carbon, hydrogen, oxygen, nitrogen, sulphur, and other mineral constituents taken up by the plant from the soil. These elements are grouped in a form obscurely, if at all, understood, and the multiplex reorganization of these compounds in decomposition and slow burning up, which that implies, results in eliminating certain products of hydrogen, oxygen, and carbon, whose aggregate effect is to increase the carbon in the parts remaining. The abstraction of carbon, hydrogen, and oxygen takes place under the form of water, carbonic acid, carbonic oxide, marsh gas, and rich oils, which are for the most part collections of a vast variety of bodies made up of carbon and hydrogen combined in different proportions. The transition then of a wood to coal embraces a series of states, and could we arrest the action at various successive points we would discover the general tendency of the changes taking place.

and probably, also, meet with a number of substances specifically distinct. In a rude way nature has done this for us, and we can arrange in a line a number of natural products, each of which represents a certain broad and comparatively permanent phase in the process, and conducts us from the raw material, wood, to the perfected product, anthracite or graphite. Such a scale would read, with its table of component parts, as follows:

	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Ash.
Wood.....	49.70	6.06	41.30	1.05	1.80
Peat.....	58.18	5.96	31.21	1.23	3.43
Lignite.....	67.09	5.55	20.35	2	4
Bituminous coal.....	75	5	13	1	6
Semi-bitum. ".....	—	—	—	—	—
" anthracite.....	—	—	—	—	—
Anthracite.....	92	2	2	2	2
Graphite.....	100	—	—	—	—

Of course, it must be understood that the above percentages of comparison are varied in every particular instance where a specific coal is examined, since the age of the coal, any peculiar circumstance of its formation, the plants or parts of plants that composed it, some modifications of the process of alteration, one or all produce corresponding variations in the result, so that the above table represents the most general average from numerous analyses and corresponds strictly with no single result. Yet the briefest inspection shows two things: first, a concentration and increase of carbon; second, a gradual disappearance of hydrogen and oxygen. To bring this latter fact into greater prominence, Prof. Thorpe has constructed a table where, by making the carbon constant, the removal of the hydrogen especially, and that of the oxygen also, gain an exaggerated effect.

	Weight of one solid cubic foot in pounds.	Carbon.	Hydrogen.	Oxygen and nitrogen.
Wood.....	30	100	12.3	86.8
Peat.....	50	100	9.7	54.7
Lignite.....	70	100	8.3	40
Brown coal.....	75	100	7.4	29.7
Bituminous coal.....	80	100	6.4	13.4
Anthracite.....	90	100	2.6	2.3

A closer examination of these substances will introduce a number of interesting facts.

The initial stage of the change of this vegetation into coal began with a complete or partial maceration and rotting of the woody tissue, accompanied or followed by a fermentation interferred with and impeded by pressure and protection from air. The albuminoid constituents of the wood start this putrefactive process, during which oxygen is absorbed and water and carbonic acid eliminated, while a rise in temperature indicates the combusive nature of the action. A stage must have been soon reached, which probably approached the state of things existent in vegetable mould, when the dark mouldy body, known as *humus*, is produced by decomposition, forming on the surface of ground a rich and efficient manure, and representing an intermediate step in the production of coal. Thus, the following table from Prof. Thorpe shows an increase of carbon and a removal of hydrogen and oxygen:

	Carbon.	Hydrogen.	Oxygen and nitrogen.
Woody tissue.....	50.2	6.2	43.6
Oak humus.....	54	5.1	40.9
" ".....	56	4.9	39.1
" ".....	55	4.8	39.9
Moss ".....	54	4.6	41.4
Average.....	54.8	4.8	40.4

It was due to this softening, which doubtless greatly varied in different places, and left the evidence of such local differences in the physical structure of the coals produced, that we find the trunks of sigillaria, ferns, and lepidodendra flattened whenever they were exposed to pressure, and their cellular cores squeezed out. Those trunks which preserve their rotundity are found in the middle of the coal veins; where the yielding and pasty mass found a cushion against external pressure.

The disintegration thus begun continues with precisely similar effects, concentrating carbon and, proportionately, discharging hydrogen and oxygen until peat-like bodies form. Peat bogs themselves show, in their vertical sections, the gradual gradations from the unchanged vegetable matter on the surface to dense and coal layers on the bottom, where organic texture seems obliterated and a real coal encountered on the very verge of its actual production.

PEAT ANALYSES.

	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Ash.
Philipstown, Ireland.....	57.52	6.83	32.23	1.42	1.99
Wood of Allen, ".....	58.30	6.43	31.36	1.22	2.74
Upper Shannon, ".....	58.53	5.73	32.32	.93	2.47
" dense.....	59.42	5.49	30.50	1.64	2.97
Average.....	58.18	5.96	31.21	1.23	3.43

It must be remembered that where the vegetable debris undergoes a stifled combustion, the products become more complicated, and, as under water, a release of both carbon and hydrogen takes place simultaneously in the form of marsh gas or carbureted hydrogen, the fire damp of mines, against whose frightful aptitude to explosion the safety lamp of Sir Humphry Davy and Ansell's indicator are both well known protections. It seems likely that the transition of peat coals to ordinary bituminous coals might have been effected by pressure; some slight degree of heat, and the continuous consolidation of fixed carbon and the formation of higher and higher homologues of marsh gas and olefant gas, which, if not effectually existent in the coal, instantly group themselves out of more elaborate mixtures upon the application of heat.

The stage of lignite chemically succeeds that of peat, though it appears questionable whether all coals passed through its physical aspects.

Lignite is a fossilized wood, light or dark brown in color, of a woody texture, yielding vinegar or acetic acid upon dry distillation, friable and brittle.

ANALYSES OF LIGNITE.

	Carbon.	Hydrogen.	Oxygen and nitrogen.
Devonshire.....	67.9	5.8	26.3
Cologne.....	.67	5.3	27.7
Washington Territory.....	.69	7	24

Brown coal is an advanced state of lignite, wherein organic structure disappears and ammonia results from distillation.

ANALYSES OF BROWN COAL.

	Carbon.	Hydrogen.	Oxygen and nitrogen.
Tasmania	71.9	5.6	23.5
Auckland	72.2	5.4	22.4
Hungary	72.5	5.4	22.1

Prof. Thorpe says: "From the brown coal we pass by insensible gradations to the black coal or coal proper. The change is attended by an absolute loss of ligneous structure, by an increased density and a tolerably well developed cubical fracture." The bituminous coals forming the next substantial group, next to the brown, so far as chemical composition is concerned, are those rich coals, burning with a smoky flame, possessing a resinous luster, yielding large quantities of volatile products, and having a fracture more or less conchoidal. They vary greatly in composition, for they occupy that broad and intermediate position between lignites or peats and anthracites, wherein are found the progressive states of carbonization and molecular change from bodies with 50 per cent. of volatile matter, to others with less than 4. The elaborate structure of wood or cellulose, with which we started, has been profoundly disturbed, a wonderful reduction and a rearrangement of atoms have taken place, accompanied with the potential birth of a great number of bodies ready to escape in the form of vapors, tar, and gases, upon the application of heat."

Prof. Rogers, in the geology of Pennsylvania, classifies bituminous coals as follows:

Common Bituminous Coals.	Semi-bituminous Coals.	Semi-bitumin. cherry coal.
		" " splint "
	Bituminous Coals.	Caking coal.
		Cherry " Splint "

The variability of composition in this class of coal is readily seen by a comparison of the subjoined analyses, selected from Barr's "Combustion of Coal."

	Mecklenburg Co., Ky.	Blossburg, Pa.
Fixed carbon	51	73.11
Gas	42.50	15.27
Water	2	
Ash	4.50	10.77
	Clay Co., Ind.	Cumberland, Md.
Fixed carbon	44	68.44
Gas	47.50	17.28
Water	4	
Ash	4.50	13.98

The examples from Kentucky and Indiana represent bituminous coals in the professional use of that term, while those from Pennsylvania and Maryland illustrate the average composition of semi-bituminous coals, though necessarily the distinction admits of no specific definition, as we can pass from one to the other through a scale of carefully graded states of carbonization. The behavior of this class of coals under the influence of heat assumes two very different aspects, and has, consequently, afforded a more or less useful means of classification. One class, known as caking coals, fuse when heated, emitting jets of gas, and becoming pasty from the generation of tar-like bodies which agglutinate the carbon particles, causing them to cohere in lumps and masses over the surface of the grate. The other class, known as non-caking coals, also as free burning coals, burn openly without melting and running together—a peculiarity, perhaps, attributable in a measure to a deficiency of tarry constituents and more to a difference in their physical condition.

As we pass beyond the states of carbonization seen in the series of bituminous coals, we encounter the semi-anthracite and anthracite coals, where a continuation of the same process of eliminating the volatile portions and increasing the carbon is carried out to its natural limits. These coals are very dense, requiring a large supply of oxygen for their combustion, generating a great heat, and burning with a low, blue flame. They form the coals most familiar to eastern eyes, their brilliant luster and stone-like weight and hardness giving them a characteristic unmistakable facies. The semi-anthracite coals contain somewhere from six to eight per cent. of volatile material, and the true anthracites only 2 or 4 per cent.

Although it is generally believed that the anthracites have attained their concentration of carbon and their compact vitrified structure through the action of heat upon the bituminous beds, previously occupying the present position of the anthracite veins, yet new evidence to the effect that coals become anthracite by exposure to the air at ordinary temperatures, opens up the question to further debate. In allusion to the prevalence of the anthracite along the Appalachian axis, Dr. Newberry remarks: "When special and local causes have operated to carry the change still further, as when the beds of coal have been involved in the upheaval of mountains and heat acted upon it, it is converted into anthracite." It is certain that heat effects this metamorphic action, as at Santa Fe, New Mexico, the cretaceous lignite is converted into anthracite by the intrusion of a dike of trap, formerly a molten channel of lava. Exactly similar alterations are known at Las Bronces, in Sonora, and on Queen Charlotte's Island, south of Alaska.

Besides the caking coals, which are properly considered gas coals, the cannel coals afford to the gas engineer the most important material for his manufacture of gas. Cannel coal is so called from its ready combustion in allusion to a candle, of which the name is a corruption; it is also called parrot coal, from the crackling noise it makes on the fire, suggesting the chattering of a parrot. It yields a large amount of hydrogen, and is properly a hydrogenous coal. The Breckenridge, Kentucky, cannel offers a good instance of this property.

PROXIMATE ANALYSIS.

Carbon	32
Volatile matter	54.40
Moisture	1.30
Ash	12.3
	100.00

ULTIMATE ANALYSIS.

Carbon	68.128
Hydrogen	6.489
Nitrogen	2.274
Oxygen and loss	5.893
Sulphur	2.476
Ash	14.8
	100.00

Cannel coal has been found under water, macerated pulpy masses of vegetable matter have settled to the bottom of some pool or lake, contributing to give it its fine homogeneous

texture, and here the slowly evolved products of internal decomposition and combustion, through admission of the oxygen dissolved in the water, have shaped themselves, resulting in a fuel where the hydrogen bears a high proportion to the oxygen and nitrogen.

Dr. McFarlane thus summarizes the features of a gas coal: "The most important requisites of gas coal are, first, that it contains a large amount of volatile combustible matter or gas; second, that the volatile matter be of good illuminating power; third, that the coal be as free as possible from sulphur; and fourth, that the coke furnished by the carbonization of the coal be bulky and at the same time firm, that is, not inclined to be granular."

Though these facts form a very hasty sketch of the questions involved in the discussion of coal, yet they may assist in explaining the nature, origin, and characteristics of that mineral, which, besides being the basis of gas manufacture, has been termed "the source and guide of civilization."

[Continued from SUPPLEMENT No. 186.]

PROGRESS OF INDUSTRIAL CHEMISTRY.

BRIEF REVIEW OF THE MOST IMPORTANT CHANGES IN THE INDUSTRIAL APPLICATIONS OF CHEMISTRY WITHIN THE LAST FEW YEARS.

By J. W. MALLET.

METALLURGY.

Nickel and Cobalt.—Within a decade the extraction of these metals has increased notably in importance; and the scale upon which they are worked has expanded greatly in consequence of their successful application in electroplating, while formerly nickel was scarcely used save in its alloys of the German silver class, and metallic cobalt was not in industrial use at all. Extensive search has been made in various countries for new supplies of ore, in the main resulting in bringing together small lots from different sources. Probably the most important single new locality is New Caledonia, furnishing, not the more common sulphides and arsenides, but the hydrous silicate of nickel and magnesium, known as Garnierite or Noumeite. The metallurgical processes in use are carried out partly in the "dry" and partly in the "wet" way. In the former direction there has been improvement, the result of experience in the concentration of poor ores, such as the nickeliferous pyrites, to mattes containing a much increased percentage of nickel, and the cobalt which may be present can be recovered in the state of oxide, to be subsequently reduced to metal, instead of obtaining it merely in the form of crude silicate, as "smalt" or "zaffer." The metallic nickel furnished to commerce is of higher purity than was known a few years ago, 98 or 99 per cent. of real nickel being easily obtainable, and even higher grades of product seen to some extent. Moreover, the small, irregular grains and the cubes of but half melted nickel which not long ago constituted the only forms in which the metal was turned out, have been largely replaced by solid ingots of various weights up to 5 or 6 kilos each, cast from crucibles in which, with the aid of well-arranged wind furnaces, the refractory metal has been completely fused.

Zinc.—The most noteworthy increase in the production of zinc of late years has occurred in the United States (New Jersey, Pennsylvania, Virginia, Tennessee, Illinois, Iowa, Wisconsin, Missouri), which may now be reckoned among the great sources of the world's supply.

The methods now and for a long time in use for the extraction of this metal from its ores still leave much to be desired; the various forms of distilling apparatus are complicated, more or less troublesome, and not adapted to continuous working; and much zinc is obtained by the burning of the metallic vapor in contact with air, or is deposited in a pulverulent form by too sudden cooling instead of condensing into liquid metal fit for casting into ingots. None of the attempts which from time to time have been made to devise a furnace capable of turning out, without serious loss, fused zinc by a continuous process, seem yet to have achieved success. The nearest approach to such success has been the continuous reduction and distillation of the metal with intentional combustion of the vapor, to produce zinc white for painters' use. It may possibly be worth consideration and experiment whether the volatilization of zinc might not be, at least to a large extent, prevented by reducing, under suitable conditions of temperature and furnace atmosphere, its ores along with those of lead, taking advantage of the fact, illustrated by the ancient method of making brass from copper heated with calamine and charcoal, that the presence of the less volatile metal in the alloy reduces notably the volatility of the other; the subsequent separation of zinc and lead admitting of being effected, as far as much the larger portion of each metal is concerned, by liquation, as in the now common Parkes process for desilverization of lead. If such a reduction method could be given practical shape, any zinc vapor which did still escape might be allowed to burn and collected as zinc oxide for painting.

Tin.—The most prominent fact for some time past in the history of this metal has been the very large addition to our annual supplies since 1870 coming from Australia, while the product from the Dutch East Indies has also largely increased. The tin-bearing territory of New South Wales and Queensland covers several thousand square miles, affording already some ore from veins likely to be much more largely opened up in the future, but much larger quantities of magnificent washings of stream tin. Tasmania also affords some smaller additional supply. Most of the Malay and Banca, Billiton, the peninsula of Malacca, etc., comes from "dry diggings" in decomposed granite or pegmatite, the more or less disintegrated remains of feldspar or quartz being washed away, and the ore smelted on the spot in rude furnaces of small size with charcoal fuel, and a blast from the hollow trunk of a tree in which a piston works to and fro. Twelve or fifteen years ago the general supply of the world might have been set down in round numbers as—

	Metallic Tin.
From England (Cornwall and Devonshire)	8,500 tons.
" Malacca and the Malay Islands	7,500 "
" Saxony, Bohemia, and all other sources	450 "
	16,450 tons.

A similar estimate for the present time stands thus:

	Metallic Tin.
From Malacca and the Malay Islands	14,500 tons.
" Australia	10,000 "
" England (Cornwall and Devonshire)	9,500 "
" Saxony, Bohemia, Bolivia, etc., etc.	650 "
	34,650 tons.

* It would have to be determined by experiment how far lead can thus give fixity to zinc at the temperature necessary for the reduction of both and separation of slag.

This doubling of production has been attended with a corresponding fall in price—from £127 to £61 per ton.

There has been no material change in the simple processes of tin smelting. The application of Oxland's method of preparing the ore by getting rid of accompanying wolfram in the form of sodium tungstate has furnished some material for the utilization of tungsten compounds; most of the latter, however, so far as in use at all, are obtained from independently mined or mechanically separated wolfram.

Bismuth.—At the chief seats of bismuth production in Saxony and Bohemia, the old and simple process of extraction of the native metal from rock through which it is disseminated by liquation in slightly inclined cast-iron tubes has been abandoned, it being found that too much of the now quite valuable metal was left in the residues of imperfectly exhausted gangue. Instead, the mixed ores, largely associated with those of cobalt, are roasted and then reduced in the furnaces of the small works with additions of charcoal, metallic iron, and slag. Two layers separate after fusion, the upper one consisting of cobalt-speiss (arsenides of cobalt, nickel, and iron), the lower of crude metallic bismuth. The latter is run off in the still fluid state after the former has solidified, and the bismuth, cast into blocks, is refined by eliquation at a gentle heat on an inclined iron plate. Almost pure bismuth flows off, while the foreign metals with a little bismuth remain as dross to be worked over.

To a limited extent the ores of this metal have of late years also been worked in the wet way—as at Meymac in France, where a small supply of oxidized ore is treated by solution in hydrochloric acid and precipitation by water or on bars of iron.

There has been a remarkable increase of demand for bismuth within a few years, leading to increase of price, since although supplies of ore have been received from several new quarters, chiefly Peru and South Australia, in less quantity from Mexico, France, etc., the aggregate of these new receipts has borne but a small proportion to the amount furnished by the one long known and most important mining region of the Erzgebirge, of which Schneeberg in Saxony and Joachimsthal in Bohemia may be considered the two chief points. At present the annual supply is estimated as,

From Saxony and Bohemia	32 tons.
From all other sources	3 "
	35 tons.

of which much the largest part is devoted to the production of bismuth oxychloride and hydrate-nitrate for use in medicine and as cosmetics, most of the rest being employed in making readily fusible alloys and producing the shell-like luster on porcelain which has given rise to the name "porcelaine nacre."

Copper.—Amongst the countries which have added most to the general supply of copper for the last quarter of a century are Chili and South Australia; the mines of the former have of late increased, those of the latter diminished in productiveness. To these will probably ere long deserve to be added Arizona, where valuable ores are abundant, and possibly at some later day Northwestern Texas. The product of the Lake Superior region has assumed an important place.

The general course of copper smelting has undergone no great change for a long time, though there have been local variations of practice, due chiefly to special supplies of ore requiring particular treatment, and to the establishment of new seats of the industry. Swansea no longer fully holds the position of supremacy it formerly enjoyed, but the tendency is still marked toward the concentration of ores, and, of late years, of mattes and crudely smelted regulus of copper, at this and a moderate number of other centers, there to be treated with all the advantages of skilled labor, suitable and abundant fuel, etc. The most remarkable proposal of a new method of furnace treatment is that of Mr. Holloway, very recently brought before the Society of Arts of London, looking to the application of the Bessemer blast of air to sulphides in a melted state, the temperature being maintained simply by addition of fresh quantities of ore. Too little is yet known of the results even of such experiments as have been made for an opinion to be formed of the probable value of the idea; some advantages at once suggest themselves, but there are also manifest difficulties, such as the effect of the presence of much silica and the risk of loss by volatilization.

Relatively, much greater extension of processes in the liquid way has occurred of late years than has characterized the furnace methods. The very large use now made of the sulphur of more or less cupriferous pyrites in the manufacture of sulphuric acid has furnished abundant material, and the saving of the copper contained in burnt pyrites residues has become a regular subsidiary industry, especially in England, where in 1875 no less than 9,600 tons of the metal were thus produced, several thousand pounds' worth of silver and gold being also obtained from the same source. The main features of the process consist in calcination of the spent pyrites mixed with common salt in furnaces often heated by gaseous fuel from a Siemens generator, leaching with water, and precipitation by metallic iron, preferably used in the spongy state obtained by reduction of some of the exhausted pyrites in a muffle furnace with ground coke.

In the United States the introduction of the Hunt and Douglas wet process should be particularly noticed—its wide range of applicability to ores of different kinds is one of its prominent merits. The material to be treated, roasted at a gentle heat if necessary to remove sulphur or decompose carbonate, is exposed to the action of a mixed solution of ferrous chloride and sodium sulphate and chloride,* this being used either cold, or, with a view to more rapid effect, in a heated state; the undissolved residue is washed with a further portion of the same solution (hot); and from the mixed liquids obtained the copper is thrown down by metallic iron, reproducing the original solvent to be used over again. Taking only the case of the copper present as cupric oxide in the roasted ore, the reactions are essentially,

the cupric chloride dissolving of course in the water used, while the cuprous chloride is rendered soluble by the presence in the liquid of ferrous and sodium chlorides, and

This method has been successfully used with copper ores (simply), both of the oxidized and sulphurous classes, and also with ores containing the precious metals, these latter being obtainable from the residues after the copper has been removed by leaching.

* Obtained by the addition of common salt in excess to solution of ferrous sulphate.