# SPECIFIC GRAVITY AND COMPOSITION IN IRON-RUTILE

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Schaller, in his study of the rutile group,[1] has shown that the iron-rutiles, known as "nigrine" and "iserite,"[2] are isomorphous mixtures of two tetragonal end members, titanyl titanate, $TiOTiO_3$, or rutile; and ferrous titanate, $FeTiO_3$, which is unknown as a mineral species, altho its rhombohedral form, ilmenite, is well known. From a study of six analyses, Schaller concluded that the specific gravity of the hypothetical $FeTiO_3$ could be determined no more definitely than as $5 \pm 0.25$. His calculations of the sp. gr. of ferrous titanate were obtained by assuming a value (4.20) for that of rutile; and from the percentage, by weight, of $FeTiO_3$, determining its sp. gr. from those of the several isomorphous mixtures. In this way he obtained the values: (1) 5.3; (2) 5.1; (3) 5.3; (4) 5.0; (5) 5.4; (6) 4.74 for the density of ferrous titanate; determined from iron-rutiles containing respectively: (1) 8.0; (2) 12.8; (3) 18.8; (4) 31.0; (5) 30.0; and (6) 64.0 per cent. by weight of $FeTiO_3$.[3] Two of the analyses which he used seem inaccurate, and not suited for calculation.[4]

The object of the present paper is a study of the iron-rutiles, with special reference to the sp. gr. of the two end members of this isomorphous series. Those respective sp. grs. of titanyl and of ferrous titanates, which together give the closest agreement between calculated and observed sp. gr. of the isomorphous mixtures, have been determined by the method of least squares. The sp. gr. of each mixture was calculated by the following formula:[5]

$$D = d + a(d' - d)/100,$$

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[1] Schaller, W. T. A Study of the Rutile Group. U. S. Geol. Survey *Bull.* **509**, 9–39, 1912.

[2] Schaller proposes that the names nigrine and iserite should be discarded, as the minerals bearing them have no claim to specific rank. Instead, they should be described as iron-rutiles. Iserite should not be confused with the rhombohedral "iserine," at times also called iserite. [The editor would prefer to call these minerals *ferriferous rutiles.*]

[3] The first, second, third, and sixth of these correspond respectively to analyses 5, 4, 6, and 7 in table 1.

[4] These are respectively the fourth and fifth of those mentioned above, and are from Ohalpian, Transylvania (Rammelsberg, *Mineralchemie* 1009, 1860) and Barien (Müller).

[5] Groth, P. and Marshall, H. *Chemical Crystallography*, 90, 1906.

in which D is the density (or sp. gr.) of the isomorphous mixture (which is to be determined), d and d′ the densities of the two end members, and a the volume percentage of the second substance present in the mixture.

Seven apparently dependable analyses of rutile, accompanied by determinations of sp. gr., were found by the author. Of these, four had been used by Schaller in his discussion of the series; the two inaccurate analyses mentioned above were not further considered. Table 1 gives those used in this investigation, arranged in order of increasing specific gravity.

TABLE 1. ANALYSES OF RUTILE

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| $TiO_2$.......... | 97.60 | 98.47 | 96.75 | 91.96 | 94.93 | 89.49 | 70.03 |
| $Fe_2O_3$.......... | 1.55 | 0.72 | 2.40 | 6.68 | —— | 11.03 | —— |
| FeO.......... | —— | —— | —— | —— | 3.77 | —— | 28.77 |
| $SnO_2$.......... | —— | —— | —— | 1.40 | —— | —— | —— |
| MgO.......... | —— | —— | —— | —— | —— | 0.45 | —— |
| $SiO_2$.......... | —— | —— | —— | —— | 1.37 | —— | —— |
| $H_2O$.......... | —— | —— | —— | —— | 0.71 | —— | —— |
| Sum.......... | 99.15 | 99.19 | 99.15 | 100.04 | 100.78 | 100.97 | 98.80 |
| Sp. gr.......... | 4.209 | 4.240 | 4.242 | 4.249 | 4.288 | 4.410 | 4.520 |

1. St. Yrieix, Haute-Vienne, France. Damour, *Ann. chim. phys.* **10**, 414, 1844. Deville (*Compt. rend.* **53**, 161, 1861), found 0.32% $V_2O_5$, 0.49% $MoO_3$, and a trace of $SnO_2$ in rutile from this locality.
2. Villeneuve-en-Montagne, Saone-et-Loire. France. Virlet, *Bull. soc. géol. France* **3**, 25, 1846.
3. Freiberg, Saxony. Kersten, *J. prakt. Chem.*, **37**, 170, 1846.
4. El Paso Co., Colo. Genth and Penfield, *Am. J. Sci.*, [4] **44**, 384, 1892.
5. St. Peter's Dome, Colo. Smith, *Proc. Colo. Sci. Soc.*, **2**, 175, 1887.
6. Bernau, Bavaria. Rammelsberg, *Mineralchemie*, 1008, 1860.
7. Iser, Bohemia. ("Iserite") Janovsky, *Sitzb. Ak. Wiss. Wien*, **80**, 34, 1886.

In those analyses in which iron had been determined in the ferric condition, $Fe_2O_3$ was converted to FeO, assuming that the mineral was pure. FeO and $TiO_2$ were recalculated to 100%; this does not materially affect the calculated sp. grs., since the proportion of impurities is small, and for the whole series those impurities causing an increase and those causing a decrease in sp. gr. practically balance each other. From the percentages of FeO and $TiO_2$ those of $FeTiO_3$ and $TiOTiO_3$ were calculated, and the percent. by weight of $FeTiO_3$ was converted to percent. by volume. The sp. gr. for each analyzed rutile was calculated as explained above. It was found that the closest agreement between calculated and observed sp. grs. was obtained when that of $TiOTiO_3$ was taken as 4.23, and that of $FeTiO_3$ as 4.77.

The method used for arriving at these values for the end-members was as follows: Preliminary trial having shown that Schaller's value for rutile was slightly too low, and that for the ferrous titanate decidedly too high, calculations were made with three different values for rutile, 4.22, 4.23, and 4.24; and five for $FeTiO_3$, 4.75, 4.76, 4.77. 4.78, and 4.79. The differences between the observed sp. grs. and those calculated from each pair of values were determined; and the sum of the squares of these differences was obtained, as given in table 2.

TABLE 2. VALUES OF $\Sigma(v^2)$

| Sp. Gr. of $FeTiO_3$ | Specific Gravity of TiO $TiO_3$ | | |
|---|---|---|---|
| | 4.22 | 4.23 | 4.24 |
| 4.75 | ——— | .010111 | ——— |
| 4.76 | .010443 | .010108 | .010751 |
| 4.77 | .010564 | .010083 | .011075 |
| 4.78 | .010544 | .010403 | .011123 |
| 4.79 | ——— | .010564 | ——— |

The sum of the squares of the individual errors is thus seen to be least for the values 4.23 and 4.77, respectively, and these are the ones used in table 3.

The results for these values are given in table 3.

TABLE 3. CALCULATED SPECIFIC GRAVITIES OF IRON RUTILES.
Sp. gr. of $TiO.TiO_3$ = 4.23, of $FeTiO_3$ = 4.77.

| No. of Analysis | Recalculated to 100 Per Cent. | | Per Cent by Weight | | Per Cent. by Volume | | Sp. Gr. | | Error |
|---|---|---|---|---|---|---|---|---|---|
| | FeO | $TiO_2$ | $FeTiO_3$ | $TiOTiO_3$ | $FeTiO_3$ | $TiOTiO_3$ | Obs. | Calcd. | (v) |
| 1 | 1.40 | 98.60 | 2.98 | 97.02 | 2.65 | 97.35 | 4.209 | 4.244 | +.035 |
| 2 | 0.66 | 99.34 | 1.39 | 98.61 | 1.24 | 98.76 | 4.240 | 4.237 | −.003 |
| 3 | 2.18 | 97.82 | 4.60 | 95.40 | 4.10 | 95.90 | 4.242 | 4.252 | +.010 |
| 4 | 6.13 | 93.87 | 12.95 | 87.05 | 11.65 | 88.35 | 4.249 | 4.293 | +.044 |
| 5 | 3.82 | 96.18 | 8.07 | 91.93 | 7.23 | 92.77 | 4.288 | 4.269 | −.019 |
| 6 | 9.99 | 90.01 | 21.10 | 78.90 | 19.17 | 80.83 | 4.410 | 4.334 | −.076 |
| 7 | 29.12 | 70.88 | 61.50 | 38.50 | 58.60 | 41.40 | 4.520 | 4.546 | +.026 |

It can be seen from table 3 that the calculated and observed sp. grs. agree as well as could be expected, when the difficulty of the analysis of rutile is considered, as well as the fact that the temperatures at which the sp. grs. were determined were not given in any case.

The probable error[1] of these results is ±0.027, the average error ±0.0305. Therefore the sp. gr. of tetragonal ferrous titanate may be given as 4.77 ± 0.03; and that of titanyl titanate, or pure rutile, as 4.23 ± 0.03. Evidence for the accuracy of these determinations is found in the close agreement between the calculated value of the sp. gr. of rutile, 4.20–4.26, and that value as commonly accepted, given by Dana as 4.18–4.25, by Miers as 4.22, and by Rosenbusch as 4.20–4.25.

Finally it has seemed of interest to plot (Fig. 1) the sp. gr.—composition curve of the iron rutiles studied, taking the values of the Fe and TiO end members as 4.77 and 4.23 respectively. The diagram shows a straight line relation between volume percentage and sp. gr. This clearly indicates that isomorphous mixtures of the ferrous and titanyl titanates are represented in iron rutile.

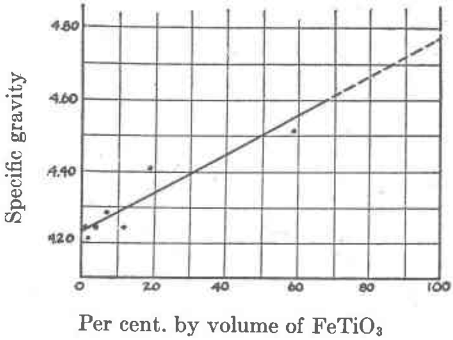

FIG. 1. SPECIFIC GRAVITY—COMPOSITION CURVE OF IRON RUTILE

# A UTAH FELDSPAR LOCALITY

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Much has been written about Utah's ores and minerals from a commercial standpoint, but that is of little aid to the collector, and as there are not many here in Utah interested in collecting mineral specimens, the good localities have not been fully explored.

The Big and Little Cottonwood mining districts, in Salt

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[1] As determined by the formula: $r = \pm \frac{2}{3}\sqrt{\frac{\Sigma(v^2)}{n - 1}}$, where r = the probable error of any single calculated result and n = number of observations (7).