ART. XXXI. — *On Sodium Amalgamation;* in a letter from HENRY WURTZ to Professor B. SILLIMAN.

IN the opinion of yourself and others upon whose judgment I rely, the time has arrived for the promulgation of the discoveries made by me, now many years since, of certain new properties of the alkali-metals, rendering them of value in the amalgamation of ores of the precious metals.

You are aware that, pending the repeated investigations which I have conducted upon this important subject, I have made communications of my results, both oral and written, from time to time to many persons, yourself among the number; but that until the latter part of the year 1864, no final step was taken to place these discoveries before the public in a tangible form. On the 27th of December, 1864, a patent of the U. S. Government was granted to me for specified modes of applying the said discoveries; the specification having been at my request retained on file in the Patent Office for six months (as the new patent law permits); so that the expiration of the term of this patent did not commence until the 27th of June, 1865.

It appears, however, that my frequent communications had led to wide discussion of the remarkable phenomena involved, phenomena which I seldom hesitated to exhibit, even to the most casual acquaintances, taking only the precaution of silence as to the agent employed (the sodium); and the inevitable consequence has been the occupation of other minds with the subject, both here and abroad. In fact, since the issue of my patent, I am informed that several applications (necessarily fruitless) have been made at Washington by others for patents covering some or all of my uses of the alkali-metals; and an English patent has been procured in the name of the eminent chemist Wm. Crookes, dated Aug. 12, 1865 (about eight months subsequent to the filing of my specification at Washington): of the specification of which I have procured a copy, and find it to present a remarkable similarity to my own. Moreover, I frequently find allusions and statements relating to this subject, generally more or less imperfect and obscure, in the public prints throughout the world.

It has clearly, therefore, become incumbent upon me—if only as a matter of justice to the mining community and others interested—to furnish authentic information as to what has actually been done, and what it is proposed to do. I have, therefore, prepared an abstract of my specification, embodying in a condensed form such portions of its substance as appear of present importance to miners and metallurgists.

Other portions of the subject-matter of the specification will form a sufficiently voluminous, and I hope interesting, topic of a future communication; as, for instance, my new modes of preparing amalgams of the alkali-metals in large masses with any desired rapidity, safety and economy; and which you, with other chemical scientists who have witnessed its operation, deem important in a purely scientific view; as involving novel phenomena, and illustrating molecular laws obscurely seen at present.

With a few explanatory observations, which seem needed, I shall conclude. I have found it necessary, for practical purposes, to prepare three different grades of the sodium amalgams, differing from each other in their proportions of sodium about as the numbers 1, 2 and 3; and which I designate accordingly.

A few lines, also, regarding the term "magnetic amalgams," which not a few will deem fantastic, and as suggesting unauthorized analogies. I hope to show, however, at some other time, that in applying the term I have followed the dictates of reason, and even the direct path of the modern leaders in cosmical dynamics, the apostles of the doctrine of correlation of physical forces; and that the analogical element which I find is that between attractive and repulsive antagonistic force which

exerts a *chemical*, or rather an *elementary discrimination* between bodies at *insensible* distances, and the antagonistic force of magnetic attraction and repulsion, which is so eminent an example of a similar elementary discrimination, though at *sensible* distances also. No one (to offer an illustration nearly, though not quite perfect) doubts the intimate relation between radiated and convected heat, although the one propagates itself throughout the universe of space, whilst the other is susceptible only of diffusion throughout insensible distances, from molecule to molecule.

More of this, however, hereafter. The term, from its convenience alone, will doubtless come into extensive use, as a technical term, among those who are most concerned in the utilization of the magnetic amalgams.

39 Nassau St., New York, January 15, 1866.

SPECIFICATION.

My invention consists: In imparting to quicksilver * a greatly enhanced adhesion, attraction, or affinity for other metals and for its own substance; by adding to it a minute quantity of one of the highly electro-positive metals * sodium, potassium * etc.

My invention * is applicable:

1st. In all arts and operations in which amalgamation by quicksilver can be made available to separate or extract gold, silver or other precious metals from their ores.

* *

3d. In all operations in which amalgamation by quicksilver, in conjunction with reducing metals, such as iron or zinc, can be made available in recovering metals from their soluble or insoluble saline compounds; such as silver from its sulphate, chlorid or hyposulphite; lead from its sulphate or chlorid; gold from its chlorid or other solution.

* *

8th. In the mercurization of metallic surfaces in general; for instance, in the amalgamation of the surfaces of zinc in voltaic batteries; of the surfaces of copper plates, pans, etc., used in the saving of gold from its ores; * *

9th. In the more convenient transportation of quicksilver, by the reduction thereof into solid forms.

* *

I shall now proceed to the description of those special and peculiar qualities of these amalgams of the alkali-metals which I have discovered, and which have led to my new uses of them in the chemical and metallurgic arts.

A quantity of one of the magnetic amalgams, dissolved in one hundred times its weight or more of quicksilver, communi-

cates to the whole a greatly enhanced power of adhering to metals; and particularly to those which, like gold and silver, lie toward the negative end of the electro-chemical scale. This power of adhesion, in the case of these two metals, is so great, that the resistance which I have found their surfaces, when in the native state, usually oppose to amalgamation (a resistance which is much greater and more general than has been hitherto recognized, and which is due to causes as yet undiscovered, or at least uninvestigated) is instantly overcome; whether their particles be coarse, fine, or even impalpable. Even an artificial coating of oil or grease (which is such an enemy to amalgamation that the smoke of the miners' lamps is pronounced highly detrimental in gold and silver mines) forms no obstacle to immediate amalgamation by this magnetic quicksilver. The atoms of the quicksilver are, as it would seem, put into a polaric condition by a minute addition of one of those metals which range themselves toward the electro-positive end of the scale; so that its affinity for the more electro-negative metals is so greatly exalted that it seizes upon, and is absorbed by, their surfaces instantaneously; just as water is absorbed by a lump of sugar or other porous substance soluble in it.

Such quicksilver (unlike ordinary quicksilver) even adheres strongly to surfaces of iron, steel, platinum, aluminum and antimony; an adhesion which, however, as I have discovered, in the case of these five metals is not of the nature of a true amalgamation, there being no penetration whatever into the substance of the metal; so that the superficially adherent magnetic quicksilver may be readily wiped off clean, just as water may be from glass. The only metal I have as yet found, which cannot be enfilmed by the use of the magnetic amalgam, is magnesium.

I shall now specify the details of my various new and useful applications of the alkali-metals:

I. *Applications of the magnetic amalgams to working the ores of the precious metals.*

My improvement in methods of amalgamating gold and silver ores consists in adding from time to time to the quicksilver used in amalgamation, about one-hundredth part, or less, of its weight of one of the magnetic amalgams. The frequency with which the amalgam is to be added cannot be exactly specified, as it will be found to depend more or less on a multitude of circumstances; such, for instance, as the temperature, the purity of the water and the quantity of water used, the ratio borne by the surface of the quicksilver to its mass, the amount and mode of agitation of the quicksilver, the nature of the process and of the

apparatus used, the character of the ore, the strength of the amalgam, etc., etc.; so that this important point can only be determined by experience in each case. Some general directions may, however, be derived from the experiments which have been made. It has been found that very much less sodium is requisite in those cases in which much water is employed, and that water frequently renewed; for instance, in the rifles of a sluice, and in all forms of amalgamators through which a continual current of fresh water is kept running; mercurial solutions of sodium, as I have discovered, being little affected by water which is free from acid, alkaline, or saline impurities. In those cases, however, in which little water is employed, and especially when the ore and quicksilver are ground up together into a "slum" or slime, this water soon becomes alkaline, and an oxydation of the sodium sets in, necessitating its frequent renewal. In such cases, therefore, the following manipulation is recommended: The whole amount of quicksilver to be used for working up a batch of slime, say 50 pounds, is magnetized by dissolving in it one per cent of amalgam No. 2; or better, two per cent of the soft amalgam No. 1, which dissolves more readily; half of the whole, or 25 pounds, is then thrown into the mill with the ore at first, and, as the incorporation proceeds, certain fractions of the other half are gradually added, at intervals of time varying according to circumstances, until the whole has been added. If, as is usual, the quicksilver is a portion which has been separated from the slime of a previous operation, it will usually retain some sodium, and therefore will require fresh amalgam in proportionately smaller quantity.

In sluicing operations the soft amalgam No. 1 is most suitable, on account of its ready solubility in mercury; and in these cases it is practicable to *test* the quicksilver in the rifles and ascertain when the magnetic quality requires restoration, by throwing in a few grains of gold-dust. Similar tests are easily applied to slimes, and in amalgamating methods generally, a slip of tarnished sheet copper being a very suitable agent for such testings.

It may be remarked in passing, that the amalgam No. 1 is at any time easily prepared from No. 2, by melting it in an iron ladle with about its own weight of quicksilver, or from No. 3, by melting with twice its weight; considerable time, however, being requisite, in the case of No. 3, to produce the additional combination. In copper-plate amalgamation, that is, in those cases in which auriferous materials are brought into contact with amalgamated metallic surfaces, it is better to substitute altogether for quicksilver itself (both in the first coating of the metallic surfaces, and in any subsequent additions of quicksilver made) the pasty amalgam No. 1. In these modes of amalgamation

great economy in wear and tear of apparatus, as well as in first cost, is effected by using, in connection with the magnetic amalgam, plates or surfaces of *iron* instead of copper. The power of coating or enfilming iron renders the amalgams in fact peculiarly valuable in every form of arrastra, drag-mill, or other apparatus for amalgamation which has internal surfaces of iron, these surfaces becoming coated over with quicksilver, and thus immensely extending its chances of contact with those particles of gold which are so fine as to remain suspended in the water.

Other important devices arise out of this power of enfilming iron surfaces, such as the keeping of iron surfaces of stamps, and of other apparatus used in *crushing* ores continually coated with quicksilver. Quicksilver possessed of the magnetic quality may be kept dropping or trickling upon the surfaces of crushing-rollers; or in those crushers in which iron balls are used, the surfaces of these balls may be kept enfilmed. In like manner as the *adhesion* of quicksilver to other metals is exalted by the alkali-metals, so, also, as I have discovered, is its *cohesion* with itself greatly increased. It is rendered more viscid, more difficult to divide mechanically, and when thus divided runs together again instantly upon contact. Hence arise new results of incalculable value. For instance, the so-called "flouring" or granulation of the quicksilver, which in the amalgamation of ores always occasions so great losses, both of the quicksilver itself and of its amalgams with the precious metals, is reduced to a *minimum* or altogether prevented.

The recovery of floured quicksilver and amalgams from slimes and similar mixtures is also greatly facilitated and accelerated thereby. For this purpose some strongly magnetized quicksilver is thrown into the separator. Such slimes may even be operated upon with advantage by the ordinary process of *panning by hand;* a little magnetic quicksilver being thrown into each pan and stirred about at first for a few moments with the hand, which will collect together and incorporate all the scattered globules of auriferous amalgam. In fact, in all panning operations, even upon the pay-dirt of placer diggings, much labor, gold, and time may in this way be saved.

It is necessary to specify an important precaution applicable in some cases in which magnetic amalgams are used, and particularly in those cases in which the ore is ground or agitated with quicksilver in contact with metallic iron. This arises from the liability of the adhesion of some abraded particles of iron to the amalgam. The following plan is therefore recommended in these cases: The amalgam, after separation from the excess of quicksilver, and before retorting, is fused in an earthen dish or iron ladle (with addition of a little quicksilver, if necessary, to make it more fluid), and the iron, which will rise and form a

scum on the surface, is skimmed off. The excess of quicksilver may then, after cooling, be again separated from the amalgam in the usual way. Any amalgam which may adhere to the iron-scum is readily detached therefrom by boiling in water to remove the sodium. This process depends on the simple fact that the adhesion to the iron totally disappears with the extraction of the last traces of sodium from the quicksilver. In fact, it is possible to remove all the iron from the amalgam by boiling directly in water, without any previous fusion; more particularly if the water be made somewhat acid or alkaline. The presence of iron in a sample of amalgam is readily detected by the magnet, which instrument may be sometimes used to advantage also in separating intermixed iron from amalgam, after all sodium has been extracted from the latter. There are still other metals which will usually be found adherent to the amalgam when sodium has been used; such as platinum and osmiridium. These, like iron, immediately detach themselves on the removal of the sodium by boiling the diluted amalgam in water. A mixture of platinum or osmiridium, or both, with iron, may of course be freed from the latter by the magnet. It will generally be found desirable, as in other cases where quicksilver is used and ores containing arsenic or sulphur operated upon, to remove as much as practicable of the arsenic or sulphur by previous roasting or other chemical treatment.

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III.—*Applications to the recovery of metals from their saline compounds.*

In the common operation of reducing silver to an amalgam from its native or artificial chlorid, or from its sulphate, by the action of metallic iron or zinc in conjunction with quicksilver, immense advantage arises from the use of the magnetic amalgams, especially in the reduction of the time occupied to a fraction of that heretofore required. This applies as well to ores in which the silver occurs naturally as chlorid, bromid or iodid, as to those in which the silver has been previously converted into chlorid, or sulphate, or both, by roasting with common salt or otherwise; and to chlorid which has been precipitated from solution. * * *

When gold has been obtained in solution, either from ores or from other materials, by the action of chlorine, aqua-regia, cyanid of potassium, or any other solvent, also when silver has been obtained in solution, in hyposulphites or otherwise, the most rapid and thorough mode of saving these metals will be found to be their conversion into amalgams, by precipitation with metallic iron in contact with magnetic quicksilver, more especially when the solutions are dilute. * * *

The greater rapidity and perfection of the precipitation, in

these cases, are obviously due to the absolute contact at once established with the iron surfaces by the magnetic quicksilver, and the perfect and powerful voltaic circuits thus kept up constantly throughout the two metals and the solution.

* *

VIII.—*Applications to the Mercurializing of Metallic Surfaces in general.*

In all cases in which it is an object to save time and labor in the coating of surfaces of other metals with quicksilver, * * * the magnetic amalgams come into play; * * *

By virtue of the adhesion to iron and other non-amalgamable metals imparted by the magnetic amalgams, I am enabled to apply quicksilver, or fluid or pasty amalgams, to any metallic surface, with great rapidity and facility, *with a brush*, after the fashion of a paint; the material of such brush being fine wire of iron, steel, aluminum, or platinum. Of these the material most generally suitable is the finest steel wire, tempered to about a spring-temper, or somewhat softer; and the most generally useful form for such brushes, is that of a *flat* varnish or white-wash brush.

Among the important uses of such brushes may be instanced: the amalgamation of copper (or iron) plates used in saving gold from ores; * * *. Another valuable use is the recovery of quicksilver which has been spilled or scattered in the form of globules; such a flat brush, saturated with magnetic quicksilver, instantly collecting, incorporating, and sucking up the scattered globules, even from the most irregular surface.

The same principle of adhesion of magnetic amalgams to a brush of steel wire, is applicable, in many obvious ways, to the separation of metals from ores, and of granulated or floured quicksilver from ores and slimes, etc.

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IX.—*Applications to the Transportation of Quicksilver.*

The ordinary mode of packing and transporting quicksilver in bulk, is very expensive and troublesome; and in its ordinary form its transfer from one vessel into another is accompanied by great liability to loss. It will therefore be found very convenient and useful to possess simple, cheap and practicable modes, such as those described above, of converting it into solid forms, susceptible of transportation in vessels of lighter and cheaper material than the ordinary wrought-iron bottles; such, for instance, as glass or earthen ware jars, wooden kegs, bags or bottles, or other envelops of caoutchouc or gutta-percha, etc., etc.

This plan also enables quicksilver to be packed, stored, transported and sold in convenient forms; such as bars, ingots, cylinders, blocks, cubes, spheres, or pellets, of definite sizes and

weights, the convenience of which for many uses, and particularly for that of miners, is at once obvious. When the quicksilver is to be used in any of the arts above specified, it will then be already in a suitable condition, or will merely require admixture with some fluid quicksilver; and when to be used as pure quicksilver, the sodium may be removed by throwing the solid amalgam in fragments into hot water, preferably mixed with a little sulphuric or acetic acid.

The modes of packing such ingots, for preservation and transportation are already sufficiently set forth in a preceding paragraph.

Claims.—The claims attached to this specification are twenty-three in number; and those only are here given which directly concern the miner and amalgamator.

What I claim as my inventions are:—

1st. The combination with quicksilver, when used for the extraction by amalgamation of any metal or metals from ores, slimes, and mixtures with other materials; of metallic sodium, or metallic potassium, or any other highly electro-positive metal equivalent in its action thereto; as above set forth.

2d. In those amalgamators in which amalgamated plates of copper or other metal are used; the substitution therefor of plates or surfaces of iron, coated with quicksilver combined with sodium, or other highly electro-positive metal; as above set forth.

3d. The coating of iron surfaces, between or under which ores or other materials are crushed, with quicksilver combined with sodium, or other highly electro-positive metal; as above set forth.

4th. The prevention of the granulation or flouring of quicksilver, when used in any method of amalgamating ores or other materials; by addition thereto of sodium, or other highly electro-positive metal; as above set forth.

5th. The separation of intermixed iron from double amalgams of gold and sodium, or of silver and sodium; by fusion with excess of quicksilver and skimming; as above set forth.

6th. The separation of intermixed iron, platinum, osmiridium, and other non-amalgamable metals, from amalgams containing sodium or its equivalent; by action thereupon of water or other oxydating liquid; as above set forth.

7th. The separation of intermixed iron from amalgams containing sodium or its equivalent, or from any metal or metals extracted from such amalgams; by magnets, either permanent or electro-magnetic; as above set forth.

8th. The combination with quicksilver, when used in conjunction with iron or other reducing metals, for reducing to an amalgam, silver from its chlorid or other compound, or any

other metal from any saline compound or solution; of sodium, or other highly electro-positive metal; as above set forth.

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12th. In all cases in which metallic surfaces, such as copper plates, the zincs of voltaic batteries, etc., are to be amalgamated; the use of quicksilver combined with sodium, or other highly electro-positive metal; as above set forth.

13th. The more rapid and convenient application of quicksilver to surfaces with metallic brushes; by virtue of its previous combination with sodium, or other highly electro-positive metal; as above set forth.

14th. The use of metallic brushes, enfilmed with an amalgam of sodium or its equivalent; for incorporating together particles of quicksilver, gold, silver, or any other metal, scattered throughout ores, slimes, or any other materials; as above set forth.

15th. The more convenient transportation, handling and subdivision of quicksilver; by conversion into solid forms; in the manner herein substantially described.

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Editorial Note.—At the session of the National Academy of Sciences held in Washington in January last, Prof. Silliman read a paper upon the sodium amalgamation, detailing the results of a series of experiments conducted by him upon a scale of sufficient magnitude to test the value of this discovery upon gold quartz. In one experiment made on over 500 pounds of low grade ores, worth about $15 per ton, the sodium amalgam extracted practically all the gold not existing in the sulphids. This experiment was conducted in a large-sized Freiberg amalgamator and was continued through one hour, the sodium amalgam being added in four successive portions of one ounce each, dissolved in a portion of the 20 pounds of mercury employed. The loss in mercury was about one ounce in this experiment, the quantity of the sodium amalgam being 1·2 per cent of the total quantity of mercury in use.

In a second series of experiments conducted on carefully prepared samples of richer ore, worth $320 per ton, treated in a revolving barrel, the saving by ordinary mercury was from 40 to 60 per cent of the total quantity of gold present. With the aid of sodium amalgam 83·3 per cent were recovered. The results in the large way in actual practice would probably be more satisfactory than those last named. Prof. S. stated that experiments had also been set on foot in California to test this process on a large scale in the actual working of quartz mills. The results of these experiments will be noticed hereafter.