of kyanite-sillimanite equilibrium at high temperatures and pressures: *Am. J. Sci.*, **255**, 628–640.

COES, L., JR. (1953), A new dense crystalline silica: *Science* **118**, 131–132.

DACHILLE, F., AND ROY, R. (1959), High pressure region of the silica isotypes: *Z. Krist.* **111**, 451–461.

GIARDINI, A. A., TYDINGS, J. E., AND LEVIN, S. B. (1960), A very high pressure-high temperature research apparatus and the synthesis of diamond: *Am. Mineral.* **45**, 217–221.

HALL, H. T. (1958), Some high-pressure, high-temperature apparatus design considerations; equipment for use at 100,000 atmospheres and 3000° C.: *Rev. Sci. Instr.* **29**, 267–275.

KENNEDY, G. C. (1955), Pyrophyllite-sillimanite-mullite equilibrium relations to 20,000 bars and 800° C.; *Geol. Soc. Am. Bull.* (abstract) **66**, 1584.

KHITAROV, N. N., SLUTSKIY, A. B., AND ARSEN'YEVA, R. V. (1957), Synthesis and characteristics of coesite: Geokhimiya **8**, 666–672 (in Russian).

MACDONALD, G. J. F. (1956), Quartz-coesite stability relations at high temperatures and pressures: *Am. J. Sci.* **254**, 713–721.

PECORA, W. T. (1960), Coesite craters and space geology: *Geotimes* **5**, 16–19.

RAMSDELL, L. S. (1955), The crystallography of "coesite": *Am. Mineral.* **40**, 975–982.

ROY, R., AND OSBORN, E. F. (1954), The system Al_2O_3-SiO_2-H_2O: *Am. Mineral.* **39**, 853–885.

SOSMAN, R. B. (1954), New high-pressure phases of silica: *Science* **119**, 738–739.

ZOLTAI, T., AND BUERGER, M. J. (1959), The crystal structure of coesite, the dense, high-pressure form of silica: *Z. Krist.* **111**, 129–141.

Note added in proof: A third natural occurrence of coesite has been found. Chao, Fahey and Littler (1961), Coesite from Wabar Crater, near Al Hadida, Arabia: *Science* **133**, 882–3.

LATTICE CONSTANTS OF SYNTHETIC LAWSONITE

CARL W. F. T. PISTORIUS, *National Physical Research Laboratory, Council for Scientific and Industrial Research, Pretoria, Union of South Africa*

Natural lawsonite, $CaO \cdot Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$, is orthorhombic, space group $C222_1$ (Pabst 1959), with lattice constants ranging between $a_0 = 8.82$–8.90 kX, $b_0 = 5.76$–5.87 kX, $c_0 = 13.19$–13.33 kX (Gossner and Mussgnug 1931, Wickman 1947, Rumanova and Skipetrova 1959). The remarkable fact that the molar volume of lawsonite, despite its two molecules of water, approximates that of anorthite, $CaO \cdot Al_2O_3 \cdot 2SiO_2$, is an indication that lawsonite might only be stable at high water vapor pressures. The stability of lawsonite should be scarcely affected by load pressure though very strongly influenced by water pressure. Fyfe and Turner (1958) pointed out that this makes lawsonite an excellent indicator of high water pressures.

Pure synthetic lawsonite has, in fact, up to the present moment only been synthesized under conditions of very high water pressure (Coes 1955; Pistorius, Kennedy and Sourirajan, in press). The latter authors

reproducibly synthesized lawsonite in the presence of a large excess of quartz or coesite at H_2O pressures above 23 kilobars at 400–600° C. and 20 kilobars at 850° C. Since their starting material was natural Iceland scolecite, their lawsonite might have been slightly impure. Furthermore, the presence of excess silica influenced the stability field of lawsonite, since the lawsonite was formed by the phase reaction zoisite+pyrophyllite+water$\rightleftharpoons$4 lawsonite+2 coesite.

In the present experiments lawsonite was prepared from a hydroxide mixture of its own composition. Analytic grade chemicals were used throughout. The finely ground samples were subjected to suitable conditions of H_2O pressure and temperature in the simple squeezer high-pressure apparatus (Griggs and Kennedy 1956).

In the absence of excess silica it was found that lawsonite starts to form at H_2O pressures at least as low as 19 kilobars, and possibly even lower. The temperatures used ranged from 500° to 650° C. This means that the field of stability of lawsonite is extended towards lower H_2O pressures by at least as much as 4 kilobars if no excess amount of silica is present. Experiments of longer duration might increase this figure slightly. At pressures of 14–19 kilobars, a mixture of zoisite, pyrophyllite and corundum was obtained at these temperatures.

Some runs were also made using a hydroxide mixture of zoisite composition as starting material. In this case lawsonite did not appear until 27 kilobars H_2O pressure at 650° C.

The best yield of lawsonite was obtained in a run made at 28.5 kilobars and 650° C. from hydroxide starting material of its own composition. The duration of the run was one hour. This lawsonite was subsequently used for the determination of the lattice constants from the powder pattern.

The x-ray powder diffraction pattern of the finely ground synthetic lawsonite at 25° C. was obtained in a Philips high angle recording diffractometer, using filtered Co Kα radiation ($\lambda = 1.7889$ Å). The resulting powder data are given in Table I.

A least-squares treatment of the observed reflections yielded the following lattice constants:

$$a_0 = 8.787 \pm .005 \text{ Å}$$
$$b_0 = 5.836 \pm .005 \text{ Å}$$
$$c_0 = 13.123 \pm .008 \text{ Å}$$

The systematic absences correspond to the space group *Ccmm*. However, Pabst (1959) has shown that false symmetry, the Templeton effect (Templeton 1956), arises in lawsonite due to special values of the y parameters of all atoms in general positions. Consequently, though the space group is actually $C222_1$, the systematic absences correspond to *Ccmm*.

TABLE I. POWDER DATA FOR SYNTHETIC LAWSONITE

(CoKα radiation)

hkl	d_{obs} in Å	d_{calcd} in Å	I
002	6.557	6.562	30
110	4.862	4.861	40
111	4.565	4.559	15
201	4.167	4.166	50
202	3.650	3.651	60
020	2.918	2.918	25
114	2.720	2.719	100
022	2.666	2.666	40
204	2.631	2.629	50
310	2.618	2.618	70
220, 312	2.432	2.431, 2.431	40
221	2.391	2.390	5
115	2.313	2.310	40
222	2.279	2.279	20
205	2.253	2.253	20
313	2.247	2.246	5
006	2.189	2.187	20
024	2.180	2.180	10
401	2.166	2.167	5
223	2.125	2.125	70
402	2.084	2.083	5
403	1.964	1.965	20
206	1.958	1.958	5
130	1.898	1.899	2
131	1.880	1.880	20
026, 117	1.752	1.750, 1.749	15 ⎫ poorly
133	1.747	1.747	15 ⎭ resolved
207	1.724	1.724	15
405, 510	1.684	1.685, 1.683	2
511	1.668	1.669	10
008, 134	1.642	1.640, 1.644	5
512, 423	1.630	1.630, 1.629	40
226	1.625	1.626	5
330	1.620	1.620	5
406, 424	1.549	1.550, 1.548	30
040, 425	1.459	1.459, 1.459	5

The calculated density of synthetic lawsonite is 3.100 g/cm³ taking 4 formula weights in the unit cell. This is in good agreement with the pycno-metric value for natural lawsonite, viz. 3.084–3.091 g/cm³.

REFERENCES

Coes, L., Jr. (1955), High-pressure minerals: *J. Am. Cer. Soc.* **38**, 298.
Fyfe, W. S., and Turner, F. J. (1958), Correlation of metamorphic facies with experi

mental data, in Fyfe, W. S., Turner, F. J., and Verhoogen, J., ed., Metamorphic reactions and metamorphic facies: *Geol. Soc. Amer. Memoir* **73**, 149–185.

Gossner, B., and Mussgnug, F. (1931), Röntgenographische Untersuchungen an Prehnit und Lawsonit: *Centralblatt Min.* 419–423.

Griggs, D. T., and Kennedy, G. C. (1956), A simple apparatus for high pressures and temperatures: *Am. Jour. Sci.* **254**, 722–735.

Pabst, A. (1959), False symmetry, the Templeton effect, in lawsonite: *Z. Krist.* **112**, 53–59.

Pistorius, C. W. F. T., Kennedy, G. C., and Sourirajan, S. (1961), Some relations between the phases anorthite, zoisite and lawsonite at high temperatures and pressures, *in press*.

Rumanova, I. M., and Skipetrova, T. I., (1959), Crystal structure of lawsonite: *Doklady Akad. Nauk S.S.S.R.* **124**, 324–327.

Templeton, D. H. (1956), Systematic absences corresponding to false symmetry: *Acta Cryst.* **9** 199.

Wickman, F. E. (1947), The crystal structure of lawsonite, $CaAl_2(Si_2O_7)(OH)_2 \cdot H_2O$: *Arkiv Kemi, Min. Geol.* **25A**, no. 2, 1–7.

ALLANITE FROM WADI EL GEMAL AREA, EASTERN DESERT OF EGYPT, AND ITS RADIOACTIVITY

Amin R. Gindy, *Department of Geology, Alexandria University, Alexandria, Egypt, U.A.R.*

Introduction

The Geological Survey of Egypt recently reported small pegmatite dikes and veins carrying sporadic large crystals of allanite in the Precambrian basement complex rocks of Wadi El Gemal area, near the Red Sea coast, Eastern Desert of Egypt. Sadek (1953) indicated the localities of these occurrences and gave a brief report of other mineral deposits there. The allanite-bearing pegmatites are particularly frequent in the rectangle limited by longitudes 34° 40′–34° 50′ and latitudes 24° 30′– 24° 40′ where they seem to be closely associated with a complex of xenolithic and gneissic tonalites, granodiorites and diorites. These pegmatite dikes and veins are of rather simple mineralogy and are mainly made up of unzoned acid oligoclase with smaller amounts of quartz and potash-rich feldspars. Allanite is almost the only colored constituent present; other accessories being either absent or in rare tiny grains. These include opaque ores, apatite, sphene and late hydrothermal clinozoisite, epidote and muscovite. The allanite-pegmatites show signs of late stage hydrothermal alterations; plagioclase being variably sericitized or kaolinized and allanite is also affected as described below.