In its chemical relations, titanium is generally tetravalent, and occurs in the same sub-group of the periodic classification as zirconium, cerium and thorium. It forms several oxides, TiO2, Ti2O3 and TiO3 being the best known; others (some of doubtful existence) have been described from time to time.

*Titanium dioxide,* TiO2, occurs in nature as the three distinct mineral species rutile, brookite and anatase. Rutile assumes tetragonal forms isomorphous with cassiterite, SnO2 (and also zircon, ZrSiO4; anatase is also tetragonal, and brookite or thorhombic. Rutile is the most stable and anatase the least, a character reflected in the decrease in density from rutile (4∙2) and brookite (4·0) to anatase (3∙9). The minerals are generally found together—a feature rarely met with in the case of polymorphs. They have been obtained artificially by Hautefeuille by the interaction of titanium fluoride and steam. At a red heat rutile is produced, at the boiling point of zinc brookite, and of cadmium anatase. It is apparent that these minerals all result in nature from pneumatolytic action. Amorphous titanium oxide may be obtained in a pure form by fusing the mineral, very finely powdered, with six times its weight of potassium bisul­phate in a platinum crucible, then extracting the melt with cold water and boiling the filtered solution for a long time. Titanic oxide separates out as a white hydrate, which, however, is generally contaminated with ferric hydrate and often with tin oxide. A better method is Wohler’s, in which the finely powdered mineral is fused with twice its weight of potassium carbonate in a platinum crucible, the melt powdered and treated in a platinum basin with aqueous hydrofluoric acid. The alkaline titanate first produced is converted into crystalline fluotitanate, K2TiF6, which is with difficulty soluble and is extracted with hot water and filtered off. The filtrate, which may be collected in glass vessels if an excess of hydrofluoric acid has been avoided, deposits the greater part of the salt on cooling. The crystals are collected, washed, pressed and recrystallized, whereby the impurities are easily removed. The pure salt is dis­solved in hot water and decomposed with ammonia to produce a slightly ammoniacal hydrated oxide; this, when ignited in platinum, leaves pure TiO2 in the form of brownish lumps, the specific gravity of which varies from 3∙9 to 4∙25, according to the temperature at which it was kept in igniting. The more intense the heat the denser the product. The oxide is fusible only in the oxy-hydrogen flame. It is insoluble in all acids, except in hot concentrated sulphuric, when finely powdered. If the sulphuric acid solution be evaporated to dryness the residue, after cooling, dissolves in cold water. The solution, if boiled, deposits its titanic oxide as a hydrate called meta- titanic acid, TiO(OH)2, because it differs in its properties from ortho- titanic acid, Ti(OH)4, obtained by decomposing a solution of the chloride in cold water with alkalis. The ortho-body dissolves in cold dilute acids; the meta-body does not. If titanic oxide be fused with excess of alkaline carbonate a titanate, R2TiOj, is formed. This salt is decomposed by water with the formation of a solution of alkali free of titanium, and a residue of an acid titanate, which is insoluble in water but soluble in cold aqueous mineral acids. The titanates are very similar to the silicates in their tendency to assume complex forms, *e.g.* the potassium salts are K2TiO3∙4H2O, K2Ti3O7∙3H2O and K2Ti6O3·2H2O.

*Titanium monoxide,* TiO, is obtained as black prismatic crystals by heating the dioxide in the electric furnace, or with magnesium powder. *Titanium sesquioxide,* Ti2O2, is formed by heating the dioxide in hydrogen. A hydrated form is prepared when a solution of titanic acid in hydrochloric acid is digested with copper, or when the trichloride is precipitated with alkalis. *Titanium trioxide,* TiO3, is obtained as a yellow precipitate by dropping the chloride into alcohol, adding hydrogen peroxide, and finally ammonium carbonate or potash. When shaken with potash and air it undergoes autoxidation, hydrogen peroxide being formed first, which converts the trioxide into the dioxide and possibly pertitanic acid; this acid may contain sexavalent titanium (see W. Manchot and Richter, *Ber.,* 1906, 39, pp. 320, 488, and also Faber, *Abst. Journ. Chem. Soc.* 1907, ii. 557.)

*Titanium fluoride,* TiF4*,* is a fuming colourless liquid boiling at 284°, obtained by distilling a mixture of titanium oxide, fluorspar and sulphuric acid; by heating barium titanofluoride, BaTiF6 (Emrich, *Monats.,* 1904, 25, p. 907) ; and by the action of dry hydro­fluoric acid on the chloride (Ruff and Plato, *Ber.,* 1904, 37, p. 673). By dissolving the dioxide in hydrofluoric acid a syrupy solution is obtained which probably contains titanofluoric acid, H2TiF6. The salts of this acid are well known; they are isomorphous with the silico-, stanno- and zircono-fluorides. They are obtained by neutral­izing the solution of the acid, or by fusing the oxide with potassium carbonate and treating the melt with hydrofluoric acid. Potassium titanofluoride, K2TiF6∙H2O, forms white, shining, monoclinic scales. When ignited in a current of hydrogen it yields *titanium trifluoride,* TiFs, as a violet powder.

*Titanium chloride,* TiCl4, is obtained as a colourless fuming liquid of 1∙7604 sp. gr. at 0° C., boiling at 136∙4° under 753·3 mm. pressure (T. E. Thorpe), by heating to dull redness an intimate dry mixture of the oxide and ignited lamp-black in dry chlorine. In the method of A. Stabler and H. Wirthwein, the titanium mineral is fused with carbon in the electric furnace, the carbides treated with chlorine, and the titanium chloride condensed. The distillate is freed from vanadium by digestion with sodium amalgam. Other methods are due to E. Vigoureux and G. Arrivaut *(Abst. Journ. Chem. Soc.,* 1907, ii. 97, 270) and Ellis (ibid., p. 270). By passing chloroform vapour over the heated dioxide the tetra- di- and tri-chlorides are formed, together with the free metal and a gaseous hydride, TiH4 (Renz, *Ber.,* 1906, 39, p. 249). When dropped very cautiously into cold water it dissolves into a clear solution. According to the amount of water used, TiCl3OH, TiCl2(OH)2, TiCl(OH)3 or titanic acid is formed. The solution when boiled deposits most of its oxide in the meta-hydrate form. It forms addition compounds similar to those formed by stannic chloride, and combines with ammonia to form TiCl4·8NH3 and TiCl4∙6NH2, both of which with liquid ammonia give titanamide, Ti(NH2)4. *Titanium dichloride,* TiCl2, obtained by passing; hydrogen over the trichloride at a dull red heat, is a very hygroscopic brown powder which inflames when exposed to air, and energetically decomposes water. *Titanium trichloride,* TiCl3, forms involatile, dark violet scales, and is obtained by passing the vapour of the tetrachloride mixed with hydrogen through a red-hot tube, or by heating the tetrachloride with molecular silver to 200°. It is a powerful reducing agent.

*Titanium tetrabromide,* TiBr4, is an amber-coloured crystalline mass. The *tetraiodide,* Til4, is a reddish brown mass having a metallic lustre. The *di-iodide,* Til2, is obtained as black lamella by passing the vapour of the tetraiodide over heated mercury in an atmosphere of hydrogen (E. Defacqz and H. Copaux, *Compt. rend.,* 1908, 147, p. 65). Sulphides are known corresponding to the best- known oxides.

*Titanium sesquisulphate,* Ti2(SO4)3∙8H2O, obtained by concentrat­ing the violet solution formed when the metal is dissolved in sulphuric acid, is interesting since it forms a caesium alum, CsTi(SO4)2·12H2O. It gives the normal sulphate as a yellow, deliquescent, amorphous mass when treated with nitric acid.

Acid solutions of titanates are not precipitated by sulphuretted hydrogen ; but ammonium sulphide acts on them as if it were ammonia, the sulphuretted hydrogen being liberated. Titanium oxide when fused with microcosmic salt in the oxidizing flame yields a bead which is yellowish in the heat but colourless after cooling. In the reducing flame the bead becomes violet, more readily on the addition of tin; in the presence of iron it becomes blood-red. Titanic oxides when fused on charcoal, even with potassium cyanide, yield no metal. Rose determined the atomic weight to be 47∙72 (H=1). A redetermination in 1885 by T. E. Thorpe gave the value 47∙7 (see *Journ. Chem. Soc.,* 1885, p. 108).

TITANOTHERIIDAE (also known as Menodontidae and Brontotheriidae), a family of large rhinoceros-like perissodactyl ungulate mammals from the Oligocène and Eocene strata of North America. The cheek-teeth are low-crowned, with the external cones of the upper molars fused into a W-like outer wall, and the inner ones retaining a regular conical form; while in the lower teeth the crown is formed of crescentic ridges, of which there are three in the last and two each in the other teeth. There is generally little gap between the canines and the premolars.

*Tilanotherium,* of the Oligocene of the Dakotas and neighbour­ing districts, was a huge beast, with the hinder upper premolars similar in character to the molars, a pair of horn-cores, arising from the maxilla, overhanging the nose-cavity, four front and three hind toes, only twenty dorso-lumbar vertebrae, and an almost continuous and unbroken series of teeth, in which the canines are short; the dental formula being *i.* 2/1, *c.* 1/1, *p.* 4/4, *m.* 3/3. The muzzle probably formed a snout in life; and there is presumptive evidence that these animals were very long-lived. *Brontops* seem scarcely separated from the type genus; but the name *Brontotherium* is applied to species with two pairs of incisor teeth in both jaws. The length of the largest species was about 14 ft.; and the height about 8 ft. The alleged occurrence of remains of members of the group in the Balkans apparently rests on insufficient evidence.

A second group is typified by *Palaeosyops,* of the Bridger Eocene of North America; *P. paludosus* being an animal about the size of a tapir. The skull, which has a longer face than in *Titanotherium,* lacks horn-cores, while all the upper premolars are simpler than the molars, and the full series of 44 teeth was present. The limbs were relatively slender, and the brain was small. In the lower, or Wasatch, Eocene the group was represented by the still more primitive *Lambdotherium.* On the other hand, *Palaeosyops* is connected with *Titanotherium* by means of *Telmatotherium* of the upper