chemico-physical or physiological ones. It is also obvious that to demonstrate the complexity and difficulty of a field of work is not an achievement to be compared in value with the demonstration that this field is simple and easily explicable on a few known principles. I am under no illusion in regard to this. The clear-cut, narrow tropism theory would be of infinitely greater value for predicting and controlling the behavior of animals than anything I have offered, if only it were true. I am sure I regret that I can make no attempt to put an equally simple schema in place of the one I criticized; if the phenomena of behavior were of elemental simplicity, that would certainly be much more convenient, though perhaps they would then be less interesting. Many of the concepts used in my analysis—"physiological states," "selection," "trial and error," and the like—are collective ones, characterizing varied phenomena of a high degree of complexity. They all require much further analysis; they are programs for future work, not final solutions of the problems. My analysis was mainly an attempt to lay out the field, to point out the principal phenomena with which we have to deal, and to define some of the main problems. If any one attempts to explain all behavior on any one basis, to unlock all its secrets by any catchword whatever, be it "trial and error," "selection," "tropisms" or what not, he lacks a realization of the complexity of his field of investigation. Like other complex fields, that of behavior, even in lower organisms, must be divided up; the various factors must be subjected to long and intense special investigation, with a realization that we have here material for the work of many generations of investigators.

H. S. Jennings
Johns Hopkins University,
Baltimore, Md.,
November 26, 1907

SPECIAL ARTICLES

INTERPRETATION OF THE CHEMICAL COMPOSITION OF THE MINERAL BENITOITE

In July, 1907, Professor G. D. Louderback published an interesting paper on the new mineral benitoite. For a description of the physical properties of the mineral the reader is referred to the original article.[1] The analysis of the mineral, made by W. C. Blasdale, showed the following:

	A	B	Average	Mol. Ratios
SiO_2	43.56	43.79	43.68	0.723
TiO_2	20.18	20.00	20.09	0.250
BaO	36.34	36.31	36.33	0.237
	100.08	100.10		

This yields the empirical formula $BaTiSi_3O_9$. From this Louderback concludes: "Benitoite is then a very acid titano-silicate of barium and stands in a class by itself, both as regards acid silicates and titano-silicates."

Upon reading the paper, immediately after its publication last year, I noticed that there was a very striking similarity to be observed between the composition of benitoite and beryl, for, if benitoite be interpreted as a metasilicate, we have:

Beryl ..... $\overset{II}{Be_3}\overset{III}{Al_2}(SiO_3)_6$

Benitoite ..... $\overset{II}{Ba_2}\overset{IV}{Ti_2}(SiO_3)_6$.

This similarity in the chemical composition is sufficient to consider the two compounds as isomorphous, for, although titanium with a valency of four replaces aluminium with one of three, the total valences in both compounds are the same. There is, however, a difference of one with respect to the number of atoms. A few examples of well-known isomorphous series will show that the above is not unusual.

In the marcasite group we have:

Marcasite ..... $\overset{II}{Fe}\overset{II}{S_2}$

Arsenopyrite ..... $\overset{III}{Fe}\overset{II}{AsS}$

Löllingite ..... $\overset{III}{Fe}\overset{III}{As_2}$.

Here the number of atoms is constant in all three compounds, but the valences vary. The albite-anorthite group furnishes another illustration.

Albite ..... $\overset{I}{Na}\overset{III}{Al}\overset{IV}{Si_2}O_8$

[1] "Benitoite, a New California Gem Mineral," University of California Publications, Bulletin of the Department of Geology, Vol. 5, 149–153, 1907.

Anorthite ..... $\overset{II}{Ca}\overset{III}{Al}\overset{III}{Al}Si_2O_8$.

In this series the valences of some of the individual elements vary, but their total and also the number of atoms in each compound are the same.

The galena group illustrates an isomorphous series in which the individual valences and the total number of atoms may both vary.

Galena ..... $\overset{II}{Pb}S$

Argentite ..... $\overset{I}{Ag}_2S$.

(For other examples of isomorphous series see Brauns's "Chemische Mineralogie," Arzruni's "Physikalische Chemie der Krystalle," and Groth's "Tabellarische Uebersicht der Mineralien," preferably the French edition of 1904.)

The similarity of beryl and benitoite is also to be noted by comparing their axial ratios. Both minerals crystallize in the hexagonal system.

	a	c
Beryl	1	0.4989
Benitoite	1	0.4230.

The value for benitoite is one half of one of those suggested by Louderback and is, no doubt, to be considered only as approximate, since no data concerning the reliability of the readings are given.

It is well known that TiO_2 has either acidic or basic properties. In the case under consideration, the quantitative analysis simply reveals the presence of TiO_2 as such. As to whether it is acid or basic, depends upon which of these assumptions will allow of the simplest explanation and yet be in strict accord with the observed facts.

The similarity of the composition of beryl and benitoite indicates a metasilicate and that TiO_2 is to be considered basic in this instance. The metasilicates are very common in nature, which is not the case with the salts of $H_2Si_4O_9$, a derivative of the tetrasilicic acid $H_4Si_4O_{10}$, to which Louderback would refer benitoite. Up to the present time only one mineral, lorenzenite with the composition $Na_2(Ti, Zr)_2Si_2O_9$, has been observed which can be referred to $H_2Si_4O_9$. In lorenzenite, Ti and Zr replace two atoms of silicon, but in benitoite, according to Louderback's interpretation, one atom of silicon would be replaced by titanium. Thus, in both cases, $H_2Si_4O_9$ is to be considered the basis. Hence, even though Louderback's interpretation be correct his statement, page 152, "Benitoite . . . stands in a class by itself, both as regards acid silicates and titanosilicates," needs to be modified.

In a very recent paper by Ralph Arnold,[2] it is pointed out that benitoite occurs in an area of basic rocks, such as serpentine and glaucophane schists. In fact, benitoite is found in cracks and cavities in the latter and is always associated with the hydrated basic metasilicate natrolite, $Na_2Al(AlO)(SiO_3)_3.2H_2O$. According to Arnold, benitoite may have crystallized before the natrolite, but some occurrences seem to indicate that probably the crystallization of these minerals was practically contemporaneous.

Therefore, the interpretation suggested above, which is based (1) upon the similarity of the chemical composition and axial ratios of beryl and benitoite; (2) upon the fact that TiO_2 may act as a base; (3) that benitoite occurs in an area of basic rocks, and (4) is always associated with the hydrated basic metasilicate, natrolite, seems amply justified. Accordingly, from what has been published, benitoite is not to be considered "a very acid titanosilicate of barium," but rather a metasilicate of barium and titanium.

EDWARD H. KRAUS
MINERALOGICAL LABORATORY,
UNIVERSITY OF MICHIGAN

SOME PHYSICAL CHARACTERISTICS OF COLLEGE STUDENTS[1]

A PHYSICAL examination is required of all freshmen in Columbia College and the Schools of Applied Science during the first month of the academic year. The examination includes

[2] "Notes on the Occurrence of the Recently Described Gem Mineral, Benitoite," by Ralph Arnold, SCIENCE, N. S., Vol. XXVII., pp. 312–314, 1908.

[1] Read before the New York Academy of Sciences, Section of Anthropology and Psychology, on October 28, 1907.