world, ending with the death of the emperor John Zimisces. Under "Constantinople" are mentioned the emperors Basil and Constantine, who succeeded John Zimisces in 975. It would thus appear that Suidas lived in the latter part of the 10th century. The passages in which Michael Psellus (who lived at the end of the 11th century) are referred to are thought by Küster to be later interpolations; one of them is wanting in the Paris MSS. The lexicon of Suidas is arranged alphabetically, with some slight deviations from the strict alphabetical order. It partakes of the nature of a dictionary and encyclopædia, containing not only definitions of words but also short articles on historical, biographical, geographical, and antiquarian subjects. It includes numerous quotations from ancient writers; the scholiast on Aristophanes in particular is much used. Although the work is uncritical and the value of the articles very unequal, it contains a great deal of important information on ancient history and life. It deals with Scriptural as well as pagan subjects, from which we infer that the writer was a Christian. Prefixed to the work is a notice stating "the present book is by Suidas, but its arrangement is the work of twelve learned men," and then follow their names.

The first edition of Suidas was that by Demetrius Chalcondylas (Milan, 1499), the next by Aldus (Venice, 1514). The chief later editions are those by L. Küster (Cambridge, 1705), by T. Gaisford (Oxford, 1834), and by G. Bernhardy (Halle, 1834-1853). There is a cheap and convenient edition by Im. Bekker (Berlin, 1854).

SULLA (138-78 B.C.). The life of Lucius Cornelius Sulla makes one of the most important chapters in Roman history. Both as a general and as a politician he stands in the foremost rank of the remarkable figures of all time. It was by his ability and his force of character that Sulla, who had neither great wealth nor noble ancestry[1] to back him up, pushed himself to the front in early manhood, distinguishing himself in the Jugurthine War in 107 and 106, and being able with a good show of reason to claim the credit of having terminated that troublesome war by capturing Jugurtha himself. In these African campaigns Sulla showed that he knew how to win the hearts and confidence of his soldiers, and through his whole subsequent career the secret of his brilliant successes seems to have been the enthusiastic devotion of his troops, whom he continued to hold well in hand, while he let them indulge themselves in plundering and in all manner of licence. "Rome's soldiers from Sulla's time," says Sallust (*Cat.*, 11), "began to drink, to make love, to have a taste for works of art, to rob temples, and to confound things sacred and profane." From the year 104 to 101 he served again under Marius in the war with the Cimbri and Teutones and fought in the last great battle near Verona, which annihilated the barbarian host. Marius, it is said, was jealous of him, and any friendly feeling there may have hitherto been between the two now finally ceased. Sulla on his return to Rome lived quietly for some years and took no part in politics. What with his genuine love of letters and his love of gay company he was never at a loss for amusement, and he must always have been a particular favourite with fashionable society at Rome. In 93 he was elected prætor after a lavish squandering of money, and he delighted the populace with an exhibition of a hundred lions from Africa, from the realm of King Bocchus. Next year (92) he went to the East with special authority from the senate to put pressure on the famous Mithradates of Pontus, and make him give back Cappadocia to its petty prince Ariobarzanes, one of Rome's dependants in Asia, whom he had driven out. Sulla with a small army soon won a victory over the general of Mithradates, and Rome's client-king was restored. An embassy from the Parthians now came to solicit the honour of alliance with Rome, and Sulla was the first Roman who held diplomatic intercourse with that remote people. In the year 91, which brought with it the imminent prospect of revolution and of sweeping political change, with the enfranchisement of the Italian peoples, Sulla returned to Rome, and it was generally felt that he was the man to head the conservative and aristocratic party. Who was to have the command in the Mithradatic War and be entrusted with the settlement of the East was the question of the day, and the choice lay plainly between Marius and Sulla. The rivalry between the two men and their partisans was as bitter as it could possibly be. Marius was old, but he had by no means lost his prestige with the popular party.

Meanwhile Mithradates and the East were forgotten in the crisis of the Social or Italic War, which broke out in 91 and threatened Rome's very existence. The services of both Marius and Sulla were needed, and were given; but Sulla was the more successful, or, at any rate, the more fortunate. Of the Italian peoples Rome's old foes the Samnites were the most formidable; these Sulla thoroughly vanquished, and took their chief town, Bovianum. But his victories were, after all, followed by the concession of the franchise to the Italian towns and communities generally, though an arrangement which made them vote in separate tribes greatly diminished their political power and became a further source of irritation. It was clear that Rome was on the eve of yet further troubles and revolutionary changes. Her armies, now recruited from the very scum of the population, had not the loyal and honourable spirit of former days, and cared only for licence and plunder. On every side it seemed that public life was demoralized and politics degraded. In 88 Sulla was consul; the revolt of Italy was at an end; and again the question came to the front—who was to go to the East and encounter the warlike king of Pontus, against whom war had been declared. The tribune Publius Sulpicius Rufus moved that Marius should have the command; there was fearful rioting and bloodshed at Rome at the prompting of the popular leaders, Sulla narrowly escaping to his legions in Campania, whence he marched on Rome, being the first Roman who entered the city at the head of a Roman army. Marius now had to fly; and he and his party were crushed for the time.

Sulla, leaving things quiet at Rome, quitted Italy in 87 for the East, taking Greece on his way, and for the next four years he was winning victory after victory against the armies of Mithradates and accumulating boundless plunder. Athens, the headquarters of the Mithradatic cause, was taken and sacked in 86, and Sulla possessed himself of a library which contained Aristotle's works. In the same year at Chæroneia, the scene of Philip of Macedon's memorable victory more than two and a half centuries before, and in the year following, at the neighbouring Orchomenus, he scattered like chaff, with hardly any loss to himself, immense hosts of the enemy. Crossing the Hellespont in 84 into Asia, he was joined by the troops of Fimbria, who soon deserted their general, a man sent out by the Marian party, now again in the ascendant at Rome. The same year peace was concluded with Mithradates on condition that he should resign all his recent conquests, give up all claim to meddle with Rome's Asiatic dependencies, and pay a considerable indemnity. In fact the king was to be put back to the position he held before the war; but, as he raised cavils and Sulla's soldiers wanted better terms and more spoil, he had in the end to content himself with being on the same footing as the other princes of Asia,—simply a vassal of Rome.

Sulla returned to Italy in 83, landing at Brundusium, having previously informed the senate in an official despatch of the result of his campaigns in Greece and Asia, and announced his presence on Italian ground. He complained, too, of the ill-treatment to which his friends and partisans had been subjected during his absence. The revolutionary party, specially represented by Cinna, Carbo, and the younger Marius, had massacred them wholesale, confiscated his property, and declared him a public enemy. They felt they must resist him to the death, and with numerous bodies of troops scattered throughout Italy, and the support of the newly enfranchised Italians, to whom it was understood that Sulla was bitterly hostile, they counted confidently on success, but on Sulla's advance at the head of his 40,000 veterans many of them lost heart and deserted their leaders, while for the most part the Italians themselves, whom he confirmed in the possession of their new privileges, were won over to his side. Only the Samnites, who were as yet without the Roman franchise, remained his enemies, and it seemed as if the old war between Rome and Samnium had to be fought once again. Several Roman nobles, among them Cneius Pompeius (Pompey the Great), Metellus Pius, Marcus Crassus, Marcus Lucullus, joined Sulla, and in the following year (82) he won a decisive victory over the younger Marius near Præneste (Palestrina), and then marched straight upon Rome, where again, just before his defeat of Marius, there had been a great massacre of his adherents, in which the famous and learned jurist Mucius Scævola perished. Rome was at the same time in extreme peril from the advance of a Samnite army, and was barely saved by Sulla, who, after a bloody and very hard-fought battle, routed the enemy before the walls of Rome. With the death of the younger Marius, who killed himself after the surrender of Præneste to one of Sulla's officers, the civil war was at an end and Sulla was master of Rome and of the Roman world. Then came, with the object of breaking the neck of the Marian or popular party, the memorable "proscription," when for the first time in Roman history a list of men declared to be outlaws and public enemies was exhibited in the forum, and a reign of terror—a succession of wholesale murders and confiscations throughout Rome and Italy—made the name of Sulla for ever infamous. The title of "dictator" was revived after a long period and conferred upon him; Sulla was in fact emperor of Rome, with absolute power over the life and fortunes of every Roman citizen. There were of course among them some really honest well-meaning men who looked up to him as the "saviour of society." After celebrating a splendid triumph for the Mithradatic War, and assuming the surname of "Felix" ("Epaphroditus," "Venus's favourite," he styled himself in addressing Greeks), he carried in 80 and 79 his great political reforms (see ROME, vol. xx. pp. 761-762). Of these the main object was to invest the senate, the thinned ranks of which he had recruited with a number of his own creatures, with full control over the state, over every magistrate and every province, and the mainstay of his political system was to be the military colonies which he had established with grants of land throughout every part of Italy, to the injury and ruin of the old Italian freeholders and farmers, who from this time dwindled away, leaving whole districts waste and desolate. Sulla's work had none of the elements of permanence; it was a mere stop-gap purchased at the cost of infinite misery and demoralization.

In 79 Sulla resigned his dictatorship and retired to Puteoli, where he died in the following year, probably from the bursting of a blood-vessel, though there is a story that he fell a victim to a particularly loathsome disease similar to that which cut off one of the Herods (Acts xii. 23). The half lion, half fox as his enemies called him, the "Don Juan of politics," to quote Mommsen's happy phrase, the man who carried out a policy of "blood and iron" with a grim humour, amused himself in his last days with actors and actresses, with dabbling in poetry, and completing the *Memoirs* of his strange and eventful life.

For Sulla and his times, there is his *Life* by Plutarch, who had his *Memoirs* for one of his authorities, and there are very numerous references to him in Cicero's writings. The best and fullest modern account of him is that of Mommsen (vol. iii., bk. iv. ch. 8, 9). (W. J. B.)

SULLY, MAXIMILIAN DE BÉTHUNE, DUKE OF (1560-1641), French statesman, was born at the château of Rosny near Mantes on 13th December 1560. He derived his early appellation and the title of baron from the place of his birth, and was known as Rosny during the greater part of his life. Some one of his numerous enemies pretended that he did not really belong to the illustrious family represented four centuries earlier by the trouvère and warrior Quenes de Béthune, but that his race was derived from Scottish Bethunes of no mark. There is, however, no reason for giving any credit to this story. Sully was a second son; his elder brother died when but just of age, and even before this his father (if his own account may be trusted) treated Maximilian (so he himself spelt his name, and not Maximilien) as an eldest son. He was only eleven years old when his father, who was a Protestant, was presented to Henry of Navarre, and from that time he was more or less inseparably attached to the future king of France. He had a narrow escape on St Bartholomew's Day, but he did escape, and when little more than sixteen began to take an active part in the Civil Wars. He distinguished himself not a little, especially in the character of engineer. In 1583 he married Anne de Courtenay, who, however, died in 1589, and in the intervals of war he lived the life of a country gentleman at Rosny. At the battle of Ivry, 1590, he had the good luck, though seriously wounded, to capture Mayenne's standard. As soon as Henry's power was established, Sully, who, though by no means always a complaisant or obliging servant, had been uniformly faithful, received his reward in the shape of numerous places, estates, and dignities. In 1601 he was made grand-master of the ordnance and in 1606 duke of Sully. He was also practically the king's minister of finance during the greater part of his reign. After the assassination of his master he makes no further figure in history, though he survived for many years, saw the rise of a far greater minister than himself, and did not die till (less than a year before Richelieu himself died) the 22d of December 1641. at Villebon near Chartres.

He had married a second time, and anecdote is not complimentary to his second wife, while his daughter, who married the great duke of Rohan, also had a not unblemished reputation. Sully, however, who, though deprived of (and indeed resigning) all control of public affairs after Henry's death, retained great wealth, lived in what was almost a caricature of the stately fashions of the time, and busied himself in the composition of memoirs which are among the most curious in form, and not the least interesting in contents, of the kind. He instructed his secretaries to draw the book up in the form of an elaborate address to himself: "you then did this"; "you said as follows"; "as you have been good enough to inform us, the affair went on this wise"; and so forth. And he not only had the book executed in this extraordinary fashion but had it read out to him. Its title is as odd as other things about it and runs thus: *Mémoires des Sages et Royales Œconomies d'Estat, domestiques, politiques, et militaires de Henry le Grand, l'Exemplaire des Roys, le Prince des Vertus, des Armes, et des Loix, et le Père en effet de ses Peuples François. Et des servitudes utiles, obéissances convenables, et administrations loyales de Maximilian de Béthune, l'un des plus confidans, familiers, et utiles soldats et serviteurs du grand Mars des François. Dediés à la France, à tous les bons soldats, et tous peuples François.* Two folio volumes were splendidly printed, nominally at Amsterdam, but really under Sully's own eye at his château, in 1634; the other two did not appear till twenty years after his death. As his wealth, his im-

[1] He belonged to quite a minor branch of the Cornelian gens.

perious and grumbling temper, the favour which he had enjoyed and his subsequent loss of it, joined to attract odium, his character and his book were rather roughly handled in his lifetime. Marbault, secretary to Du Plessis-Mornay, Sully's chief rival, wrote a very caustic criticism of the *Memoirs*, from which, though it remained in MS. till the 19th century, Tallemant des Réaux, the insatiable scandal-monger, compiled a not unamusing but distinctly calumnious article on Sully. Most of the stories it contains may be unhesitatingly disbelieved. At the same time Sully was by no means the ideally wise and good minister that he has not unfrequently been represented as being. He was as faithful as a dog, and as surly. He grasped wealth and place to an extent not quite compatible with the idea of pure devotion to his king or his country, and his jealousy of all other ministers and all other favourites was extravagant and unceasing. Still there is no doubt that he was an excellent man of business, that, if not exactly what would be now called an incorruptible minister, he made no gains not sanctioned by the customs of the time, that he was inexorable in interfering with peculation and malversation on the part of others, that he opposed the ruinous personal expenditure which was the bane of almost all European monarchies in his day, and that he did much both as a man of war and as a man of peace to make France strong, united, and happy. His literary power, moreover, was far from small. Although the fantastic form of his *Memoirs*, after being diverting for a time, grows not a little wearisome, they have phrases and passages of great vivacity, which it is reasonable to attribute to Sully himself rather than to his spokesmen, and they show much grasp of administrative business.

The arrangement of the *Memoirs* so shocked the 18th century that in 1745 the abbé de l'Écluse re-edited or rather rewrote them in the ordinary form of narrative. This text has of course no interest; the proper version with the commentary of Marbault may be found in the collection of Michaud and Poujoulat (vols. xvi. and xvii.).

SULMONA, or SOLMONA, a city of Italy, in the province of Aquila (Abruzzo Ulteriore), now reached by a branch line from the railway between Pescara and Aquila, lies, at a height of 1575 feet above the sea, at the junction of the Vella with the Gizio (a tributary of the Pescara), which supplies water-power to its paper-mills, fulling-mills, copper-works, &c. Besides its cathedral (S. Panfilo), rebuilt by Bishop Walther of Ocre (Frederick II.'s grand chancellor) in 1119, and several times remodelled in the 15th and 16th centuries, Sulmona has in Santa Maria della Tomba a good example of pure Gothic, and in Corpus Domini a striking instance of the vagaries of Gothic in its decay. The communal buildings are half Gothic, half Renaissance. A statue of Ovid, the most celebrated native of the city (which also gave birth to Innocent VII.), stands in front of the cancellaria. In the vicinity of the town is Monte Morrone, where Celestine V. lived as a hermit and founded a monastery of "Celestines," which remained till 1870, when it was transformed into a penitentiary. The population of Sulmona was 12,594 in 1861 and 14,171 in 1881 (commune, 17,601).

Sulmo, a city of the Peligni, is first mentioned during the Second Punic War (211 B.C.). It became a Roman colony probably in the reign of Augustus, and as a municipium it continued to flourish throughout the empire. Charles V. erected it into a principality, which he bestowed on Charles Lannoy of "Pavia" celebrity. It ultimately passed to the Corno and Borghese families. The bishopric is known as that of Valva and Sulmona.

SULPHUR.[1] The sulphur minerals, which are very numerous and varied, arrange themselves under three heads,—(1) *metallic sulphates*, of which hydrated sulphate of lime, $CaSO_4 . 2H_2O$, gypsum, is the most abundant; (2) *metallic sulphides*, a numerous family, including the majority of metallic ores, of which, however, only iron pyrites serves as a source for sulphur; (3) *elementary sulphur*. In the organic world we meet with sulphur everywhere, this element forming an essential (though quantitatively subordinate) component of the albumenoids, a class of compounds contained in all vegetable and animal structures. Of organic materials rich in sulphur we may name animal hair (containing about 4 per cent.) and the essential oils of the onion, garlic, and mustard.

[1] This chemical element has already been treated in its scientific aspects under CHEMISTRY (vol. v. p. 498 *sq.*). The present article is intended to supplement what is there given, in the direction chiefly of practical applications.

Elementary Sulphur.

This occurs as a mineral chiefly in the Upper Miocene deposits and in the Flötz, associated in general with gypsum, massive limestone, and marl. Commercially important deposits are found in Sicily (provinces of Caltanissetta, Girgenti, Catania), Italy (Latera and Scrofano, province of Rome), Spain (Teruel and Arcos), France (dept. Vaucluse), Transylvania, Poland (Swoszowice near Cracow), and Germany (Lüneburg, in Hanover). The exhalations of volcanoes include, as a rule, sulphurous acid, SO_2, and sulphuretted hydrogen, H_2S, which two gases, if moist, readily decompose each other into water and sulphur,—a circumstance which accounts for the constant occurrence of sulphur in all volcanic districts. Mt Purace in Colombia wears a cap of sulphur (derived from its own crater) which accumulates at the rate of about 2 feet per annum,—its superficial area amounting to 1435 square yards. The solfatara at Bahara Saphinque on the Red Sea is said to yield 600 tons of sulphur annually. The molten sulphur discharged from the crater of the Alaghez in the Armenian highlands forms solid excrescences, which the natives dislodge from their inaccessible positions by means of rifle-shots. A sulphur deposit near the Borax Lake in California is estimated to contain 20,000 tons. Most of the sulphur or brimstone of commerce comes from the rich fields of Sicily, where in 1884 the annual production had almost reached 400,000 tons. The mode of mining there adopted is by a network of horizontal galleries (tunnels) driven through the deposit; the solid squares thus marked off are hewn out, a central pillar being left to support the roof. The total excavation is generally 100 feet high and from 25 to 50 wide; not unfrequently the whole collapses. Down to a comparatively recent date all the work used to be done by hand, boys of eight to ten years of age being employed to carry the ore to the shaft and thence to the surface; only where a mine has reached a depth of 325 feet or more is water-power, if available, resorted to. Since 1868, however, the ore at Grotta Calda at least has been raised by properly constructed shafts with the help of steam-power, and this system is spreading.

Sicilian sulphur.

The Sicilian ores are customarily classified as follows:—

	Per 100 parts of ore Sulphur present.	Per 100 parts of ore Sulphur recovered.
Richest ores	30-40	20-25
Rich ores.....	25-30	15-20
Ordinary	20-25	10-15

The poor yield of actual sulphur is explained by the rather primitive method used for its extraction. A semicircular or semi-elliptical pit (*calcarone*) about 33 feet in diameter and 8 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 by the combustion of the least sufficient quantity of sulphur, the rest is liquefied. The molten sulphur accumulates on the sole, whence it is from time to time run out into a square stone receptacle, from which it is ladled into damp poplar-wood moulds and so brought into the shape of truncated cones weighing 110 to 130 lb each. These cakes are sent out into commerce. A calcarone with a capacity of 28,256 cubic feet burns for about two months, and yields about 200 tons of sulphur. The immense volumes of sulphurous acid evolved give rise to many complaints; all the minor pits suspend work during the summer to avoid destruction of the crops. A calcarone that is to be used all the year round must be at least 220 yards from any inhabited place and 110 from any field under cultivation.

The yield of sulphur, as seen from the table given above, is miserably small, but the scarcity of fuel in Sicily almost prohibits the introduction of any more rational method. As sulphur fuses at 114° C., high-pressure steam at once suggests itself as a suitable medium of heating. In the sulphur-works of Latera, in the province of Rome, the following apparatus (constructed by Gritti) is being used with success. A vertical truncated perforated cone of thick sheet-iron serves for the reception of the ore. This cone is enclosed in a similar cone of iron, which terminates in a detachable deep iron basin below, and is provided with a tightly fitting lid. All the joints in this outer shell are steam-tight. The inner cone having been charged and the lid secured, steam of sufficient pressure to ensure a temperature of from 125° to 135° C. is blown into the apparatus, which soon causes the sulphur to melt and collect in the basin below. After from 30 to 50 minutes, reckoning from the time when the above temperature is reached, the operation is completed. The steam is then turned off and the sulphur made to run from the basin into a receptacle beside the apparatus, to be cast into sticks or cakes. The iron basin is then detached, and by turning aside an iron damper which held the ore in its place the exhausted ore is made to drop into a pit. Each charge of ore amounts to about from 25½ to 26½ cwts., containing about 385 lb of sulphur. Of this some 360 lb are recovered as saleable sulphur, at the expense of about 286 lb of oak-wood as fuel.

R. E. Bollmann in 1867 proposed to extract the sulphur by means of bisulphide of carbon. The process, after having been tried at Bagnoli near Naples and given up as hopeless, was introduced in 1873 in Swoszowice near Cracow under the guidance of Winkler and has proved a success. The apparatus is constructed so that the bisulphide used in the process of extraction is recovered by distillation; the loss of bisulphide amounts only to one-half per cent., sometimes to less, and the sulphur produced is very pure. But by far the greater part of the purer qualities of commercial sulphur is produced from Sicilian calcarone sulphur by distillation, which removes the 3 per cent. or so of earthy impurities contained in it. The following apparatus (invented originally by Michel of Marseilles and improved subsequently by others) enables the manufacturer to produce either of two forms of "refined" sulphur which commerce demands. It consists of a stone-built chamber of about 2825 cubic feet capacity, which communicates directly with two slightly slanting tubular retorts of iron, each of which holds about 660 lb of sulphur. The retorts are charged with molten sulphur from an upper reservoir, which is kept at the requisite temperature by means of the last heat of the retort fires. The chamber has a safety valve at the top of its vault, which is so balanced that the least surplus pressure from within sends it up. The first puff of sulphur vapour which enters the chamber takes fire and converts the air of the chamber into a mixture of nitrogen and sulphurous acid. The next following instalments of vapour, getting diffused throughout a large mass of relatively cold gas, condense into a kind of "snow," known in commerce and valued as "flowers of sulphur" (*flores sulphuris*). By conducting the distillation slowly, so that the temperature within the chamber remains at a sufficiently low degree, it is possible to obtain the whole of the product in the form of "flowers." If compact ("roll") sulphur is wanted the distillation is made to go on at the quickest admissible rate. The temperature of the interior of the chamber soon rises to more than the fusing-point of sulphur (114° C.), and the distillate accumulates at the bottom as a liquid, which is tapped off from time to time to be cast into the customary form of rods of about 1½ inches diameter.

In some places sulphur is extracted from iron pyrites by one of two methods. The pyrites is subjected to dry distillation from out of iron or fire-clay tubular retorts at a bright red heat. One-third of the sulphur is volatilized—$3FeS_2 = Fe_3S_4 + S_3$—and obtained as a distillate. The second method is analogous to the calcarone method of liquation: the ore is placed in a lime-kiln-like furnace over a mass of kindled fuel to start a partial combustion of the mineral, and the process is so regulated that, by the heat generated, the unburnt part is decomposed with elimination of sulphur, which collects in the molten state on an inverted roof-shaped sole below the furnace and is thence conducted into a cistern. Such pyrites sulphur is usually contaminated with arsenic, and consequently is of less value than Sicilian sulphur, which is characteristically free from this impurity.

Milk of sulphur.

The substance known as "milk of sulphur" (*lac sulphuris*) is very finely divided sulphur produced by the following, or some analogous, chemical process. One part of quicklime is slaked by means of 6 parts of water, and the paste produced diluted with 24 parts of water; 2·3 parts of flowers of sulphur are added; and the whole is boiled for about an hour or longer, when the sulphur dissolves,—

$$3CaO + 12S = 2CaS_5 + CaS_2O_3.$$

The mixed solution of pentasulphide and thiosulphate of calcium thus produced is clarified, diluted more largely in a tub, and then mixed with enough of pure dilute hydrochloric acid to produce a feebly alkaline mixture; this shows that only the bulk of the pentasulphide is decomposed,—$CaS_5 + 2HCl = CaCl_2 + H_2S + 4S$ of precipitated sulphur). The addition of more acid would produce an additional supply of sulphur (by the action of the $H_2S_2O_3$ on the dissolved H_2S); but this thiosulphate sulphur is yellow and compact, while the CaS_5 part has the desired qualities, forming an extremely fine, almost white, powder. The precipitate is washed, collected, and dried at a very moderate heat. It is used as a medicine. If sulphuric acid is used instead of hydrochloric acid the preparation is apt to be contaminated with hydrated sulphate of lime. In the United Kingdom, indeed, precipitated sulphate of lime used to be added intentionally to produce what the public had got accustomed to; but this practice has been rightly stopped by the authorities.

During the year 1875 the production of sulphur in Europe is stated to have been as follows:—

	Tons.
Italy	320,000
Spain	4,000
Austria-Hungary	3,750
German empire (including 5000 tons of regenerated[1] sulphur)	14,500
Belgium	450
Total	382,700

By far the greater part of all the sulphur produced in Sicily and elsewhere is used for the manufacture of sulphuric acid. Subjoined is an enumeration of some other applications. (1) The manufacture of gunpowder (see vol. xi. p. 320). (2) The taking of casts. (3) The making of cements: (*a*) a mixture of molten sulphur and ferric oxide is used to cement the isolating bells to telegraph posts; (*b*) a mixture of iron filings (100), flowers of sulphur (8 to 20), and sal-ammoniac (3 to 5) made into paste with water is used to cement iron bars (fences, &c.) into stone sockets; (*c*) a mixture of molten sulphur with powdered quartz or glass has been recommended as an acid-proof material for sulphuric acid chambers; (*d*) a mixture produced by the incorporation of powdered quartz and colouring matters, such as vermilion, &c., with molten sulphur is employed for ornamental articles. (4) The vulcanization of india-rubber (see vol. xii. p. 840 *sq.*). (5) Dusting vine-plants with flowers of sulphur is said to keep off the fungus *Oïdium Tuckeri*, which has caused such devastation in the vineyards in France and elsewhere.

Sulphur Compounds.

Sulphuretted hydrogen, H_2S (see CHEMISTRY, vol. v. p. 499 *sq.*), is used largely as such, or as sulphide of ammonium, $(NH_4)_2S$ etted $= 2NH_3 + H_2S$, for the detection, discrimination, and separation of hydrometals. To give an example: the least quantity of lead dissolved gen. in water as (say) nitrate can be detected by the addition of sulphuretted hydrogen, which brings down the lead as a black precipitate of sulphide of lead,—$Pb(NO_3)_2 + H_2S = PbS + 2HNO_3$. The presence of a moderate quantity of mineral acid in the original solution does not interfere with the test. What we said of solution of salts of lead holds substantially of those of the following groups of metals. The formulæ and the colours of the sulphides are given in brackets. A. Lead (black, PbS), silver (black, Ag_2S), mercury as mercurous or mercuric salt (black, HgS + Hg or HgS respectively), copper (greenish black, CuS), bismuth (brown, Bi_2S_3), cadmium (yellow, CdS). B. Arsenic (yellow, As_2S_3), antimony (orange-red, Sb_2S_3), tin as stannic salt (yellow, SnS_2). The sulphides A are insoluble; the sulphides B are soluble in sulphide of ammonium solution, and the latter, from this solution, can be reprecipitated by acidification with dilute sulphuric or hydrochloric acid. The brown SnS precipitated from stannous salts is insoluble in the (colourless) solution of $(NH_4)_2S$, but soluble in the yellow solution of the polysulphide $(NH_4)_2S_2$, as SnS_2. C. The following metals are not precipitated from their salt solutions if these are acidified sufficiently by added mineral acid; but they are precipitated from their neutral or alkaline solutions by sulphide of ammonium:—iron (black, FeS), nickel (black, NiS), cobalt (black, CoS), manganese (flesh-coloured, MnS), zinc (white, ZnS). Aluminium and chromium, given as salts of their oxides, R_2O_3, are precipitated by sulphide of ammonium as hydrated oxides ($Al_2O_3 . xH_2O$, colourless; $Cr_2O_3 . xH_2O$, green or violet). The reagent acts on these as ammonia, NH_3, the H_2S being liberated, and behaves in a similar way to acid solutions of certain salts, *e.g.*, the phosphates, of the following group D, these salts, *e.g.*, $Ca_3P_2O_8$, being precipitated as such. The ordinary salts of group D (barium, strontium, calcium, magnesium), and the salts of the alkali metals E (potassium, sodium, &c.) generally, give no precipitate with either sulphuretted hydrogen or sulphide of ammonium. It is easy to translate what we have stated into a method for the separation of groups A, B, C (D and E), from one another.

Of the three chlorides treated of in CHEMISTRY (vol. v. p. 501) only the lowest, S_2Cl_2, is of industrial importance. It is prepared by passing perfectly dry chlorine gas over heated sulphur contained in a retort, the retort being connected with a condenser constructed so that the uncondensed vapours are led away into the chimney. The two elements unite readily, and chloride of sulphur, S_2Cl_2, distils over, contaminated, however, by more or less of surplus chlorine present as higher chlorides. To remove (or decompose) these the crude product is subjected to fractional distillation; the thermometer rises rapidly and soon becomes constant (at about 136° under 758 mm. pressure). What afterwards distils over, at the constant boiling-point, is collected as pure S_2Cl_2,—a yellowish red liquid of 1·68 sp. gr. at 16°·7 C. and 1·7055 at 0° (Kopp), which emits fumes of hydrochloric acid in moist air. Its smell is charac-

[1] See SODIUM, "Le Blanc process for making soda-ash," p. 243 above.

teristic and unpleasant. Chloride of sulphur is decomposed by water, alcohol, ether (see CHEMISTRY); and benzol and bisulphide of carbon mix with it in all proportions without decomposition. A mixture of 100 parts of bisulphide of carbon and some 2·5 of chloride of sulphur is used for the vulcanization of (chiefly sheet) india-rubber. The mixture is readily imbibed by the rubber, which when allowed to dry (at from 22° to 25° C.) gives up the bisulphide of carbon and the chlorine of the reagent, the latter as HCl, but retains its sulphur in a state of chemical combination.

The gas SO_2 (see CHEMISTRY, vol. v. p. 501), produced extempore by the combustion of sulphur, is used for the bleaching of silk, wool, straw, and wicker work, also for the disinfection of rooms and of wine-casks (to prevent acetous fermentation). A solution of the gas in water is manufactured industrially, for use chiefly in the manufacture of sugar. It is added to the beetroot or cane juice to prevent its fermentation while awaiting concentration. A solution of "bisulphite of lime" (produced by saturating milk of lime with sulphurous acid gas) is much used as an antiseptic generally. Liquefied sulphur dioxide has found an application as a frigorific for the manufacture of ice. The apparatus used is so constructed that the volatilized sulphur dioxide is all caught and recondensed. Sulphurous acid when required as such or for the making of sulphites is always produced, even industrially, from oil of vitriol, by reduction with either sulphur or charcoal. In the heat the reactions are $2SO_4+S=3SO_2$ and $2SO_4+C=CO_2+2SO_2$ respectively, and either can be (and is) executed practically in cast-iron vessels. The presence of carbonic acid in the gas produced by the charcoal process does not interfere with the preparation of sulphites.

Thiosulphates.

The soda salt $Na_2S_2O_3+5H_2O$, known commercially as hypo-sulphite of soda, is used industrially for chiefly two purposes, namely, (1) as a solvent for chloride of silver in photography (see PHOTOGRAPHY),—$AgCl+Na_2S_2O_3=NaCl+AgNaS_2O_3$,—and (2) as an "antichlor" in paper-making, to destroy the remnants of chlorine in bleached paper pulp. To understand its action we need only know that chlorine and water in such cases act like oxygen,—$Cl_2+H_2O=2HCl+O$; every $4\times O$ thus produced converts one S_2O_2 of $Na_2OS_2O_3$ into $2SO_3$ of sulphuric acid. For the preparation of this salt a great many methods have been invented. The simplest to explain is the treatment of a solution of normal sulphite of sodium with sulphur,—$SO_3Na_2+S=S_2O_3Na_2$. Instead of adding free sulphur, Liebig prepares a solution of polysulphide of sodium (by dissolving sulphur in caustic-soda ley) and adds it to the sulphite. The surplus sulphur combines with the sulphite; besides, the poly-sulphide contains thiosulphate from the first. Another method is to pass sulphurous acid through a solution of sulphide of sodium. Here, by first intention, if we may say so, sulphite of sodium and H_2S are produced; but the H_2S and the excess of SO_2 give water and sulphur, and two-thirds of this sulphur unite with the sulphite first formed into thiosulphate. The crude sulphide of calcium, which is produced so largely in the Le Blanc process (see SODIUM, *supra*, p. 243), when exposed to the air gets oxidized, with formation of calcium thiosulphate, which can be extracted by means of water and converted into sodium salt by double decomposition with carbonate or sulphate of soda. Pure thiosulphate of soda forms large transparent monoclinic prisms, which lose no water on exposure to ordinary air in the cold. At about 48° C. they fuse into a liquid, which may remain liquid on cooling, but solidifies suddenly when a fragment of the solid salt is dropped in. 100 parts of water dissolve

at 16°	25°	35°	45° C.
65	75	89	109 parts of the salt (Mulder).

The solution is not subject to oxidation in the air.

Sulphuric acid.

The anhydride SO_3 is used largely in the manufacture of tar colours. Oil of vitriol is decomposed by dropping it on a mass of platinum scrap kept at a bright red heat within a fireclay retort,—$SO_4H_2=H_2O+SO_2+\frac{1}{2}O_2$; and, after removing the water—the bulk by partial condensation and the rest by means of vitriol—the sulphur dioxide and the oxygen are made to recombine by passing them over platinized asbestos at a dull red heat. The fumes of SO_3 formed are condensed in a dry receiver by application of cold from without (Winkler's process).

The fact that finely divided platinum, in virtue of its power of condensing oxygen, induces the union of SO_2 and $\frac{1}{2}O_2$ into SO_3 has been known for a long time; but all attempts to utilize the reaction for the production of sulphuric acid from a mixture of sulphur dioxide, air, and nitrogen produced by the combustion of sulphur or pyrites in air have failed. The platinum acts too feebly in the presence of the unavoidably large mass of nitrogen, and soon loses its efficacy altogether owing to the accumulation on it of particles of incombustible matter from the kiln gases. Oxide of chromium, Cr_2O_3, and oxide of iron, Fe_2O_3, act like platinum, through transitory formation of the respective sulphates—the gases produced in pyrites kilns include a considerable quantity of ready-made SO_3—but they also are not available practically for the making of sulphuric acid. In short, all attempts to produce this reagent otherwise than by means of the old Nordhausen or the chamber process have so far been unqualified failures industrially. In regard to the chamber process we may add a few notes to what has been said under CHEMISTRY (vol. v. p. 503 *sq.*). As stated in that article, nitrous acid, N_2O_3, when brought into contact with sufficiently strong vitriol unites with it, giving rise to bodies similar to chamber crystals,—

$$N_2O_3+H_2O+2SO_3=2SO_2\begin{matrix}OH\\NO_2\end{matrix};$$

or, what comes practically to the same,

$$N_2O_3+SO_3(\text{out of the vitriol})=SO_2\begin{matrix}NO_2\\NO_2\end{matrix}.$$

In the presence of sufficient water this union does not take place, because the water causes the product to break up as shown by the equation if read from right to left. These facts explain why a stronger acid than one containing some 60 per cent. or so of real H_2SO_4 cannot be produced directly in the chamber. This inconvenience has led, in the hands of Gay-Lussac, to an important improvement on the original process. He inserts between the chamber outlet and the chimney a tower made of acid-proof stone and filled with pieces of coke, over which concentrated oil of vitriol is made to trickle down while the chamber gases ascend through the tower on their way to the chimney. The vitriol absorbs all or most of the N_2O_3 which would otherwise be lost. But the practical reliberation of the N_2O_3 was beset with very great difficulties, which have been fully overcome only by a more recent invention of Glover's. He places between the kiln and the entrance side of the chamber a tower similar in construction to Gay-Lussac's, which the kiln gases have to traverse before they get into the latter. Through the tower he runs at the same time a stream of nitrated (Gay-Lussac) acid and one of ordinary chamber acid. The latter acts on the nitrated acid as water; at least it virtually sets free the combined nitrous acid, so that it is reduced by the sulphurous acid coming from the kiln to nitric oxide, which travels into the chamber with the rest of the gases to do duty there in the well-known manner. As the kiln gases are very hot, a considerable quantity of the water which goes through a Glover tower (as chamber acid) is volatilized and thus made to supply part of the steam necessary for the process. The Glover tower, besides fulfilling its primary object, serves to concentrate part of the chamber acid and to supply part of the necessary steam without expense for fuel. The expenditure of nitrate of soda, which before the introduction of the two towers used to amount to from 8 to 13 parts per 100 of sulphur burned, has been reduced to from 3·5 to 6·5. The actual loss of nitrous acid of course is the less, *cæteris paribus*, the larger the chamber, and (for a given chamber) the greater the care with which the process is conducted. But even under the most skilful management more nitrous acid is lost than can be accounted for by the unavoidable imperfections in the apparatus and in the mode of working them. From the investigations of Weber and of Frémy it appears that, in the presence of relatively much water more especially, part of the nitrous acid suffers reduction, not to nitric, but to nitrous oxide, N_2O, which being unsusceptible of direct oxidation, is lost for the process.

For a great many purposes (*e.g.*, the manufacture of "superphosphate" from bones or mineral phosphate of lime) the 60 to 64 per cent. acid which comes out of the chamber can be used as it is; but it is not strong enough for all purposes. In the production of acid stronger (from chamber) acid the first step always is to run the acid into long, very shallow lead pans and to simply boil it down in these, either by the application of heat from below, in which case the bottoms of the pans must be protected by making them rest on plates of iron, or by enclosing the pans in a vault and causing the hot gases of a furnace fire to strike along the surface of the acid. The result in either case is that, while more and more water goes away as steam, the residual acid of course gets stronger and stronger. But with the strength the boiling-point rises, and, as necessary consequences, the extent to which the acid attacks the lead (with formation of sulphate and sulphurous acid) and the danger of melting down the pans by local overheating become greater and greater. When the acid has come up to about from 78 to 80 per cent. (corresponding to a specific gravity of 1·7 after cooling), it is not safe to push the concentration any further, quite apart from the fact that an acid of 80 per cent. when boiled down emits a very appreciable proportion of acid along with the volatilized water. An acid of 1·7 indeed is amply strong enough for a variety of applications, such as, for instance, the conversion of salt into sulphate. If a stronger acid is wanted the concentration must be continued in glass or platinum retorts.

Protosulphate of iron.

The vitriol maker's glass retort, as a rule, consists of two detachable parts, namely, a pear-shaped body about 3½ feet high and nearly 2 feet in diameter, and a glass alembic whose wider end fits the mouth of the pear, while its narrower outlet end points downwards and terminates within a slightly slanting lead-pipe, which conveys the distillate to a leaden tank. The retort rests on a layer of sand contained in a closely fitting iron basin, and the lateral space between the two is filled completely with sand. The iron basin is suspended within a furnace in such a way that only it, and not any part of the retort, is touched directly by the flame. As a rule, some twelve retorts stand side by side, each in its own sandbath, and are heated by the same fire. As the temperature of the boiling liquid and of the vapour rises at the end to beyond 300° C., a sudden draught of cold air might cause rupture of a retort; the apparatus is therefore placed in a special room accessible only through double doors, and the inner door is not permitted to be opened before the outer has been shut. The acid, as it is boiling down, gets stronger and stronger, because, although the vapour is very strongly acid from the first, its percentage *p'* of real H_2SO_4 at any given stage is less than the value *p*, which obtains in the boiling liquid as it is at the time. *p'* at a given barometric pressure is a fixed function of *p* only, and increases as *p* increases; the difference *p*—*p'* accordingly gets less and less. It becomes nil, not when the acid has become pure H_2SO_4, but when it has come up to the composition $12SO_3+13H_2O$ (Marignac). This particular hydrate only boils without change of composition; even pure H_2SO_4 when distilled, by giving up more than $1SO_3$ for $1H_2O$, becomes reduced to that hydrate $12SO_3+13HO$, which then boils without further change of composition. A stronger acid than "Marignac," as we may call it, cannot be produced by the concentration of weaker acid, and even its production (from 1·7 acid) involves a very considerable loss of acid as distillate. Hence practically the process is stopped when the acid in the retorts has come up to some 96 per cent. of H_2SO_4, which is ascertained by the specific gravity of the last runnings being at a certain value. As soon as this point is reached the retorts are allowed to cool till the contents can be withdrawn with safety by means of lead siphons into glass carboys. This, however, means a considerable loss of time and fuel; besides, the process of distilling from out of glass vessels is not free from danger, and for these reasons it is preferred in many establishments to concentrate the pan acid in large platinum stills, although these are extremely expensive. The great advantage of the platinum still is that it admits of continuous working; while pan acid (containing say 1 lb of water per *N* lb of full strength—96 per cent. or so—acid) runs in, and a far weaker acid (containing for the same period of time 1 lb of water and *n* lb of full strength acid) is distilling over, the balance *N*—*n* lb of finished acid is being withdrawn by means of a platinum siphon. The outer limb of the siphon in its middle portion divides into a system of four narrower tubes and is cooled down by means of a cold-water jacket surrounding it, so that the acid can be run directly into carboys.

Platinum retort.

The platinum retort in its latest form has a large undulating bottom made of strong metal, on which a rapidly converging low body joins, made of thinner metal because it is not so directly exposed to the flame. Along with this still a flat platinum pan is used with an undulating bottom similar to that of the still for the preliminary concentration of the acid. As platinum is not liable to fuse or be attacked by any strength of boiling acid, a relatively small platinum pan does as much work as a far larger one made of lead.

Sulphates.

Several of these are treated of under the heads of the respective bases. Thus, for the sulphates of ammonia, see NITROGEN, vol. xvii. p. 515 *sq.*; for POTASSIUM and SODIUM, see these articles; for calcium, see LIME (vol. xiv. p. 648) and GYPSUM (vol. xi. p. 351); for barium, see BARYTES (vol. iii. p. 406); for magnesium, see EPSOM SALTS (vol. viii. p. 496) and MAGNESIUM (vol. xv. p. 217); and for iron, see COPPERAS (vol. vi. p. 352).

Sulphate of aluminium.

Sulphate of aluminium, $Al_2(SO_4)_3+18H_2O$, the active ingredient of ALUM (vol. i. p. 643), is now being produced industrially in a state of perfect freedom from iron, and is more and more taking the place of alum. Paper-makers, at least, no longer use anything else for the production of alumina soap, which in machine-made paper serves as the principal ingredient of the size. The crude salt is easily produced by treatment of relatively pure bauxite (native hydrated alumina) or china clay with chamber acid at a suitable temperature. The resulting mass is dissolved in water, the undissolved matter (silica, &c.) allowed to settle, the clear liquor drawn off, and from it an apology for what is wanted is obtained by evaporation to a small volume and allowing to crystallize. But the salt thus obtained is always contaminated with a variety of foreign sulphates, including sulphate of iron, and this last-named impurity, for the majority of applications, cannot be suffered to remain. One of the best methods for its removal, if not the best, is that discovered by Semper and Fahlberg: the solution, which must contain all its iron as ferric salt and contain somewhat less than the normal proportion of sulphuric acid, is digested with hydrated binoxide of lead. In the course of about a week all the iron is completely precipitated. The better qualities of sulphate of alumina nowadays have at most only a few thousandths per cent. of iron.

Sulphate of copper.

Sulphate of copper (blue vitriol) is made technically in chiefly two ways. One method is to heat metallic copper to redness in air until it is almost completely oxidized, and to dissolve the oxide by means of dilute sulphuric acid. The Cu_2O present behaves like a mixture of metal and CuO. Another process starts from the sub-sulphide Cu_2S (produced metallurgically as "mat," or perhaps expressly from its elements), and converts this into sulphate and oxide by careful roasting. The product is dissolved in dilute sulphuric acid. Large quantities of blue vitriol are produced incidentally in the "parting" of auriferous silver (see GOLD, vol. x. p. 749) by means of oil of vitriol. Sulphate of copper crystallizes from its aqueous solution in large transparent blue crystals of the triclinic system; their composition is $CuSO_4.5H_2O$. The crystals are stable in the air. At 100° C. they lose $4H_2O$, the last H_2O requiring a temperature of 200° C. for its expulsion. The anhydrous salt is dirty white; it readily reunites with water, and consequently is available as a dehydrating agent, for instance, for the preparation of absolute alcohol from spirit of wine. 100 parts of water dissolve at

0°	10°	20°	50°	100° C.
31·6	37·0	42·3	65·8	203·3 parts of crystallized salt (Poggiale).

The salt is insoluble in alcohol. Blue vitriol is used largely in electrotyping and for many other purposes.

Subjoined are two general tests for sulphur. (1) All sulphur compounds when brought in contact at a red heat with a mixture of nitre and carbonate of soda (or some other equivalent alkaline oxidizing mixture) are changed so that the sulphur assumes the form of alkaline sulphate, which can be extracted by means of water. From the (filtered) solution the SO_4 is precipitated by addition of chloride of barium as $BaSO_4$,—a white powdery precipitate characteristically insoluble in water and in dilute acids. (2) Any non-volatile sulphur compound, when heated on charcoal in a reducing flame with carbonate of soda, yields sulphide of sodium ("hepar"), which, when moistened with water on a silver coin, produces a black stain of metallic sulphide. (Compare SELENIUM, vol. xxi. pp. 631-632.) (W. D.)

SULPICIUS SEVERUS. See SEVERUS.

SULTÁNPUR, or SULTANPOOR, a district of British India, in the Rái Bareli (Roy Bareilly) division of Oudh, under the jurisdiction of the lieutenant-governor of the North-Western Provinces, lying between 26° 39′ and 27° 58′ N. lat. and 81° 36′ and 82° 44′ E. long. With an area of 1707 square miles, it is bounded on the N. by Faizábád, on the E. by Jaunpur, on the S. by Partábgarh, and on the W. by Rái Bareli. The surface of the district is generally level, being broken only by ravines in the neighbourhood of the rivers by which its drainage is effected. The central portion of the district is highly cultivated, while in the south are widespread arid plains and swampy jhils and marshes. The principal river is the Gumti, which passes through the centre of Sultánpur and affords a valuable highway for commerce. Minor streams are the Kándu, Pili, Tengha, and Nandhia, the last two being of some importance, as their channels are deep, though narrow, and form the outlet for the superfluous water of the extensive series of jhils. There are no forests in the district, the only tree-covered tracts being stunted *dhák* jungles used for fuel. Wild animals are very few, chiefly wolves, nylghau, and wild hog. There are some good roads in the district, chief of which is the imperial high road from Faizábád to Allahábád, which intersects it from north to south. The Oudh and Rohilkhand Railway traverses the district for a few miles in the extreme east. The climate is considered mild, temperate, and healthy; the average annual rainfall is about 46 inches.

The population, according to the census of 1881, was 957,912 (males 475,125, females 482,787), of whom 856,329 were Hindus and 101,524 Mohammedans. The only town with a population exceeding 5000 is Sultánpur, the administrative headquarters of the district, which is situated on the right bank of the Gumti, and in 1881 contained 9374 inhabitants. Of the total area 571,795 acres were returned as cultivated in 1884-85 and 368,911 as cultivable; the total area under crops in the same year was 672,058 acres, wheat and rice being the principal products. The trade of the district deals principally with grain, cotton, molasses, and native cloth, and its manufactures—which, however, are unimportant—comprise coarse cotton cloth, brass vessels and other metal work, sugar, and indigo. The only incident worthy of note in the history of the district since the British annexation of Oudh is the revolt of the native troops stationed at Sultánpur during the mutiny. The troops rose in rebellion on 9th June 1857, and, after firing on and murdering two of their officers, sacked the station. Upon the restoration of order Sultánpur cantonment was strengthened by a detachment of British troops; but in 1861 it was entirely abandoned as a military station.

SULU ISLANDS. See PHILIPPINES, vol. xviii. p. 752.

SUMACH. See LEATHER, vol. xiv. p. 382.