cessary as iron is to our own bodies. Indeed, the blood of man and of the higher animals appears never to be without traces of copper as well as iron.

Water, as we have seen, is a universal solvent, and the matters which it may bring and deposit in the fissures of the earth are very curious. There is scarcely a spar or an ore to be met with in the stratified rocks that is not also found in some of these veinstones, which are often very heterogeneous in composition. In some veins we find the elements of limestone or of granite, and these often include the gems, such as amethyst, topaz, garnet, hyacinth, emerald, and sapphire; while others abound in native metals, or in metallic oxides or sulphides. The nature of the materials thus deposited depends very much on conditions of temperature and of pressure, which affect the solvent power of the liquid, and still more upon the nature of the adjacent rocks and of the waters permeating them.

We are apt in explaining the appearances of the earth's crust to refer the formation of ore beds and veins to some distant and remote period when conditions very unlike the present prevailed, when great convulsions took place and mysterious forces were at work. Yet the same chemical and physical laws are now, as then, at work; in one part dissolving the iron from the sediments and forming ore beds, in another separating the rarer metals from the ocean's waters, while in still other regions the consolidated and formed sediments are permeated by heated waters, to which they give up their metallic matters, to be subsequently deposited in veins. These forces are always in operation, re-arranging the chaotic admixture of elements which results from the constant change and decay around us. The laws which the First Great Cause imposed upon this material universe on the first day are still irresistibly at work fashioning its present order. One great design and purpose is seen to bind in necessary harmony the operations of the mineral with those of the vegetable and animal worlds, and to make all of these contribute to that terrestrial circulation which maintains the life of our mother earth.

PHENOMENA ASSOCIATED WITH A HYDROGEN FLAME.

Phenomena of much interest, and possibly of future usefulness, are associated with the combustion of ordinary hydrogen.

1. To study these phenomena free from disturbing causes, three things should be attended to, although the effects to be described can be obtained without any special precaution. (1) The gas must be stored and purified in the ordinary way namely, by passing into a glass holder through a solution of potash, and then through a solution of perchloride of mercury or nitrate of silver. (2) From the holder, the gas must be led through red or black india rubber tubing to a platinum or, better, a steatite jet. (3) And then the gas should be burnt in a perfectly dark room, and amid calm and dustless air.

2. In this way, the flame gives a faint reddish brown color, invisible in bright daylight. Issuing from a narrow jet in a dark room, a stream of luminosity, more than six times the length of the flame, is seen to stretch upwards from the burning hydrogen. This weird appearance is probably caused by the swifter flow of the particles of gas in the center of the tube. The central particles as they shoot upward are protected awhile by their neighbors; metaphorically they are hindered from entering the fiery ordeal which dooms them finally to a watery grave. Dr. Tyndall has shown that the radiation from burning hydrogen is hugely ultra-red, and moreover, that it has not the quality of the radiation from an elementary body like hydrogen, but practically is found to be the radiation from molecules of incandescent steam. So that, except at its base a hydrogen flame is a hollow stream of glowing water raised to a prodigious heat.

3. Bringing the flame into contact with solid bodies, in many cases phosphorescent effects are produced. Thus, allowing the flame to play for a moment on sand paper and then promptly extinguishing the gas, a vivid green phosphorescence remains for some seconds. The appearance is a beautiful one, as a luminous and perfect section of the hollow flame is depicted. Similar phosphorescence is produced by the flame on white writing paper, or on marble, or chalk, or granite, or gypsum, etc. But no such effect is produced by coal gas, or olefiant or marsh gas. It is evidently a question of temperature, as oxygen driven through coal gas shows the phosphorescence well.

Far exceeding in generality the effect just noticed is a really magnificent blue image of the flame that starts up on almost every substance with which the flame is brought into contact. I have already drawn attention to this effect in the *Philosophical Magazine* for November, 1865, and the same effect has more recently formed the subject of a memoir, presented to M. Wurtz, of the Paris Academy of Sciences, the author of that paper evidently being unaware that the subject had already been investigated by myself.

The appearance is as follows: When the hydrogen flame is brought either vertically or sideways, say upon a white plate or a block of marble, there instantly appears a deep blue and glowing impression of the exact size and shape of the hollow flame. The moment the gas is extinguished, or the flame removed to the slightest distance from the solid, the effect as instantly ceases. If the flame be brought successively to the same spot on the solid, the effect grows fainter and finally vanishes, but instantly reappears upon an adjoining portion.

Other combustible gases, such as carbonic oxide, or marsh gas, or olefiant, or coal gas, do not yield this effect, nor does any lamp flame, luminous or otherwise; nor is it obtained in the oxidizing flame of an ordinary blowpipe; but it is imperfectly produced in the reducing flame when coal gas is used; it is not seen when oxygen is driven through coal gas, unless the latter be in excess; and it is poorer and vanishes more quickly with the oxyhydrogen flame than with hydrogen alone. This blue luminosity is therefore, not a question of heat, but some property depending either on (*a*) the chemical nature of hydrogen, or on (*b*) the physical effect of its radiation. At first I thought it was the latter, and that it was a new form of fluorescence, so closely did it resemble those phenomena. But after a weeks' incessant experimenting, the true cause was hunted down and found to be dependent on the former effect (*a*), and in every case ultimately due to the presence of sulphur. A chemically clean body, or a freshly broken surface, did not show the blue coloration; but after exposure for a short time to the air of London, the substance invariably yielded the blueness; this, however, was not the case when the clean surface was covered by a shade, or exposed to the air of the open country. The combustion of coal gas and coal fires yields sulphate of ammonia, a body often deposited in acicular crystals in the glass tube in a laboratory. Sulphate of ammonia is decomposed by a hydrogen flame, and when that salt is brought into contact with burning hydrogen, it permanently yields the blue colorescence. Hence this body is the main source of the blueness seen whenever a hydrogen flame comes into contact with glass tubes or a dirty surface. The effect must repeatedly have been seen by every one who has experimented on singing flames.

When the blueness, as is so often the case, is seen tinging the flame itself, without contact with any body, the sulphur is derived either from the vulcanized tubing, the dust of which is taken up by the passing gas, or, if the hydrogen be burnt from the bottle generating it, the blueness is due to the decomposition of the sulphuric acid spray, as will be shown further on.

As a chemical re-agent for detecting sulphur, the delicacy of a hydrogen flame is extraordinary. This fact was estimated as follows: Pure precipitated silica yields no blueness with the flame; 500 grains of silica were intimately mingled with one grain of milk of sulphur. Less than one hundredth of a grain of this mixture was thrown on the surface of pure water or placed upon chemically clean platinum foil. The water is best, but in either case the blue color (absent before) now shot forth on bringing the hydrogen flame down. Tried again and again with fresh portions, the effect was very evident, but quickly vanished. The sulphur in a similar portion of the mixture could not be detected chemically by nitro prusside of sodium. The wonderful sensitiveness of the flame may be still better seen in another way. Immediately after washing, the fingers show no color when brought for a moment into the flame, but if a white india rubber tube be touched ever so lightly, the fingers not only show a vivid blueness, but for some time any clean object touched by them, such as platinum foil, shows traces of sulphur by the appearance of the blue coloration with the flame. A block of melting ice continually weeps itself free from dust, and thus presents an excellent surface upon which to try the foregoing experiment. Or a plate of platinum, after heating to redness, may be written over with a stick of sulphur. If kept covered, the invisible letters may long after be traced out by sweeping the hydrogen flame over the surface of the platinum.

Examined through a prism, the blueness derived from any source shows blue and green bands, similar to the spectrum of sulphur, but I have noticed also a red band. This mode of obtaining a sulphur spectrum suggests further inquiry White marble smeared over with a bit of sulphur, or with vulcanized rubber tubing, is a convenient source for obtaining the effect at pleasure.

Some sulphates and sulphides show the blueness with the flame, and are evidently composed by the hydrogen. Thus sulphate of soda gives no blue appearance, while sulphate of ammonia, or alum, does.

Various liquids were tried in contact with the flame. Sulphuric acid was very notable. Here a magnificent blue effect was observed. For persistence and brilliancy of the of the color, this experiment leaves nothing to be desired; the spectrum is very fine. If the liquid is in a glass dish when the flame is brought vertically down, the blueness lights up the glass in a lovely manner.

6. But the presence of sulphur is by no means the only body that a hydrogen flame reveals. The least trace of phosphorus is detected by the production of a vivid green light. It is striking to notice the wonderful sub division of matter in these experiments, and how an immeasurable trace of an element can evoke pronounced and disproportionate effects.

Might not this ready detection of minute quantities of sulphur and phosphorus be of use in the manufacture of iron? And might not hydrogen introduced into the molten metal be employed for the removal of these great enemies of the iron worker? I speak ignorantly.

7. Among the range of substances I have tried, tin was was found to yield the most conspicuous effect, after the bodies named. A fine scarlet color is almost instantly produced when the hydrogen flame is brought into contact with tin or any alloy of tin. Tin is somewhat volatile, and its spectrum is rich in red rays. The tin must be clean; or the sulphur blue, which is much brighter, will mask the effect. A charming experiment may be made by partially scraping a soiled surface of tin; the blue and the scarlet colors mingle and a lovely purple is the result. When a trace of phosphorus is present, there may be obtained a green belt encircling a rich blue, then a purple zone, and finally a glowing scarlet at the root of the flame. These colors, it must be remembered, are not imparted to the flame, but reside on the surface of the body which the flame touches. And where the combustion of the hydrogen is complete, as in the upper part of the flame, or in the luminous stream referred to (2), these effects are not produced: they are best developed at the root of the flame.

8. Passing from liquids and solids, I next tried gases in contact with the flame of hydrogen. Many gases imparted a color to the flame, but here the effect was different to that previously noticed. The whole flame was tinged with the color imparted to it. A mere trace of hydrochloric acid gas imparts a reddish brown to the flame; ammonia gas gives a yellow, and burns freely. It is striking to note the combustion of ammonia gas rising from an unstopped bottle that contains the usual solution and which is placed below the flame.

But carbonic acid gas yields the most striking result in contact with the flame. A pale lilac tinge is instantly produced by a stream of this gas. This, I imagine, is due to the decomposition of the carbonic acid by the hydrogen, and the production and combustion of carbonic oxide. For it is at the lower part of the flame that the effect is most marked. One per cent of pure carbonic acid, admitted to a jar of air, can be detected on holding the jar over the flame. The breath, of course, shows the effect most strikingly.

9. Here then is an eminently practical method of noting the presence of vitiated air in rooms or public buildings. A continuous hydrogen apparatus might be employed with a wash bulb attached. The flame might be burnt from a brass burner or lava jet, placed within a blackened tin cylinder. Opposite the flame a hole might be pierced in the cylinder and closed by a lens for better viewing the flame within. As soon as the atmosphere in a room becomes unpleasantly vitiated, the flame would indicate the fact by its changed color. A similar apparatus might likewise be employed by miners, in metal mines as a warning against impure air, and in coal mines as a detector of fire damp. In this latter case the ends of the cylinder could be covered with wire gauze.

Irrigation Canal of the Rhone.

The proper irrigation of the four departments of France, the Drôme, Garde, Hérault, and Vaucluse, has been for many years under consideration, and at last the Minister of Public Works has granted a credit of small amount for the necessary preliminary steps to be taken to carry out the plans of M. Aristide Dumont, Engineer in Chief of *Ponts et Chaussées*, who proposes to cut a canal for irrigation from the Rhone, at Condrieu, to Mornas.

The length of the canal from its source to Mornas will be about one hundred and twelve miles; all the towns by which it passes can be supplied with water, and it is anticipated that many new factories will spring up in consequence. From a reservoir at Mornas, the canal passes to the right bank of the Rhone by means of a siphon aqueduct. After passing Uyés through a tunnel more than three miles long, it reaches Montpellier at the hight of 180 feet above the level of the sea, irrigating the whole of the environs of this town by means of numerous channels which will distribute the water over the vast plains, which suffer terribly and frequently from drought, that lie between Montpellier and the sea.

The amount of water to be taken from the Rhone at its lowest level is set down at 33 tuns per second, but during about half the year the volume will be increased to 40 or 45 tuns.

The distribution is calculated in the following proportions: 20 tuns for agricultural irrigation, 10 for irrigation in the vicinity of towns, and 3 tuns for evaporation and loss.

The great importance of this canal consists in the fact that, while in the summer all the other rivers in the South of France are nearly dry, the Rhone, being fed by the snow and glaciers of the Alps, pours a grand stream into the sea, which would make the fortune of agriculture. At extreme low water, this noble river passes Lyons at the rate of 235 tuns per second, Tournon at the rate of 310 tuns, Valence at 410, Avignon at 450, and Beaucuire at the rate of 530 tuns per second. At average states of the river, the flow at the spot where the canal is to commence is equal to more than 600 tuns per second; there is little fear then of exhausting such a supply as this, and it is asserted that the abstraction of the volume of water above named will have no effect, even upon the shallowest parts.

The estimated cost of this important work is equal to ten millions of dollars for the formation of the canal and its distributing conduits, and the time required for its execution is three years.

The great hight of the source of this proposed canal will allow the irrigation to be carried to poor dry lands on the slopes of the hills, and thus greatly increase their value and the author of the plan sets down the increased value of such lands at about sixty dollars.

Grand as this scheme is, there is nothing extraordinary or even novel in it; the canal of the Muzza takes 77 tuns of water per second from the Adda, and the grand canal of the Techino, 48 tuns per second from that river.

The great quantity of water proposed to be taken from the Rhone will require the canal to be very little larger than an ordinary one for navigation.

RESTORING WASTE RUBBER.—Among the recent patent extensions is that of Baschnagel's patent of 1858, for restoring waste vulcanized rubber. The invention consists in subjecting the old rubber to a heat of from 150° to 600° F, either with or without immersion in water or other cooling liquid. This process so restores the qualities of the gum that it can be used again in the manufacture of rubber goods.

THE density of the four satellites of Jupiter has been ascertained to be nearly fifty per cent greater than that of the planet itself.