Scientific American.

ESTABLISHED 1845.

MUNN & CO., Editors and Proprietors.

PUBLISHED WEEKLY AT

NO. 37 PARK ROW, NEW YORK.

O. D. MUNN. A. E. BEACH.

TERMS FOR THE SCIENTIFIC AMERICAN.

One copy, one year postage included.................................... $3 20
One copy, six months, postage included 1 60

Clubs.—One extra copy of THE SCIENTIFIC AMERICAN will be supplied gratis for every club of five subscribers at $3.20 each; additional copies at same proportionate rate. Postage prepaid.

Remit by postal order. Address
MUNN & CO., 37 Park Row, New York.

☞ To Advertisers.—The regular circulation of the SCIENTIFIC AMERICAN is now **Fifty Thousand Copies** weekly. For 1880 the publishers anticipate a still larger circulation.

The Scientific American Supplement

Is a distinct paper from the SCIENTIFIC AMERICAN. THE SUPPLEMENT is issued weekly. Every number contains 16 octavo pages, uniform in size with SCIENTIFIC AMERICAN. Terms of subscription for SUPPLEMENT, $5.00 a year, postage paid, to subscribers. Single copies, 10 cents. Sold by all news dealers throughout the country.

Combined Rates.—The SCIENTIFIC AMERICAN and SUPPLEMENT will be sent for one year, postage free, on receipt of *seven dollars*. Both papers to one address or different addresses, as desired.

The safest way to remit is by draft, postal order, or registered letter Address MUNN & CO., 37 Park Row, N. Y.

Scientific American Export Edition.

The SCIENTIFIC AMERICAN Export Edition is a large and splendid periodical, issued once a month. Each number contains about one hundred large quarto pages, profusely illustrated, embracing: (1.) Most of the plates and pages of the four preceding weekly issues of the SCIENTIFIC AMERICAN, with its splendid engravings and valuable information; (2.) Commercial, trade, and manufacturing announcements of leading houses. Terms for Export Edition, $5.00 a year, sent prepaid to any part of the world. Single copies 50 cents. ☞ Manufacturers and others who desire to secure foreign trade may have large, and handsomely displayed announcements published in this edition at a very moderate cost.

The SCIENTIFIC AMERICAN Export Edition has a large guaranteed circulation in all commercial places throughout the world. Address MUNN & CO., 37 Park Row, New York.

NEW YORK, SATURDAY, JULY 24, 1880.

Contents.

(Illustrated articles are marked with an asterisk.)

TABLE OF CONTENTS OF
THE SCIENTIFIC AMERICAN SUPPLEMENT
No. 238,
For the Week ending July 24, 1880.
Price 10 cents. For sale by all newsdealers.

MATTER AS A MODE OF MOTION.

It is a curious circumstance that while from the non-scientific point of view the unpardonable fault of modern science is its "materialistic tendency," the actual drift of scientific thought is toward eliminating from the scientific idea of matter everything which answers to the popular notion of it. Already science has permanently transferred to the domain of motion all those possibilities of sensation, such as light, heat, electricity, and so on, formerly defined as imponderable matter; and latterly the indications have been very clear that ponderable matter may sooner or later share the same fate.

This comes out strongly in the discussion awakened by Professor Crookes' discoveries touching the behavior of molecules in high vacua. As our readers are well aware, Professor Crookes claims to have demonstrated an ultra-gaseous or fourth state of matter, as unlike the other three recognized states of matter as they are unlike each other. In answer to a friendly challenge to make good his position, Professor Crookes has reviewed (in a letter to the Secretary of the Royal Society, to be found in full in the current issue of the SCIENTIFIC AMERICAN SUPPLEMENT) the accepted views as to the constitution of solids, liquids, and gases, and has added thereto a concise explanation of the ultra-gaseous state and his reasons for holding it worthy of a class by itself.

Stated with the utmost brevity, a solid is an aggregation of molecules held together by cohesion and oscillating about fixed centers. The movements of the molecules are large in comparison with their diameters, since the mass "must be able to bear a reduction of temperature of nearly 300° C. before the amplitude of the molecular excursion would vanish." What would result from the arrest of molecular movement and the actual contact of the molecules is beyond our conception, all we know of matter being based wholly upon our experience of molecular movements.

When the temperature of a solid is raised and the force of cohesion so far overcome that the molecules lose their fixity of position, the second or liquid state of matter obtains. A further raising of the temperature brings the liquid at last to a point at which cohesion ceases, the molecules fly apart freely, and the third or gaseous state begins. Under the restraining force of gravitation or the resistance of an inclosing vessel, the molecules of a gas fly about in every conceivable direction, with constant collisions with each other and with the vessel's sides. The gaseous state is thus pre-eminently one dependent on molecular collisions, the mean free path of the molecules, in other words, their flight between collisions, being small compared with the dimensions of the inclosing vessel.

The fourth state of matter, according to Professor Crookes, obtains when the gas has been so rarefied that the collisions of the molecules are few compared with the misses, the free path of the molecules being so long, on an average, that each molecule is allowed to obey its own motions or laws, without interference from collisions with other molecules or with the sides of the inclosing vessel. The same condition prevails when the molecules of a denser gas are so marshaled in their flight that their motion is rectilinear and no collisions occur. Between the third and fourth states there is no sharp line of demarkation, any more than there is between the solid and liquid states, or the liquid and gaseous states; they merge insensibly one into the other.

Thus starting from a possible, though in our present state undemonstrable, condition of matter, in which the molecules are motionless and in contact—a condition, we must remember, in which "matter" would in no way answer to the definition of matter as discovered by our senses—we pass on through stages of increasing molecular freedom and amplitude of motion, until we arrive at a stage of comparative molecular independence and rectilinear flight, limited in our experiments by the necessary walls of our vacuum apparatus. If we try to follow in imagination the free molecule in its flight into unlimited space, it loses all known properties of matter and becomes as if it were not. For what is a single free molecule in space? Is it solid, liquid, or gas?

Professor Crookes answers: "Solid it cannot be, because the idea of solidity involves certain properties which are absent in the isolated molecule. In fact, an isolated molecule is an inconceivable entity, whether we try, like Newton, to visualize it as a little hard spherical body, or, with Boscovitch or Faraday, to regard it as a center of force, or accept Sir William Thomson's vortex atom. But if the individual molecule is not solid, *a fortiori* it cannot be regarded as a liquid or a gas, for these states are even more due to intermolecular collisions than is the solid state. The individual molecules, therefore, must be classed in a distinct state or category."

Further on Professor Crookes takes up again the consideration of the molecule, and describes it as the only true *matter*. "What we call matter is nothing more than the effect upon our senses of the movements of molecule. The space covered by the motion of molecules [from which we derive our idea of continuous matter] has no more right to be called matter than the air traversed by a rifle bullet can be called lead. From this point of view, then, matter is but a mode of motion; at the absolute zero of temperature the intermolecular movement would stop, and, although something retaining the properties of inertia and weight would remain, *matter* as we know it would cease to exist."

Thus, whether we pursue our quest of the ultimate basis of matter atomward or massward, we lose matter as a reality the moment we eliminate molecular interaction; and molecular movement forms no part of the popular idea of matter.

EXPLOSIVES.

Were the question suddenly proposed to any intelligent person, "What is an explosive?" the chances that he would give a correct answer are indeed small. Our first and usual idea is that an explosive is something which will blow up, making a big noise and doing more or less damage. Generally it is some solid or liquid capable of burning with great rapidity and thus generating a large quantity of gas. Gunpowder is a familiar example; the niter furnishes oxygen to burn the sulphur and charcoal, most of the products being gaseous. Bunsen, who made some careful quantitative experiments upon the combustion of gunpowder, found that 1 gramme of sporting powder produced 193 c.c. of gas, while Linck obtained 218 c.c. of gas from 1 gramme of war powder, and as one gramme of powder will occupy less than 1 c.c. of space, the increase of volume is very considerable. But this is not all, for the temperature at the time of explosion is calculated to be about 3,000° C., and gases double their volume whenever the temperature is raised 273°.

Explosions are in but few cases due to the rapid combustion of solids or liquids, but more frequently they consist in the rapid combination of two gases, or of a vapor and a gas. When pure hydrogen and oxygen are mixed in proportion of two volumes of the former to one of the latter, a spark causes them to unite with explosive violence, although the resulting product, at 100° C., occupies but two-thirds as much space of the mixed gases, and at ordinary temperatures it occupies but $\frac{1}{2000}$ as much space. The rapidity with which a flame travels in such a mixture is not less than 100 feet per second. The temperature produced is very high, and at this temperature, of course, the gases occupy a very large space.

Rapid combustion of solids in a fine state of division may exhibit the usual phenomenon of an explosion, as has several times occurred in flouring mills, or wherever dust mixed with air has been ignited by a spark. The explosion of gasolene and benzine is of the same nature. The vapor is the substance in an extremely fine state of division and mixed with the air; as in the case of oxygen and hydrogen a union of the two takes place instantaneously throughout the mixture.

Explosives are not always combustible substances, and their explosion is not the result either directly or indirectly of their rapid combustion. A good example of this class of explosives is found in chloride of nitrogen. Neither of its constituents will unite directly with oxygen, but they are wedded to each other so slightly that each seems equally eager for divorce on the slightest provocation. It is the dissociation of this substance, which suddenly passes from the liquid to the gaseous form, that renders it a dangerous explosive. Many other nitrogen compounds behave in a similar manner; such, for example, as the iodide nitrogen, formed when iodine is washed with ammonia.

Then follow the nitro compounds, or nitrous ethers, familiar among which are nitro-cellulose, nitro-glucose, nitro-starch, and nitro-glycerine. These substances, which are so readily formed by treating cotton, glucose, starch, or glycerine with strong nitric acid, contain an atom of nitrogen united with two of oxygen. This nitro group is a mischievous partner, and is pretty sure to break up any stock company that he gets into as a member. He is not satisfied to walk out peacefully, but like Goliath pulls the whole fabric down about his ears. Although nitro-glycerine requires a high temperature to explode it, a very slight shock or jar will set up decomposition. Nitro-cellulose, or gun-cotton, on the other hand, burns quietly but rapidly. The former produces a powerful effect when exploded without confinement, as on the surface of a body; gun-cotton can be exploded on the open hand without inconvenience.

Another nitro compound of some interest as an explosive is picric acid, a trinitro-phenol, formed by treating carbolic acid with strong nitric acid. The nitro groups here, as in nitro-benzol, seem to possess an entirely different position, the result not being, as in nitro-cellulose, a nitrous ether. The potassium and some other salts of this acid possess explosive properties.

Finally we have a class of bodies known as *fulminates*. They have the same percentage composition as the harmless cyanates and cyanurates, with which they are said to be polymeric. They consist of a metal combined with carbon, oxygen, and nitrogen in the proportion of their atomic weights. Fulminating mercury was discovered by Howard in 1800. It is made by dissolving 1 part of mercury in 12 of nitric acid (sp. gr. 1·3), and when cold it is mixed with 11 parts of 85 per cent alcohol, and the mixture heated on a water bath. It must be removed from the fire as soon as it begins to show turbidity, then left to cool, decanted, and recrystallized from boiling water. It crystallizes in white silky needles. It detonates with great violence when forcibly struck, hence it is used in percussion caps, torpedoes, and the like. Ten grains of this substance produces 4 cubic inches of permanent gases, but at the high temperature of explosion occupy far more space. The explosion is so sudden as to be particularly dangerous when in large masses. Mixed with 30 per cent water it can be triturated on a marble slab with a wooden pestle, but when dry must be kept in small separate portions. One kilogramme (2·2 lb.) of mercury will make enough fulminate to fill 57,600 gun caps, but their preparation is not unattended with danger. Fulminating silver is made by the action of nitric acid and alcohol on nitrate of silver.