Isotypism overlaps to some extent the chemist's concept of isomorphism; it denotes compounds of equivalent structural types. Nevertheless, it is apparent that ionic substitution of the isomorphic sort is not a part of the connotation of isotypism. Actually the distinction between isomorphism and isotypism is somewhat arbitrary because it depends upon our knowledge of the mutual relationships of the compounds. Although miscibility among several isolated compounds may be unknown at present, the existence of one or more intermediate members, and hence limited or complete isomorphism, may be demonstrated at a later date.

Elementary texts on mineralogy may show the composition of garnets as $R''_3R'''_2(SiO_4)_3$, suggesting within this group the isomorphism which is well known. However, a more complex type formula is necessary to cover the phosphates, arsenates and hydrates which are now recognized as isotypes. These are:

$Ca_3Al_2(OH)_{12}$
$Ca_3Fe_2(OH)_{12}$
$Ca_3Al_2(SiO_4)_2(OH)_4$ (Pabst)
$Na_3Al_2(PO_4)_3$ (Thilo)
$(Ca_2Na)Mg_2(PO_4)_3$ (idem.)
$[Na(Ca,Fe)Al]Mn_2[(PO_4)_{2.5}(OH)_2]$ (McConnell)
$(Ca_2Na)Mg_2(AsO_4)_3$ (Bubeck & Machatschki)
$(Ca_2Na)Mn_2(AsO_4)_3$ (idem.)

These garnetoids have the type formula $X_3Y_2(ZO_4)_{3-m}(OH)_{4m}$, all are cubic and, with one probable exception, all have the space group of the common garnets (anhydrous silicates).

Isomorphism has not been demonstrated among these compounds except for the first three (Flint, McMurdie and Wells) and the last pair. However, P_2O_5 has very recently been found to the extent of about four per cent. (Mason and Berggren) as a constituent of a silicate garnet, demonstrating at least limited isomorphism of spessartite and a phosphate garnetoid. Replacements of R″ of the simple textbook formula are not necessarily bivalent elements, nor are the replacements of R‴ necessarily trivalents, although these valence conditions are almost universally fulfilled among the common garnets.

Turning to the apatites, the examples become even more complex but, again, a general formula may be devised: $X_{10}(F,OH,Cl)_2(ZO_4)_6$, where X is usually Ca or Pb, and Z is P, As or V. These compounds have been known for many years and will not be discussed. Several isotypes have been described recently and some of these are of considerable interest. They are:

$(Ce_{5.5}Ca_{3.5}Na)(OH,F)_2[(SiO_4)_{4.5}(PO_4)_{1.5}]$
(Hägele & Machatschki)
$(Na_6Ca_4)F_2(SO_4)_6$ (Klement & Dihn)
$Ca_{10}(OH,Cl,F)_2[(SiO_4)_3(SO_4)_3]$ (McConnell)

The last of these seems to form a complete isomorphous series with the corresponding phosphate compound, $Ca_{10}(F,OH,Cl)_2(PO_4)_6$.

Another very interesting feature of the isomorphism of apatite is the limited substitution of C for P, together with the suggested substitution of C for Ca. The isotypic carbon compounds, however, have not been discovered and probably do not exist. A more or less complete list of the substitutions, then, is:

X $\overset{\frown}{=}$ Ca, Mn, Sr, Na, K, Ce, and, in lesser amounts, Y, La, Th, Ta, Fe, Al, Mg, and C (?).
Z $\overset{\frown}{=}$ P, As, V, S, Si, Cr, and C.

Some of these are strange bedfellows indeed.

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SCIENTIFIC APPARATUS AND LABORATORY METHODS

A DEVICE FOR CALIBRATING SMALL AIR PUMPS

To measure the concentration of moisture in the air at two or more levels, in connection with the development of a method for determining the rate of evaporation from land surfaces,[1] a chemical absorption hygrometer satisfactory for field use was devised.[2] An essential element of the hygrometer is a reciprocating pump of approximately 5 cc capacity per stroke, which for satisfactory operation must be accurately calibrated. Since the device that was developed for making the calibration may have other laboratory uses, it is described in the following note.

The essential operation of the device is replacing an unknown volume of air with an equal volume of water, the transfer taking place at atmospheric pressure and measuring this volume of water.

In Fig. 1, a diagram of the device (a) represents a liter flask in which water replaces a volume of air to be measured. The flask has a drain valve (b) in the bottom and a graduated glass stem (c) in the top. In the upper end of the stem is a three-position valve (d) through which flask (a) is opened or closed to the atmosphere or connected to the intake of an air pump. The stem is enlarged below valve (d) to enclose a spout (e) which is a water passage from reservoir (f) to flask (a). A glass tube (g), opened

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[1] C. W. Thornthwaite and Benjamin Holzman, *U. S. D. A. Tech. Bull.* No. 808, May, 1942.

[2] C. W. Thornthwaite, *Trans. Amer. Geophys. Union*, pp. 429–432, 1941.

to atmospheric pressure, extends into reservoir (f) and the tube is adjusted so that its lower end will be at the level of spout (e). The operation of the device depends on this adjustment. Valve (h) releases air trapped when filling reservoir (f) with water.

The intake of an air pump to be calibrated is connected to valve (d) and this valve closed to the pump and atmosphere. Valve (b) is closed and valve (h) opened. Reservoir (f) is then filled with water through tube (g). As reservoir (f) is being filled an amount of water will flow through spout (e) into flask (a) which maintains air pressure in flask (a) equal to the head of water above spout (e). When reservoir (f) is full valve (h) is closed and the three position valve (d) opened to the atmosphere. Releasing the air pressure in flask (a) causes pressure readjustments in reservoir (f) and sufficient water will drain from the reservoir to establish less than atmospheric pressure above the water in the reservoir and atmospheric pressure at the surface of the water in spout (e) and the end of tube (g). The excess water in flask (a) is drained to a zero mark on the stem of valve (b). Valve (d) is closed to the atmosphere and opened to the pump. The apparatus is now ready for a pump calibration.

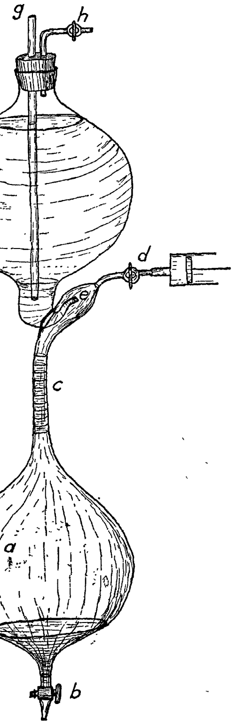

Fig. 1.

As the pump exhausts air from flask (a) the pressure in flask (a) tends to decrease, but a spontaneous adjustment of pressures in the system takes place which maintains atmospheric pressure in flask (a). The process of adjustment is: decreasing pressure on the surface of the water in spout (e) forces water from reservoir (f) into flask (a) until the pressure in flask (a) is brought back to atmospheric pressure. At the same time water flowing from reservoir (f) decreases the water pressure in reservoir (f) and air will be forced into reservoir (f) through tube (g) until atmospheric pressure is again reached in the water at the level of spout (e). Thus the device maintains atmospheric pressure in the flask (a) and any volume of air pumped from this flask will be replaced by an equal volume of water.

For a calibration the pump is run until the water flowing into flask (a) has reached the graduations on stem (c), from which its volume can be determined. This volume divided by the number of strokes made by the pump during the operation gives the volume per stroke of the pump.

The pressure of the air enclosed in the system is affected by any temperature change, and any variation in this pressure affects the accuracy of the device. To eliminate this source of error all parts of the system should be at a uniform temperature, and as the enclosed air responds more rapidly to temperature changes than the water the temperature range, during a run, should be kept to a minimum. Another source of error is incomplete water drainage from flask (a) between runs. This can be avoided by keeping the glass chemically clean.

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