when it separates in the form of white crystals, which melt at 10∙5°, and on gentle heating evolve sulphur trioxide and again form the same hydrate. When strong sulphuric acid is mixed with water there is a great development of heat; the heat evolved when four parts of acid are mixed with one of water being sufficient to raise the temperature from 0° to 1oo° C. (Hence the laboratory precaution of always adding the acid to the water and not the water to the acid.) In addition to the heat evolu­tion there is also a diminution in volume, the maximum occurring when the components are present in the ratio H2SO4:2H2O, thus pointing to the existence of a hydrate H2SO4,2H2O. A second hydrate, H2SO4,H2O, may be obtained as rhombic crystals, which melt at 7° and boil at 2050, by diluting the strong acid until it has a specific gravity of 1∙78, and cooling the mixture; this compound is sometimes known as *glacial sulphuric acid.* Both the mono- and di-hydrates form freeing mixtures with snow. Other hydrates have also been described.

*Reactions.—*Sulphuric acid has the widest commercial application of all chemical reagents. Here only reactions of commercial utility will be considered, and reference should be made to the article Sulphur for reactions which are more of a purely scientific interest. In inorganic chemistry its principal applications are based on its solvent power for metals, and its power of expelling other acids from their salts. In the first group we have to notice the use of iron or zinc and dilutesulphuric acid for the manufacture of hydro­gen, which may be used directly, as for inflating balloons or for purposes of combustion, or in the *nascent* condition, for reduction purposes, as generally is the case in organic chemistry (see Aniline). It is worthy of notice that while many metals dissolve in cold dilute sulphuric acid, with the liberation of hydrogen, in accordance with the typical equation: M + H2SO, = MSO4 + H2 (M denoting one atom of divalent or two atoms of a monovalent metal), there are several (copper, mercury, antimony, tin, lead and silver) which are insoluble in the cold dilute acid, but dissolve in the hot strong acid with evolution of sulphur dioxide, thus: M + 2H22SO4= MSO4 + SO2 + 2H2O. Carbon decomposes hot strong sulphuric acid on long continued boiling, with the formation of carbon dioxide and sulphur dioxide. The power which sulphuric acid exhibits for expelling other acids from their combinations, a power occasioned by its comparative involatility and high degree of avidity, forms the basis of a considerable number of commercial processes. Hydro­chloric, hydrobromic, hydriodic, hydrofluoric, nitric, phosphoric and many other acids are manufactured by the action of sulphuric acid on their salts; the alkali and chlorine industries, and also the manufacture of bromine and iodine, employ immense quantities of this acid.

In organic chemistry sulphuric acid is extensively employed. Its powerful affinity for the elements of water makes it a valuable dehydrating and condensation agent. It extracts the elements of water from formic acid, giving carbon monoxide; from oxalic acid, giving a mixture of carbon monoxide and dioxide; from alcohol, to give ether or ethylene according to the conditions of the experi­ment; and from many oxygenated compounds (e.g. sugar, tartaric acid, &c.), with the production of charred masses. The formation of esters and ethers are generally facilitated by the presence of this acid. It also acts in an opposite manner in certain cases, *adding* the elements of water to compounds; thus, nitriles are converted into acid-amides, and various acetylene derivatives may be caused to yield ketonic derivatives. As an oxidizing agent its application is limited. The transformation of piperidine into pyridine by W. Königs, and the observation that anthraquinone yielded oxyanthraquinones when treated in the cold with strong sulphuric acid, and the recent introduction of fuming sulphuric acid for the oxidation of naphthalene to phthalic acid, a process of great value in the manufacture of artificial indigo, may be noted. But its chief technical application depends upon the formation of sulphonic acids when it reacts with aromatic hydrocarbon residues; these compounds being important either as a step towards the preparation of hydroxy-compounds, *e.g.* resorcin, the naphthols, alizarin, &c., or for preparing dye-stuffs in a more soluble form.

*Sulphates.—*Sulphuric acid, being a dibasic acid, forms two series of salts with monovalent metals: an acid sulphate, MHSO<, and a normal sulphate, M2SO4, Acid sodium sulphate, NaHSO4, has been employed in the manufacture of sulphur trioxide. When heated it loses water to form sodium pyrosuíphate, Na2S2O7, which on treatment with sulphuric acid yields normal sodium sulphate and sulphur trioxide. The normal sulphates are the more impor­tant, and occur widely and abundantly distributed in the mineral kingdom; anhydrite, gypsum, anglesite, barytes, celestite and kieserite are among the commonest species. As a general class, the sulphates are soluble in water, and exhibit well crystallized forms. Of the most insoluble we may notice the salts of the metals of the alkaline earths, barium, strontium and calcium, barium sulphate being practically insoluble, and calcium sulphate sparingly but quite appreciably soluble. Lead sulphate is very slightly soluble in water, soluble in strong sulphuric acid, and almost insoluble in alcohol.

Sulphates may be detected by heating the salt mixed with sodium carbonate on charcoal in the reducing flame of the blowpipe; sodium sulphide is thus formed, and may be identified by the black stain produced if the mass be transferred to a silver coin and then moistened. In solution, sulphates are. always detected and estimated by the formation of a white precipitate of barium sulphate, insoluble in water and all the common reagents.

*Manufacture.—*The first step in its manufacture is the com­bustion of sulphur. Formerly this was employed exclusively in the free state as brimstone, and this is still the case to a considerable extent in some countries, notably in the United States, but the great bulk of sulphuric acid is now made from metallic sulphides, especially those of iron and zinc Most of the brimstone of trade comes from Sicily, but in the United States Louisiana sulphur is playing an important part, and seems likely to oust the Sicilian sulphur. Free sulphur is also contained as “ gas sulphur ” in the “spent oxides ” of gasworks, which are actually utilized for the manufacture of sulphuric acid. Sulphur is also recovered in a very pure state from the “ alkali waste ” of the Leblanc process, but this "recovered sulphur” is too expensive to be burned for the purpose in question. In the United Kingdom much gas sulphur is used for the manufacture of sulphuric acid, together with a limited quantity of Sicilian sulphur for the production of sulphuric acid free from arsenic.

A much larger percentage of the sulphuric acid is made from pyrites, *i.e.* more or less pure disulphide of iron, which occurs in large quantities in many countries. Great Britain produces very little of it, Ireland a little more, but of poor quality. Most oí the pyrites consumed in the United Kingdom come from Spain; this Spanish pyrites generally (not always) contains enough copper (say 3 or 4%) to make its extraction from the residues (" cinders ”) a paying process, and this of course cheapens the price of the sulphur to the acid manufacturer. Spain also supplies much pyrites to Germany, France and America, all of which countries are them­selves producers of this ore. Sweden and Norway are exporters of it to all these countries. Good pyrites contains from 48 to 50%, exceptionally up to 52 % of sulphur, of which all but from 1 to 4% is utilized when burning the ore. Another metallic sulphide, blende, ZnS, is of importance for Germany, Belgium and the United States, much less so for the United Kingdom, as a source of sulphur. Blende contains only about half as much sulphur as good pyrites, and this cannot be burned off as easily as from pyrites, but this “ roasting ” has to be done somehow in any case in order to prepare the ore for the extraction of the zinc.

Brimstone is easily burned without any extraneous help; indeed the only precaution required is to take care lest the heat produced by the burning sulphur should not volatilize part of it in the un­burned state. This can never be entirely avoided, and sometimes causes trouble in the succeeding apparatus.

The roasting of pyrites always takes place without using any extraneous fuel, the heat given off by the oxidation of the sulphur and the iron being quite sufficient to carry on the process. If the ore is in pieces of the size of a walnut or upwards, it is roasted in plain “ kilns " or “ burners,” provided with a grating of suitable construction for the removal of the cinders, with a side door in the upper part for charging in the fresh ore on the top of the partially burned ore, and with an arch-shaped roof, from which the burner-gas is carried away in a flue common to a whole set of kilns. The latter arc always set in a row\* of twelve or more, and are one after another charged once or twice a day at appropriate intervals, so that a regular evolution of gas takes place all the day round. By employing suitable precautions, a gas of approximately uniform composition is obtained, containing from 6 to 8 % sulphur dioxide, SO2, with a little trioxide, SO2, and about 12% of oxygen, which is more than sufficient for converting later all the SO2 into SO2 or H2SO4. The burning of " smalls ”or“ dust " was formerly considered much more difficult and incomplete than that of pieces, but this difficulty has been entirely overcome in various ways, principally by the “ shelf-burner,” originally constructed by E. Malétra, and mechanical burners, which were formerly almost entirely confined to America, where the saving of labour is a primary consideration. The first really successful mechanical pyrites-burner was constructed many years ago by MacDougall Bros, of Liverpool. The drawbacks still present in this burner caused it to be abandoned after a few years, but they have since been overcome by several recent inventors, principally American. The Hereshoff burner has been most widely introduced, both in America and in European countries. The roasting of blende is nothing like so easy as that of pyrites, since the heιt developed by the oxidation of the zinc sulphide itself is not sufficient for carrying on the process, and external heat must be applied. It is now usually performed by a series of muffles, super­posed one over another, so that the whole forms a kind of shelf­burner, with internally heated shelves (the “ Rhenania ” furnace). This operation is both more costly and more delicate than the roasting of pyrites, but it is now perfectly well understood, and gas is. obtained from blende furnaces hardly inferior in quality to that yielded by pyrites kilns. In America, and quite exceptionally also in Europe, mechanical furnaces are used for the roasting of blende.