NEPHELINE

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In 1912 Bowen[1] produced pure sodium nepheline artificially and measured its optical propoerties; he also showed that it could take into crystal solution as much as 35 per cent of the materials of anorthite; with increase in the tenor of these constituents he showed that the index, N_o, remained constant at 1.537, while N_e increased from 1.533 to 1.539, thus changing the optic sign from minus to plus. In 1917 he showed[2] that $NaAlSiO_4$ can intercrystallize *at a high temperature* with all proportions of $KAlSiO_4$. In 1931 Bannister and Hey[3] made it clear that at low temperatures no more than about 30 per cent of $KAlSiO_4$ is stable in $NaAlSiO_4$. In 1933 the writer suggested[4] that (in harmony with atom for atom explanation of crystal solution) $CaAl_2Si_2O_8$ does not intercrystallize with $NaAlSiO_4$, but that its components, $CaAlAlO_4$ and $SiSiO_4$, do so. Bowen himself reported in 1912 that $NaAlSiO_4$ can take into crystal solution at least as much as 5 per cent of $SiSiO_4$; so far as known to the writer no tests of the solubility of $CaAlAlO_4$ in $NaAlSiO_4$ have been made. It seems probable that if it is soluble it would increase the density and refractive index. Is it because $SiSiO_4$ would leave a vacancy in the structure and therefore lower the density and index that the combination of these two does not change the index (for the ordinary ray)?

In an attempt to solve the problem of the constitution of nepheline, the writer has made a rather detailed study of recent analyses of the mineral, with special reference to those which are accompanied by determinations of the physical properties. The results seem to be significant. The analyses in question have been calculated into $NaAlSiO_4$, $KAlSiO_4$ and other formulas which imply atom for atom replacement, that is, $CaAlAlO_4$, $SiSiO_4$, $AlSiO_3(OH)$ and $CaCaSiO_4$. The last one of these is the least satisfactory; perhaps impurities or inaccuracies of analysis are sufficient to render it unnecessary. The results are assembled in the following table.

[1] Bowen, N. L., *Am. Jour. Sci.*, **33,** 49 and 551 (1912).
[2] Bowen, N. L., *Am. Jour. Sci.*, **43,** 115 (1917).
[3] *Min. Mag.*, **22,** 569 (1931).
[4] Optical Mineralogy, Part 2, 299 (1933).

TABLE 1. COMPOSITION OF NEPHELINES IN MOLECULAR PER CENT OF $NaAlSiO_4$, $KAlSiO_4$ $CaAlAlO_4$, $SiSiO_4$, $AlSiO_3(OH)$ AND $CaCaSiO_4$ AS CALCULATED FROM RECENT ANALYSES

No.	$NaAlSiO_4$	$KAlSiO_4$	$CaAlAlO_4$	$SiSiO_4$	$AlSiO_3(OH)$	$CaCaSiO_4$
A	100.0 (artificial)					
1	75.0	9.6	5.6	9.3		0.4
2	69.5	12.0	4.8	9.2	4.5	
3	64.2	14.5	4.8	9.1	7.4	
4	53.2	14.8	11.2	14.5	6.2	
5	74.5	15.6	2.3	7.1		0.4
6	69.0	16.2	5.5	7.3	2.0	
7	68.3	17.4	3.8	10.4		
8	55.1	23.0	1.8	17.9		2.2
9	64.2	26.5	5.5	1.9		2.0
10	81.2	14.6		2.4		1.8
11	60.2	35.2	1.0	2.4		1.2
12	73.0	11.8	1.4	13.0		0.7
13	68.1	20.2	1.2	3.3	7.2	
14	77.6	13.1	1.9	7.1		0.3
15	79.1	16.7		2.7		1.4
16	61.9	32.2	1.7	1.7		2.6
17	68.0	17.7	5.5	8.7		
18	77.8	10.9	2.2	9.0		
19	68.0	17.3	2.0	2.5	10.2	
20	75.9	14.3	1.7	8.1		

References for Table 1 and Figs. 1, 2, 3.

A. Bowen, N. L.: *Am. Jour. Sci.*, **33,** 49 (1912). A in Fig. 2 derived from Fig. 1.
1–9. Bannister, F. A., and Hey, M. H.: *Min. Mag.*, **22,** 569 (1931).
10. Dunham, K. C.: *Am. Mineral.*, **18,** 369 (1933).
11, 12. Bowen, N. L., and Ellestad, R. B.: *Am. Mineral.*, **21,** 363 (1936).
13. Walker, T. L., and Parsons, A. L.: *Univ. Toronto Geol. Stud.*, **21,** 8 (1925).
14–15. Zambonini, F.: *App. Mineral. Vesuvius and Rend. Accad. Fis. Mat. Napoli,* **15,** 26 (1912). Abst. in *Zeits. Krist.*, **55,** 301 (1915).
16. Zambonini, F.: *Rend. Accad. Fis. Mat. Napoli,* **49,** 83 (1910). Abst. in *Zeits. Krist.*, **52,** 313 (1913).
17. Starraba, F. S.: *Riv. Min. Crist. Ital.*, **48,** 53 (1917); *Min. Abst.* **I,** 108.
18. Washington, H. S., and Merwin, H. E.: *Jour. Wash. Acad. Sci.*, **5,** 389 (1915).
19. Walker, T. L., and Parsons, A. L.: *Univ. Toronto Geol. Stud.*, **22,** 5 (1926).
20. Barth, T.: *Vid. Akad. Oslo,* No. 8, 66 (1927).

If the components of nepheline were $NaAlSiO_4$, $KAlSiO_4$ and $CaAl_2Si_2O_8$, then the percentages of $CaAlAlO_4$ and $SiSiO_4$ would be equal in each analysis. Such a condition is found in only one analysis (16); in one case (9) $CaAlAlO_4$ is nearly three times as abundant as $SiSiO_4$, but in most cases $SiSiO_4$ is two to six times as plentiful as $CaAlAlO_4$. Of course this may be due to imperfections in the analyses, but such large discrepancies are somewhat surprising.

If nepheline contains all of these components (or even the first four), it is clear that there can be no simple relation between the tenor of $KAlSiO_4$ and the physical properties, since the latter must depend upon all of the components. To obtain an approximation of the properties in the $NaAlSiO_4$–$KAlSiO_4$ series those analyses with the least amounts of other components are used. In Fig. 1 all those analyses which contain at

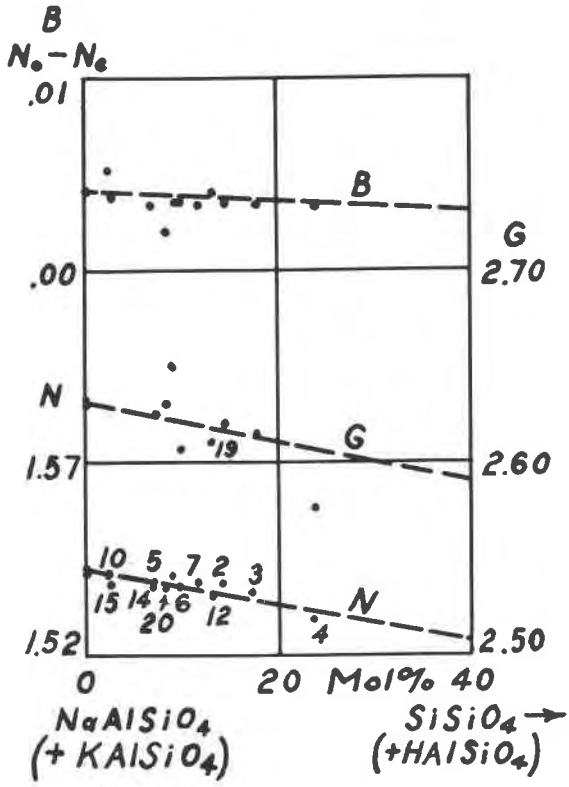

FIG. 1

least 90 per cent of $NaAlSiO_4+KAlSiO_4$ are recorded. The results are reasonably concordant except for the specific gravity of No. 16. Since the refractive index of 16 falls on the line, it seems probable that the specific gravity is somewhat in error.

Is it possible to find any correlation between the content of $SiSiO_4$ ($+HAlSiO_4$) and the physical characters? If all the analyses containing

about 15 per cent of $KAlSiO_4$ (exactly 11.8–17.7) are plotted on the basis of their tenor of $SiSiO_4$, as in Fig. 2, it is clear that the refractive index and specific gravity decrease with increase of this component. This condition is in harmony with the idea that the presence of $SiSiO_4$ implies a vacant position (occupied by the alkali atom in the usual structure). The fact that the decrease is not as rapid as required by assuming such vacant positions is perhaps due to the presence of water in them. Nearly all of these analyses show that water is present in small amount.

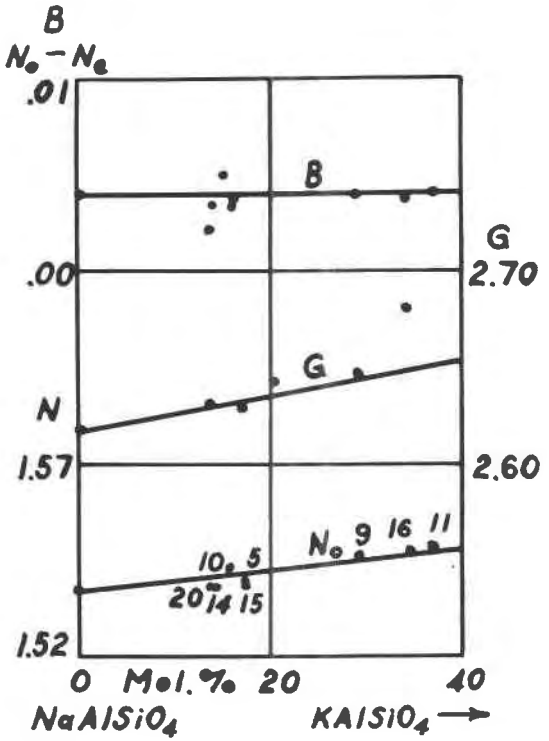

FIG. 2

Finally, in Fig. 3, an attempt is made to show the effects of both of these variables in one diagram. But the data are insufficient to give more than a first approximation, and such a diagram can never be more than an approximation because other variables (notably Ca) are disregarded. Figure 3 shows clearly that SiO_2 and K_2O vary quite independently of each other.

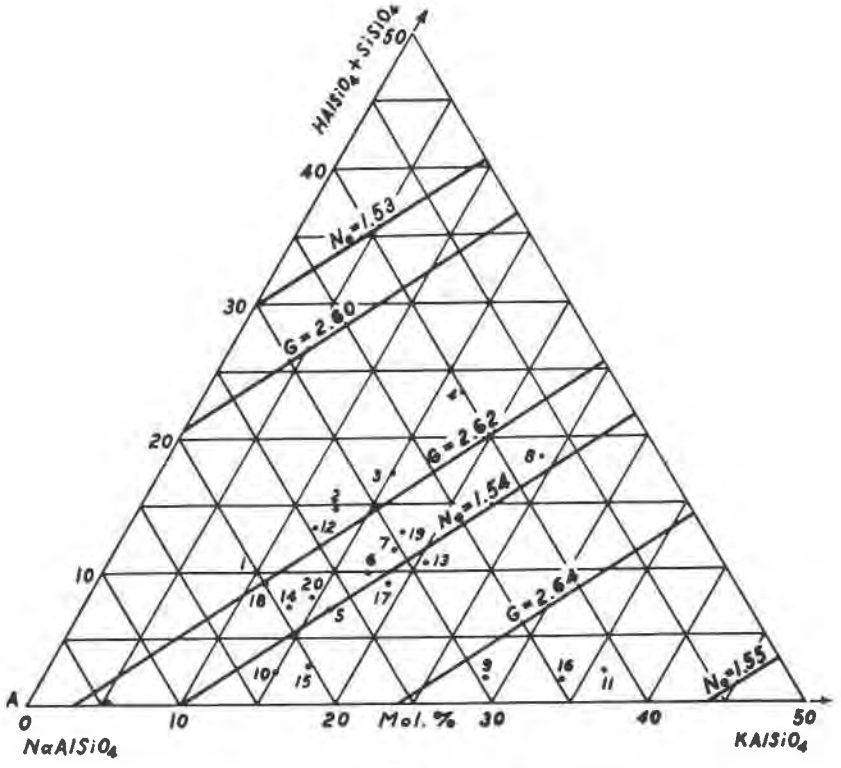
HAlSiO4 + SiSiO4
50
40
30
20
10
A
0
10
20
Mol. %
30
40
50
NaAlSiO4
KAlSiO4
Ng=1.53
G=2.60
G=2.62
Ng=1.54
G=2.64
Ng=1.55
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

FIG. 3