

BRIGHTON COLLEGE.

BRIGHTON COLLEGE was founded about the year 1846, and a building was provided for it by Sir G. Gilbert Scott, then Mr. Gilbert Scott, shortly after its establishment. Subsequent additions have been made at various times, and especially within the last few years, by Mr. T. G. Jackson, who is now the architect to the college. Under his direction the playground has been leveled, and a cricket pavilion built. A new boarding house, to contain 40 boys, is just completed ready for occupation, and the foundations of another similar boarding house, together with those of the entrance tower, shown in our illustration, have been brought up to the surface of the ground. Plans are also prepared for a new chapel, a laboratory, and a gymnasium, to replace existing buildings, which are inadequate to the requirements of the school; also for additional classrooms and a great hall, the want of which has long been felt. These buildings, together with two more boarding houses, will eventually form three sides of a large quadrangle, of which Sir Gilbert Scott's building will form the fourth. In the college chapel a number of monuments have lately been erected, from Mr. Jackson's designs, to distinguished pupils of the college, among others to Mr. Margary, who was murdered in Western China while engaged on public service, and Captain Gill, who shared the fate of Professor Palmer in Arabia, at the beginning of the late Egyptian campaign. Mr. T. Griffiths, of Brighton, has been the contractor for the boarding house just completed, and Mr. Mockford the clerk of works, under whom the present works are being carried out without a contractor.—*Building News*.

MINERAL ACIDS IN SOLID FORM.

The danger which is connected with the carrying of liquid mineral acids to any distance, and the high freight expense it involves, have induced Dr. H. Gruneberg to look for a method of putting these acids in solid form, so as to make them more easily transportable, and to do away altogether with the risk of the danger of breakage. Thus English sulphuric acid used by the petroleum refineries of Roumania was advantageously replaced by solid anhydride. It was also tried to make liquid acids to be absorbed by porous indifferent bodies. Kieselguhr (infusible earth), which is found in almost inexhaustible quantities in Luneburg, was found to be the substance most adapted to absorb and retain mineral acids in quantities relatively considerable. After being deprived, by drying, of about 15 per cent. of moisture which it contains on the average, kieselguhr can absorb from 3 to 4 times of its weight of sulphuric acid at 66°, and twice its weight of muriatic acid at 20° B., and nitric acid of 36°. No difficulty is found in the operation. The silicious earth is dried and passed through sieves, then taken into a shallow wood, iron, or stone vessel, and the acid is added in a thin stream. The mixture is well agitated, and the lumps which at first form are broken up. The apparatus now used for the manufacture of superphosphates can be used for this process. The obtained product may be sieved. The sulphuric acid thus changed into solid form attracts moisture very quickly, and has to be therefore packed at once. For packing, lead-lined sheet iron vessels are used which are closed hermetically and soldered. Petroleum vessels can also be used, which are covered internally with a layer of gum lac.

Sulphuric acid solidified as above can find application in the form of a dry powder in several branches of industry, such as the refining of petroleum or of the fat oils, in the manufacture of dynamite, in stearine works, in the manufacture of carbonic acid for aerated waters (it is exported in large quantities to India for this purpose), in the manufacture of superphosphates, and of sulphate of ammonia, etc. In these cases the acid powder is put into direct contact with the substance to be treated, such as raw petroleum, glycerine, powdered phosphate, carbonate of lime, etc., and is then diluted by the addition of water to the degree of concentration required for the operation. In those cases in which only the acid in the liquid state can be employed, such as for metal ores, etc., the acid can be previously liquefied by being placed, together with water, in lead-lined tanks, the remaining powder being then separated from the liquid by means of filter presses.

The high cost of transportation of the liquid acids may render the application of this solidified product convenient in far distant countries, but in Europe it is most likely that manufacturers will not see any advantage to be derived from the use of these solid acids.

THE INFRA-RED EMISSION SPECTRA OF METALLIC VAPORS.

By H. BECQUEREL.

LAST year I submitted to the Académie des Sciences a short account of my first researches on the infra-red spectra emitted by metallic vapors, till then unknown.* Since that time I have investigated the subject still further by making use of a special spectroscopic, which shall be described in a future paper. I will simply mention here, that the method consists in throwing the spectra about to be examined upon a suitable phosphorescent substance, which has been previously rendered luminous, and in observing the temporary excitation which precedes extinction under the influence of the infra-red rays. The lines and bands of the emission spectra then appear brilliant, and can be examined with the microscope.

In experimenting on different phosphorescent substances, notably certain preparations of sulphide of calcium, I found some much more sensitive than others for infra-red rays. These substances have permitted me to determine directly the wave lengths for the more brilliant lines of several incandescent metallic vapors (potassium, sodium, cadmium), by using the diffraction spectra produced by a very beautiful metal grating of Mr. Rutherford's, which was kindly lent me by M. Mascart.

For other metals, the spectra were obtained by means of a bisulphide of carbon prism. The positions of the

lines were referred to those of the potassium and sodium lines, and to the positions of the bands and characteristic lines in the infra-red region of the solar spectrum, as well as the absorption bands of samarium; the wave length for each line was then determined by interpolation with great accuracy.

The wave lengths for the lines and principal bands in the infra-red of the solar spectrum have been again determined by means of the grating, which had been placed at my service; and the more sensitive substances in my possession have permitted me to extend these measurements much further than I was enabled to do in my previous researches.* I propose to return shortly to this work, which has led me to rectify several numbers relating to wave lengths at the less refrangible end of the spectrum; I will only give here the wave lengths of the principal lines used for reference: the band indicated by A' in my former memoir is made up of two bands, whose wave lengths are from 0.00115 to 0.00119 millim., and from 0.001132 to 0.001142 millim.; the large band A* extends from 0.001351 to about 0.001400 millim., and the extreme band A' from 0.001800 to about 0.001900 millim. The wave lengths of the characteristic absorption bands of samarium, directly determined, are: from 0.001079 to 0.001097 millim. for the first, and from 0.001239 to 0.001267 for the second.

The metals were volatilized in the voltaic arc. The intensity was such that I could make use of a very narrow slit, and observe, on the phosphorescent substance, interesting details. In this case, it is necessary that the image of the line be brought to an exact focus on the phosphorescent screen; for, unless this be so, the results are not observable when the slit is narrow. I have not yet been able to invent a suitable arrangement for giving a complete and definite image of the whole of the infra-red spectrum; but, by repeated trials, it was possible to obtain sufficiently distinct images of the group of lines which are to be examined. I am occupied, however, at the present moment with an improvement which will admit of still greater delicacy.

Wave Lengths of the Principal Emission Rays of Several Incandescent Metallic Vapors.

Wave length.		POTASSIUM.
770	} Lines very brilliant.	
1098		
1162		
1233		
SODIUM.		
819	} Visible to the naked eye. Capt. Abney has photographed this line, and discovered that it is double.	
1142		
STRONTIUM.		
870	} Lines and bands feeble; approximate wave lengths.	
961		
1003		
1034		
1098		
CALCIUM.		
858-876	} Broad bands, probably groups of lines.	
883-888		
MAGNESIUM.		
899	} Very intense, perhaps compound. Very feeble. Broad, and perhaps double. This group resembles group <i>b</i> .	
1047 (?)		
1200		
1212		
ALUMINUM		
1128	} Broad and intense, perhaps compound.	
1361.5		
1125	} ZINC.	
1306		
1850.	CADMIUM.	
LEAD.		
1059.8	} Very intense. Feebler group. Approximate wave length.	
1087		
1133		
1221		
1229		
THALLIUM.		
1150.	Approximate wave length.	
BISMUTH.		
837	} Approximate wave lengths.	
973		
SILVER.		
771	} Visible to the naked eye.	
825		
1083	} TIN.	
1199		

The preceding table contains the wave lengths for the most intense lines, bands, or groups of lines which characterize the spectra of several metallic vapors. The numbers are expressed in millionths of a millimeter, and are generally exact to one or two millionths of a millimeter.

Nickel gave several rather feeble bands or groups of lines; while iron, in our experiments, gave no band sufficiently intense to examine.

The results, indicated above, show how rich the field of research is which the phenomena of phosphorescence open up in the invisible part of the infra-red of the spectrum, and which, alone, covers an interval of wave lengths greater than the visible and ultraviolet parts together.

Besides the interest it may excite by proving the existence of these rays, of which the wave lengths are considerable, in the spectra of metallic vapors, this research, more than any other, is of the kind which give most valuable information concerning the unknown laws that govern the vibratory motion of incandescent vapors.—*Comptes Rendus*, Aug. 25, 1884; *Phil. Mag.*, Oct., 1884.

LEAD: ITS PROPERTIES AND USES.

By ALEX. W. MURRAY.

IT occurred to the writer, when reading the questions submitted at a recent examination in plumbing, of the city and guilds of the London Institute, published in *The Sanitary News* on October 1, that answers to them would be appropriate matter for your columns; if the answers here given are not what they should be, you can find more room for them in the waste basket than in your valuable paper. Literal answers will not be given to each question, but the subject upon which the question is based will be treated as concisely as the ability of the writer will permit; each answer will form a topic by itself, appearing (if worthy) at regular intervals.

It is the duty of plumbers to acquire a knowledge of the chemical and physical properties of metals, especially of those used in their trade, in order that they may be able to judge which metal is best adapted for use in the several appliances in the trade, both as to their durability and freedom from corrosion. The cheapness of books and the great number of authors to select from, upon any special subject, brings knowledge within the reach of all who may seek for it. The lack of systematic reading is a prominent feature in our trade. Is it not a pleasure and a source of profit to know the reason why *this* or *that* acts so and so? Or to know *why* and *how* you should do *this* or *that*? Or to know when, where, and by whom anything was made? My readers, God has given you a mind to use, and you will be held to a strict accounting for the use you put it to. You can best serve your Master and fellow-man by being an intelligent worker in the vocation you have chosen.

Question No. 1 asks to describe the principal physical properties of lead. Lead is a part of the mineral division of the earth, being an elementary body. It is opaque, a better conductor of electricity than of sound, than of caloric; and it is of a bluish gray color, having a glimmering metallic luster while in the condition of pig, pipe, sheet, or hot; but when free from oxidation, as when cut or shaved by a knife or plane, it has a glittering metallic luster, near akin to that of nickel; and when examined under sun, electric, or gas light, it possesses the property of refracting the rays of light, producing the seven primary colors upon such bright surface. It is the least elastic and sonorous of all the metals. These properties are exemplified in target practice and the manipulating of the metal in the art of plumbing. Being malleable and laminable, it can therefore be hammered or rolled into thin plates. It is fusible and melts at a temperature of 612 degrees Fah., and can be alloyed with many metals. If three parts are combined with five of bismuth and two of tin, the alloy can be melted at a temperature of 212 degrees, the heat of boiling water, and is therefore naturally the best adapted metal that plumbers could have adopted for the various uses it serves in their trade. Though it is not very ductile, in fact being the least ductile but one (nickel) of all the metals, it can be pressed while in a partially melted condition into any shape—wire, tube, or sheet. It is crystallized by hammering and bending. To this property can be charged the cracks or breaks that are often met with in waste-pipes that have been indented or buckled, or in that portion of hand-made traps where the greatest number of blows have been struck in forming the trap. I reason in this manner: The metal being crystallized by the hammering, it is more readily oxidized (by the assistance of air and moisture) at these points than the rest of the pipe or trap, from the facility by which the air and moisture can get at each atom of lead, on account of such crystallization. When melted and slowly cooled, it forms octahedral crystals. To this property the writer ascribes the cause for the leakage of soldered joints, made in connecting the kitchen boiler with the heater or water-back of the kitchen stove. The joints being overheated during ironing or baking, the metal is crystallized, and in time becomes so porous that water easily passes through it. This trouble can be avoided by letting the hot water occasionally flow at the sink.

Although lead, in many instances, has been found in a native state, it is more generally discovered as sulphuret of lead. This is known in commerce by the name of galena. Knight says lead was known in old times. "They sank as lead in the mighty waters" is a part of the triumphant song of Miriam, 1491 B. C. Job refers to its use for writing-tablets—"an iron pen and lead." "A work of Hesiod's was preserved for many centuries stretched on leaden tablets." Iron, tin, and lead were enumerated by Ezekiel as among the commercial objects of the Tyrian trips to Tarshish. The Romans used sheet-lead largely in making water-pipes. Lead was probably the first metal worked, because its ores are abundant in all countries, and it is frequently found at or near the surface of the ground, rising at so low a temperature of 612 degrees Fah. The discovery of melted lead must have attracted the attention of the ancients at an early day, while building fires in the mineral districts. Ewbank relates that the terraces of Nebuchadnezzar's hanging-gardens were covered with sheets of lead soldered together to retain moisture in the soil. Archimedes used lead pipe to distribute water by engines in the large ship built for Hiero. The plumbers of Pompeii used lead pipes, for we read that the Neapolitan government sold large quantities of "lead" pipes as old metal. Plumbing is, therefore, no new art, but among the earliest of which we have any record. Rolling or milling lead was invented by Thomas Hale in 1670.

In 1538 Robert Brocke was the first to cast short lengths of lead pipe, by the use of moulds. The lengths were jointed together by a process of burning. A native of St. Germain, in the reign of Henry the IV. of France, invented a process by which the pipe could be made any desired length, as follows: The mould was placed in a horizontal position, the metal poured in on top near one end, and, when cast, was drawn out; only one or two inches were left in near the spout where the metal entered, so that when another length was cast the hot metal would melt the end thus left, and become a continuous part of the pipe, and so on until the required length was made. The practical making of pipe by the use of piston, cylinder, and press was begun in 1820, but it was talked of as far back as 1705.

The symbol by which lead is known in the mathematics of chemistry is Pb, from plumbum, the Latin name of lead. These letters are used to prevent confusion. The natural inference is that L would be the most appropriate abbreviation, but L is the symbol of

* Comptes Rendus, t. xcvi. p. 71.

* Annales de Chimie et de Physique, 5 serie, t. xxx. p. 5.

lithium. The proportion by weight (*chemical equivalent*), in which it unites with other elements, is 103.6. Its specific gravity being 11.44, it is therefore eleven times heavier than water. This makes it available for use in sounding-leads, in ascertaining the depths of seas and oceans. We learn the following from Steele: From it are made litharge, used in the manufacture of glass, in paints, and as a glaze upon earthenware, oxide of lead (PbO), red-lead, minium (Pb_3O_4), used in coloring sealing-wax, as a paint, and by plumbers, steam and gas-fitters, as a luting in joining pipes, and white-lead—carbonate of lead (PbO, CO_2).

Lead is corroded by the assistance of acetic acid (vinegar). Care should be taken in vinegar and pickle factories to have thicker lead used. We are informed that soft or rain water, when aerated, silt of rivers, and vegetable matter (in a state of decay), will oxidize lead; also, that pure water, assisted by oxygen, and sewer-gas, are enemies to lead. We know it can be turned into dross by heat. Nitric acid is the proper solvent for lead, producing whitish opaque crystals of nitrate of lead. Comparative freedom from lead poisoning can be attained by workers in lead by cleanliness of person, taking regularly warm baths, seeing to it that the fumes while melting are properly carried off, and changing the working apparel when done with the day's work. In the matter of diet, drink plenty of fresh milk and eat fat mutton, and as medicine consult your physician, although an occasional dose of Epsom salts would not hurt you. Steele gives the following test for the presence of lead: Hydrosulphuric acid (HS), which forms with the metal the black sulphuret of lead (PbS). A very comical illustration is as follows: Thicken a solution of sugar of lead (PbO_2) with a little gum arabic, so that it will not flow too readily from the pen, and draw some comical figure upon paper. This, when dry, will be invisible, but when dampened on the wrong side and passed over a jet of HS the picture will blacken into sight. The Franklin Institute officially declared, in 1870, that there exist no authenticated accounts of the health of the numerous towns and cities supplied by leaden distributing pipes having been injuriously affected. Samples of lead pipe two hundred years old were submitted to the French Academy, which showed so little corrosion that the impression of the sand of the mould in which the pipe was cast was distinctly visible.

"Are lead service pipes safe? How often this question is asked, and for want of an intelligent reply, how much nervous anxiety caused, as well as needless expense! We answer, yes, especially in the West, where all the water contains so much carbonate of lime. This was demonstrated, a few years since, by the very intelligent head of the water department of Paris, France. He took up lead service pipes that has been in use for hundreds of years, and found no change in the interior or exterior surfaces and no loss in weight. He stated that where lime, even in very small quantities, was present in the water, there was quickly formed a coating on the inside of the pipe that entirely prevented any further action of the lead upon the water, and that there was always present enough of lime dust in the atmosphere of Paris to make it perfectly safe to use even the rain water, conducted through leaden pipes. There can be no question but that good pure lead makes the best service pipes for conveying water to and through our dwellings from springs and street mains. It is durable, lasting for generations. It is easily and rapidly laid, being pliable, and furnished in long coils. It is easily and cheaply repaired, requiring often the removal of only a few inches, expanded by frost, and insertion of a new piece, when a whole length of iron pipe would have to come out, at great cost and inconvenience."

Where used for supplying water, to guard against a possible chance of danger, one should let the water run until he is satisfied that the capacity of the pipe has been emptied.

Heavy lead soil-pipe, put up properly, in my opinion makes the best soil-pipe that can be used. To guard against its being eaten by rats, it can be bound with brass wire gauze.

In conclusion, the writer supposes the reason we plumbers are "leaden-heeled" and dull is, because we, in time, partake of the nature of the principal metal we work in, "lead." As a piece of advice to my brother "Chips," do not fuse your metal near the nostrils of your customer, lest you make him so dull that he may not see the justice of your bill, and be slow in paying it.—*Plumbers' Trade Journal*.

NEW FORMS OF SWEDISH HEARTH AND WELDING FURNACES.

By Mr. G. A. FORSBERG.

THE author describes a modification of the Swedish "Lancashire" hearth finery which has been introduced at the Skutskar ironworks. The hearth is of the rectangular form usual in Sweden, but differs from the ordinary construction in having a third tuyere, in the back wall, that opposite to the working or front side. The side walls are formed of hollow iron castings, which are cooled by allowing the blast to pass through them, whereby it becomes heated before arriving at the tuyeres. The hearth is covered by an arched roof of brickwork, carrying a hopper closed by a slide, in which the charcoal is charged and dropped into the fire as required, instead of the old plan of shoveling it in through the working door in front. The waste flame, on its way to the chimney, passes over a bed in which the pig-iron for the following charge is brought up to a strong heat before its introduction into the melting-hearth. A comparative trial of one of these hearths against one of the ordinary kind with two tuyeres, carried on for a period of four weeks, gave the following results:

The two-tuyere hearth produced an average of 265 cwt. of blooms per week, with a consumption of $5\frac{1}{2}$ bushels of charcoal per cwt.

The three-tuyere hearth produced 366 cwt. per week of bloom-iron, with a consumption of $4\frac{1}{3}$ bushels charcoal per cwt.

The loss in the metal in working was about the same in both cases, namely, 12.93 percent., or 1.1485 cwt. of pig-iron were required to make 1 cwt. of bloom-iron.

The author suggests a method for further increasing the production of this class of furnace, by doing away with the melting of the pig-iron in the refining hearth. For this purpose the heating-bed for the metal in the flue is to be converted into a melting-bed, which is kept

warm by the waste flame during the actual firing period, and receives the heat necessary for melting from a gas producer, placed at right angles to the working axis of the hearth. This arrangement is figured in the plate illustrating the paper. Two hearths, placed back by back, communicate with the same stack, and are served by a producer common to both. The gas being only required during the melting period, the producer is damped during the refining of the metal in the hearth. The gas-producer may be worked with inferior fuel, in which case the melting of the pig is done at less cost than in the fining hearth, where charcoal must be used.

The welding furnace described by the author is a gas-furnace, with a flat bed about 20 feet long, and low arch, standing within its own blast-heating apparatus, the latter being a series of short upright and horizontal pipes, the former being also part of the structural iron-work of the furnace. The horizontal pipes are placed below the bed, and correspond in some degree to the long horizontal air way in Bicheroux's furnace. The gas-producer has a stack 10 feet high, shaped somewhat like that of a charcoal blast-furnace, the bottom being closed by a grate arranged to work upon a central axis. The charging is effected by a gas-tight covered hopper and valves. The gas passes by a siphon up-take and down-come within the same mass of brickwork as the stack to a chamber forming the ashpit of the furnace, where it meets the heated air in jets from a square pipe in the roof, a short distance in front of the fire-bridge. The producer is worked with waste short ends of deals and planks, previously dried at 104° to 150° Centigrade, the consumption being equivalent to 2.7 bushels of charcoal, supposing the wood to be equal to 63 per cent. of the latter. The loss upon the blooms heated for rolling into merchant iron was 11.5 per cent. A further modification of this furnace is provided with two similar gas-producers, which are worked alternately, the fuel charged wet in one being dried while the other is being converted into gas. For the former purpose the gas delivery passage is closed by a valve at the bend of the gas delivery siphon, and the charging-valve of the hopper is opened while heated air from the hot-blast tubes is passed through the wet wood from below, until hygroscopic water is converted into steam.—*Sernkontorets Annaler, through Proc. Inst. Civ. Eng.*

THE THEORY OF BLAST-FURNACE SLAG REFINING.

By A. D. ELBERS.

BLAST-FURNACE slag and glass are both amorphous mixtures of silicates. As glass is a perfect, and slag an imperfect, mixture, a comparison of their behavior under like treatment may lead to a better understanding of what can be done to redeem the slag from its scoriaceous nature.

When liquid melted glass is cooled slowly, it becomes pasty before it solidifies; when glass is remelted, it again changes to the semi-fluid condition before absolute liquefaction sets in, and when devitrified glass is remelted, it liquefies suddenly.

When a stream of liquid slag is tapped from the blast-furnace it is of dazzling white color, but the latter turns readily into orange and red, because the slag cools and solidifies rapidly on the surface. When the flow of the stream becomes sluggish, the slag seems to be in the semi-fluid or pasty condition in which glass can be spun out mechanically into continuous threads. This appearance is, however, fallacious, for the semi-fluid glass is of the same consistency throughout the mass, whereas the sluggish slag consists of already solidified particles which are embedded in other still liquid particles, and as the latter solidify the whole mass becomes suddenly stiff. When such an incongruous mass is remelted, it passes suddenly from the solid to the liquid state.

When a stream of liquid melted glass is subjected to the impinging force of a strong jet of steam or air, it is torn asunder into quick-chilling particles, which flatten out into rather uniform thin scales. When liquid and not too calcareous blast-furnace slag is subjected to the same treatment, the disjointed but still partly liquid particles change into short fibers and globules which intermix in settling, and the voluminous mass which is thus obtained is called slag-wool. The fibers are spun out immediately upon the detachment of the slag particles from the main body of the stream, just as liquid slag can be squeezed out of a partly solidified or apparently semi-fluid mass, and are mostly the direct issue of one silicate out of another. This tendency of liquid melted masses to rearrange themselves into more definite compounds while they have the freedom of motion; is characteristic of all imperfect compositions of silicealcalcareous minerals which, like blast-furnace slag, have not been kept long enough in the liquid state to become more perfectly assimilated.

That the investigation of slag is less difficult, after the latter has been reduced to slag-wool, is evident. Slag-wool is sometimes white as the driven snow, but if it contain sulphur, it can be remelted into dark, bad-looking scoria just the same as if slag from the cinder bank were remelted. Sulphur can exist in different or allotropic forms; its combinations with other ingredients of the slag undergo similar changes of form, partly by oxidation and deoxidation, while the liquid slag is exposed to the blast, and partly by disintegration in the slag-wool, while the latter is already solid, but still red hot. When the cooled slag-wool is reheated quickly to a temperature of about $1,800^{\circ}$ F., the sulphur exhibits great inclination to return to its former state, the sulphides melt, and the rest of the mass is thereby impelled to reunite chemically, which leads to its sudden fusion, when the heat is slightly increased. If the slag-wool has been compressed to a proper density, and is then reheated in such manner that the atmospheric air can gradually enter the mass, expel sulphur, and thereby set other impurities free, the fibers become readily decomposed, while the interspersed globules remain unchanged in form; the decomposed mass subsequently reunites without fusion into a soft, loosely fritted mass, just as silicates are formed by merely fritting their constituents together.

The bisilicate and more acid slags are deficient in sulphur; their slag-wool is very coarse, and the fibers become irregularly disintegrated in roasting. A small percentage of volatilizable sulphur therefore seems necessary for that thorough decomposition of the mass

without which no recombination into more homogeneous compounds can take place.

The soft or reduced mass of the roasted slag-wool can be separated from the globules in leaching and washing, and the globular part can be purified in the same manner, after it has been pulverized and roasted over. When either mass has been purified to such an extent that it is insoluble in water, it may then be called refined slag, provided that in melting it will change gradually from the solid to the liquid state.

If the slag-wool is made from subsilicate slags, many constituent parts do not recombine in roasting, or become soluble in water; these defects are lessened in the measure in which the oxygen ratio of the silicic acid is nearer to that of the combined bases, counting alumina as a base. When silica is in excess, the slag is apt to contain ferrous and manganous silicates, which impart to the refined slag a slight tinge of rose or cream color, and when alumina is in excess, nearly all ferruginous impurities are in complete solution or chemical combination with the slag, which will then retain a darker color in the refined state.

Alumina is acid in the formation of the singulo-silicate slag; in slowly cooling slag it may be assumed to turn basic up to certain proportions, which can be construed to remain within the limits of an equal oxygen ratio of acid to bases (1:1) or do not exceed the ratio of $1\frac{1}{2}:1$, if it is counted on the acid side. In many slags, in which the percentage of alumina is nearly in accord with either formula, the sudden change from acidity to basicity is probably influenced by simultaneous changes in the atomicity of oxides of sulphur or iron. In whichever manner these slags may become chemically affected, it is known that they can be vitrified by sudden chilling, whereas they become opaque or stonelike in cooling gradually, and that the vitrified kind can be reduced to the latter condition by annealing.

As all the chemical changes in the slowly cooling slag lead to scorification, or sudden fusion, in reheating to that temperature at which sulphur can be expelled, the prevention or even interception of these changes must leave the slag in a much better condition for roasting. This is accomplished by thorough chilling, which can best be attained by flushing the slag, or by causing it to spread, into very thin layers, in order to expose the greatest possible surface to aeration. If such slag is pulverized and then roasted, its reduction may progress more slowly than that of slag-wool, but will be so uniform that the mass can be fritted quite dense or compact without the least scorification. After the sulphur has been expelled from the mass, the latter is still in the loose-fritted condition, in which it can be purified by the wet process.

The conversion of liquid slag into slag-wool allows of producing distinct grades of refined slag from the same raw material; the undivided composition of the chilled slag has to be reduced in one operation to a uniform mass. The former method yields the most valuable qualities, whereas the latter is cheaper, and therefore better adapted for putting blast-furnace slag into competition with the natural substances which are used in vast quantities in the manufacture of cements. As the results differ only in degree, the final conclusions on slag refining may be arrived at without special reference to either method.

The basic condition of alumina in refined slag cannot be changed to acidity below complete fusion of the mass, unless the latter is roasted in intimate contact with some intermixed substance for which alumina has great affinity, as for lime which has just been reduced from the carbonate. In such admixture it is easily converted, and the silica, which is thus set free, is then also in a condition to combine most readily. As many slags contain alumina and silica in such proportions that the proper composition of artificial Portland cements can be attained by the addition of lime only, it seems quite practical to manufacture cements in that way. The roasted slag can be more readily converted into cement than the much more refractory natural silicates of alumina, and contains already so much lime that less than its own weight of chalk or limestone need be added to the charge. Other roasted slags which contain but little alumina can be used in the manufacture of glass, after having been purified by the wet process.

The fusion of the glass composition is quickened in the measure in which sand and earthy bases are replaced with refined slag in the usual proportion of constituents. Under the trisilicate formula for glass, the substitution of singulo-silicate slag is feasible to the extent of from about ten to twenty-five per cent. of the weight of the composition. The use of refined slag in such proportions is either equivalent to a saving in heat and time, or to a saving in alkalies, borax, oxides of lead and zinc, and also to an improvement in quality, inasmuch as the diminution of these other ingredients renders glass more enduring, physically and chemically. This improvement is especially desirable in pottery glazes and enamels.

Refined slag can be fritted hard, melted opaque, and melted transparent or glass-like, at temperatures corresponding respectively to light red, ordinary white, and full or perfect white heat; it is more fusible than orthoclase feldspar, and a mixture of both substances can be melted into a transparent flux at a still lower heat.

True porcelain can, however, be made from pure China clay or kaolin and refined slag without any other flux, these materials being wet-mixed, formed, air-dried, and subjected to the hard porcelain fire in the usual manner. If the refined slag melted suddenly or became quite liquid, the body in which it has been incorporated would collapse, and if it were not melted into transparent glass the body could not be translucent, because a kaolin body without flux will remain opaque after having been subjected to the most intense heat.

Having thus considered the most important changes of refined slag, the various uses which it is destined to find in the arts and technical industries can probably be deduced from the following definition:

The refining of slag means to purify the slag without destroying its peculiar silicate constitution, which is that of a singulo-silicate, having usually several bases. The peculiar properties of these singulo-silicates are solubility in strong acids and partial decomposition in the caustic hydrates of lime and alkalies, easy combination in fritting with other substances, and energetic saturating capacity in the melted state.

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