

According to the most reliable data pure metallic vanadium is a hard white lustrous metal. It is the hardest of metals, its hardness being above 7 on the mineralogists's scale. It is not scratched by quartz or steel. It is not magnetic. The density of perfectly pure vanadium is not known, but Moissan's vanadium containing about 5 per cent. carbon possessed a specific gravity of 5.8, and the hydrogen-containing material of Roscoe a specific gravity of 5.5. According to Mache its specific heat between zero and one hundred degrees is 0.1153. Smith reported its melting point to be above 2000°C., and Moissan said that although it would melt in his electric furnace it took a higher heat than any other metal, but it is now known pretty definitely from the work of Werner von Volton and others that the melting point is not so high, about 1680° being near the right temperature. His data were obtained from photometric measurements of great accuracy. Its atomic weight is 51 in round numbers.

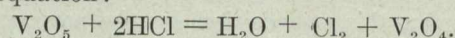
The most noteworthy general chemical property of the metal is the great number of compounds to which it gives rise and the extraordinary readiness with which it combines with most elements. When not heated it does not oxidize readily in the air, and preserves a bright lustre for weeks at a time, but very little heat will cause it to take on a coating of vanadium pentoxide, V_2O_5 . According to Chilesotti, hydrochloric, hydrobromic and cold sulphuric acids and potassium hydroxide have no effect on the metal. Hot sulphuric acid and hot solutions of potassium hydroxide attack it readily, and it dissolves rapidly in nitric acid and aqua regia forming green solutions. It alloys readily with iron, nickel, cobalt, copper, aluminum, tin, platinum and other metals. It also forms binary compounds with silicon, phosphorus, nitrogen and carbon, and possibly with hydrogen. Colloidal vanadium has been obtained by Svedberg by his usual method, using some of the higher alcohols (e.g. isobutyl) as the solvent, and these solutions, which are dark brown in color, are stable for several weeks.

Vanadium forms five well defined oxides. These are the pentoxide, V_2O_5 , often alluded to as vanadic acid, the tetroxide V_2O_4 , the trioxide V_2O_3 , and the lower oxides VO and V_2O . Each of these except the last forms series of salts with acids, and two of them form acids which give rise to vanadates and vanadites and a host of more complex compounds. When vanadium can find nothing else to combine with it combines with itself, and vanadates of the radical (VO) called vanadyl are well known. The nomenclature of these various oxides and their compounds is very unsettled, and the best that can be done is to refer the reader to Gmelin-Kraut, Bd. III. Ab. 2, page 73 et seq., where the whole matter is discussed at length. Other intermediate oxides have been reported, but they probably are mixtures of those listed above.

The interesting thing about these oxides is the ease with which one is converted into the other, especially in the case of the tetroxide and pentoxide. Vanadium pentoxide is reduced to tetroxide and again takes up oxygen from any oxidizing agents present with such rapidity, that this catalytic power has been much studied and some practical applications made of it. The most satisfactory black dye for fabrics is aniline black, and this black is made by the oxidation of aniline hydrochloride with various oxidizing agents, potassium chloride being the commonest. In order to make the reaction proceed with sufficient velocity for commercial purposes copper salts were added. Lightfoot, an English dye works chemist, tried salts of various

elements and found that many of them possessed the property of accelerating this reaction, and that copper was superior to all the elements except vanadium, but when they tried vanadium they found almost infinitesimal traces of this element would turn immense quantities of aniline solution into aniline black. Since that time this catalytic property of the salts of vanadium has been the subject of much study and it is quite unique. In addition to its application in dyeing it has been used in medicine and no doubt will find many other applications.

The only one of the compounds of vanadium which requires detailed description in such an article as this is the pentoxide. It exists in several modifications, a crystalline one which is almost insoluble in water, and two amorphous modifications, one of which dissolves in water, but with difficulty, and the other readily. This last solution is now thought not to be a true solution, but a colloidal one. This acid dissolves in concentrated sulphuric acid giving deep red solutions. When these solutions are diluted with water they turn green, owing to a partial reduction of the vanadium pentoxide to tetroxide. With concentrated HCl it forms green solutions and gives off chlorine, according to the equation:



In alkalies it dissolves and forms alkaline vanadates of which potassium vanadate, KVO_3 is a type. Ammonium vanadate is insoluble and ammonium metavanadate NH_4VO_3 is the commonest commercial salt of vanadium, and from it vanadium pentoxide is prepared by calcination.

Although a great deal of work has been done on the compounds of vanadium there still remain innumerable points to be cleared up, many of which would lead to remarkable improvements in the methods of extracting the metal from its ores, for the metallurgist who essays to invent a hydrometallurgical treatment for any of the vanadium ores to be found in America is continually hampered by the inadequate data regarding the reactions of the element. Up to the present only a few chemists have been in a position to obtain vanadium salts in large enough quantities to work with the element; but now that these salts can be got comparatively cheaply and of great purity, it is to be hoped some of the mysteries surrounding the chemistry of the element will be cleared up. There has also been a tendency to attribute an inherent waywardness to the reactions of this element. The author has often heard the remark made, "Well, if it wasn't vanadium we might expect such and such things, but no one knows what vanadium will do—it never does the same thing twice." Now, we all know that such talk, even if in fun, is wrong, for vanadium no less than any other element is amenable to ordinary laws of chemistry. Under the same conditions it will give the same reactions at all times and in all places. Only these reactions may be so complex that changes in conditions which would not interfere with the reactions of other more easily handled elements will here be of great importance, and this fact must be heeded. In the next section of this article we will deal with the metallurgical properties of vanadium, and with vanadium-steels. A reference list of a few of the more important contributions to the literature of the subject is appended.

Bibliography.

Abegg.—Handbuch der anorganischen Chemie Bd. III, 3, pgs. 683-788.