the sodium salt of which is used as an indicator (*q.v.*). *Metanilic acid* C6H4(NH2) (SO3H) [1.3], which crystallizes in prisms, is formed by the reduction of meta-nitrobenzene sulphonic acid and is used in the preparation of various azo dyes.

*Sulphinic acids,* R∙SO2H, are formed by reducing sulpho­chlorides with zinc dust; by the action of sulphur dioxide on the zinc alkyls (Hobson, *Ann,* 1857, 102, p. 72; 1858, 106, p. 287) ; by the action of sulphochlorides on mercaptans in alkaline solution; and by the action of the Grignard reagent on sulphur dioxide or thionyl chloride (Rosenheim, *Ber.,* 1904, 37, p. 2152; Oddo, *R. Accad. Lin., 1905* (5), 14 (i.), p. 169). The free acids are unstable. They are readily oxidized to sulphonic acids and reduced to mercaptans. Their alkali salts on treatment with the alkyl halides yield sulphones, R2SO2. Ethyl sulphinic acid, C2H6∙SO2H, is a colourless syrup. Benzene sulphinic acid, C6H5∙SO2H, crystallizes in large prisms and acts as a reducing agent. It decomposes when heated with water under pressure: 3C6H6∙SO2H = C6H5∙SO2H+C6H6∙SO2∙S∙C6H6+H2O. The potas­sium salt when fused with caustic potash yields benzene and potassium sulphite.

**SULPHUR** [symbol S, atomic weight 32∙07 (O=16)], a non-metallic chemical element, known from very remote times and regarded by the alchemists, on account of its inflammable nature, as the principle of combustion; it is also known as brimstone *(q.v.).* The element occurs widely and abundantly distributed in nature both in the free state and in combination. Free or native sulphur, known also as “ virgin sulphur,” occurs in connexion with volcanoes and in certain stratified rocks in several modes, viz. as crystals, and as stalactitic, encrusting, reniform, massive, earthy and occasionally pulverulent forms as “ sulphur meal.” It seems rather doubtful whether the unstable monoclinic modification of sulphur (ß-sulphur) is ever found in a native state.

The crystals belong to the orthorhombic system, and have usually a pyramidal habit (fig.), but may be sphenoidal or tabular. Twins are rare. The cleavage is imperfect, but there is a well-marked conchoidal fracture. The hardness ranges from about 1 to 2, and the sp.gr. from 1∙9 to 2∙1. Crystals of sulphur are transparent or translucent and highly refractive with strong birefringence; they have a resinous or slightly adamantine lustre, and present the characteristic sulphur-yellow colour. Impurities render the mineral grey, greenish or red­dish, bituminous matter being often present in the massive varieties. Sulphur containing selenium, such as occurs in the isle of Vulcano in the Lipari Isles, may be orange-red; and a similar colour is seen in sulphur which contains arsenic sulphide, such as that from La Solfatara near Naples. The presence of tellurium in native sulphur is rare, but is known in certain specimens from Japan.

Volcanic sulphur usually occurs as a sublimate around or on the walls of the vents, and has probably been formed in many cases by the interaction of sulphur dioxide and hydrogen sulphide. Sub­limed sulphur also results from the spontaneous combustion of coal seams containing pyrites. Deposits of sulphur are frequently formed by the decomposition of hydrogen sulphide, on exposure to the atmosphere: hence natural sulphureous waters, especially hot springs, readily deposit sulphur. The reduction of sulphates to sulphides by means of organic matter, probably through the agency of sulphur-bacteria, may also indirectly furnish sulphur, and hence it is frequently found in deposits of gypsum. Free sulphur may also result from the decomposition of pyrites, as in pyritic shales and lignites, or from the alteration of galena: thus crystals of sulphur occur, with anglesite, in cavities in galena at Monteponi near Iglesias in Sardinia; whilst the pyrites of Rio Tinto in Spain sometimes yield sulphur on weathering. It should be noted that the oxidation of sulphur itself by atmospheric influence may give rise to sulphuric acid, which in the presence of limestone will form gypsum: thus the sulphur-deposits of Sicily suffer alteration of this land, and have their outcrop marked by a pale earthy gypseous rock called *briscale.*

Some of the most important deposits of sulphur in the world are worked in Sicily, chiefly in the provinces of Caltanisetta and Girgenti, as at Racalmuto and Cattolica; and to a less extent in the provinces of Catania, Palermo (Lercara) and Trapani (Gibellina). The sulphur occurs in Miocene marls and limestone, associated with gypsum, celestine, aragonite and calcite. It was formerly believed that the sulphur had a volcanic origin, but it is now generally held that it has either been reduced from gypsum by organic agencies, or more pro­bably deposited from sulphur-bearing waters. Liquid occasion­ally enclosed in the sulphur and gypsum has been found by O. Silvestri and by C. A. H. Sjögren to contain salts like those of sulphur-springs. An important zone of sulphur-bearing Miocene rocks occurs on the cast side of the Apennines, constituting a great part of the province of Forli and part of Pesaro, Cesena and Perticara are well-known localities in this district, the latter yielding crystals coated with asphalt. Sulphur is occasionally found crystallized in Carrara marble; and the mineral occurs also in Calabria. Fine crystals occur at Conil near Cadiz; whilst in the province of Teruel in Aragon, sulphur in a compact form replaces fresh-water shells and plant-remains, suggesting its origin from sulphur-springs. Nodular forms of sulphur occur in Miocene marls near Radoboj in Croatia, and near Swoszowic, south of Cracow. Russia possesses large deposits of sulphur in Daghestan in Transcaucasia, and in the Transcas­pian steppes. Important deposits of sulphur are worked at several localities in Japan, especially at the Kosaka mine in the province of Rikuchiu, and at Yatsukoda-yama, in the province of Mutsu. Sulphur is worked in Chile and Peru. A complete list of localities for sulphur would include all the volcanic regions of the world. In the United States, sulphur occurs in the following states, in many of which the mineral has been worked: Louisiana (*q.v.*), Utah, Colorado, California, Nevada, Alaska, Idaho, Texas and Wyoming. The Rabbit Hole sulphur-mines are in Nevada, and a great deposit in Utah occurs at Cove Creek,· Beaver county. In the British Islands native sulphur is only a mineralogical rarity, but it occurs in the Carboniferous Limestone of Oughterard in Co. Galway, Ireland.@@1

In combination the element chiefly occurs as metallic sul­phides and sulphates. The former are of great commercial importance, being, in most cases, valuable ores, *e.g.* copper pyrites (copper), galena (lead), blende (zinc), cinnabar (mer­cury), &c. Of the sulphates we notice gypsum and anhydrite (calcium), barytes (barium) and kieserite (magnesium). Gaseous compounds, *e.g.* sulphur dioxide and sulphuretted hydrogen, are present in volcanic exhalations (see Volcano) and in many mineral waters. The element also occurs in the animal and vegetable kingdoms. It is present in hair and wool, and in albuminous bodies; and is also a constituent of certain vegetable oils, such as the oils of garlic and mustard. There is, in addition, a series of bacteria which decompose sulphureous compounds and utilize the element thus liberated in their protoplasm (see Bacteriology).

*Extraction'.—*As quarried or mined free sulphur is always contaminated with limestone, gypsum, clay, &c.; the principle underlying its extraction from these impurities is one of simple liquation, *i.e.* the element is melted, either by the heat of its own combustion or other means, and runs off from the earthy residue.

In the simplest and crudest method, as practised in Sicily, a mass of the ore is placed in a hole in the ground and fired; after a time the heat melts a part of the sulphur which runs down to the bottom of the hole and is then ladled out. This exceptionally wasteful process, in which only one-third of the sulphur is recovered, has been improved by conducting the fusion in a sort of kiln. A semicircular or semi-elliptical pit *(calcarone)* about 33 ft. in diameter and 8 ft. deep is dug into the slope of a hill, and the sides are coated with a wall of stone. The sole consists of two halves slanting against each other, the line of intersection forming a descending gutter which runs to the outlet. This outlet having been closed by small stones and sulphate of lime cement, the pit is filled with sulphur ore, which is heaped up considerably beyond the edge of the pit and covered with a layer of burnt-out ore. In building up the heap a number of narrow vertical passages are left to afford a draught for the fire. The ore is kindled from above and the fire so regulated (by making or unmaking air-holes in the covering) that, by the heat produced

*@@@, References.—*A very full article (“Zolfo") by G. Aichino, of the Geological Survey of Italy, will be found in the *Enciclopedia delle arte e industrie* (Turin, 1898). This includes a full bibliography. See also J. F. Kemp in Rothwell’s *Mineral Industry* (1893), vol. ii.; Jules Brunfaut, *De l'Exploitation des soufres* (2nd ed., 1874) ; Georgio Spezia, *Sull’ origine del solfo nei giacementi solfiferi della Sicilia* (Turin, 1892). For Japanese sulphur see T. Wada, *Minerals of Japan* (Tokyo, 1904).