

for some workers to express compositions in terms of "ideal" formulae which can obscure relationships rather than clarify them. Considerable confidence can be placed in the view that the number of oxygen atoms within the framework of linked  $(\text{Si}, \text{Al})\text{O}_4$  tetrahedra is virtually constant for the unit cell of each species. This number must be even, is commonly a multiple of 8, and can be determined unambiguously from reasonably precise chemical, X-ray and density data. Following HEY (1932a) and others, unit cell contents on the basis of this ideal number of structural oxygens have been calculated by the writer for a large number of zeolite analyses. More attention has been given to variations in the Si : Al ratio than to variations in the other cations, as the latter are subject to secondary, base exchange effects and are therefore less fundamental in reflecting conditions of formation. Nevertheless as the various lime zeolites appear to accept such elements as Na, K and Sr into their lattices to varying degrees, the concentration of these latter elements in the environments of formation must influence stability fields. The Mg-bearing species ferrierite and the barium zeolites are not here considered.

It will be found convenient to describe the range of composition of certain zeolites not only in terms of the familiar isomorphic substitutions: (i) NaSi for CaAl; and (ii)  $\text{Na}_2$  for Ca, or more generally  $(\text{Na}, \text{K})_2$  for  $(\text{Ca}, \text{Sr}, \text{Ba})$  but also in terms of the substitution: (iii) Al for Si within the tetrahedral framework with additional W group cations  $(\text{Na}, \text{K}, \text{Ca}^{1/2})$  occupying otherwise vacant lattice sites. This results in a marked variation in the number of W group cations per unit cell and is equivalent to simultaneous operation of the other two types of replacement.

The ranges of composition tentatively accepted for valid species are listed below together with estimates of the specific gravity for some of the compositions listed. Specific gravity is not significantly affected by the substitution of  $\text{Na}_2$  for Ca (compare analcime and wairakite), but it does vary markedly with the other types of substitution. The values given have been selected, averaged or interpolated from previously published determinations and in some cases are capable of considerable refinement. Only a few leading references have been cited; many others have been considered.

In Fig. 5 compositions of the calciferous zeolites are plotted in molecular proportions on the triangle  $(\text{Ca}, \text{Na}_2, \text{K}_2)\text{O} : 2\text{H}_2\text{O} : 2\text{SiO}_2$ , the component  $(\text{Ca}, \text{Na}_2, \text{K}_2)\text{O}$  being numerically equal to  $\text{Al}_2\text{O}_3$  for zeolites and for other true tectosilicates such as anorthite. Horizontal lines therefore represent the range of variation in Si : Al ratios through each series. Prehnite, pumpellyite and epidote have been plotted for comparison and in these the  $\text{Al}_2\text{O}_3$  content is not directly related to the other components. The water content has been plotted arbitrarily at the value which is judged to best reflect the chemical analyses and structural data. In several cases it is open to question. Compositions plotted are based on analyses of apparently good quality of natural zeolites. Laboratory crystallization from highly reactive and unstable starting materials such as glasses is likely to lead to a greater range of metastable compositions than in the case of the natural materials.

*Analcime.*  $\text{Na}_{17}\text{Al}_{17}\text{Si}_{31}\text{O}_{96} \cdot 16\text{H}_2\text{O}$  to  $\text{Na}_{14}\text{Al}_{14}\text{Si}_{34}\text{O}_{96} \cdot 16\text{H}_2\text{O}$ , with minor substitution of  $(\text{K}, \text{Ca})$  for Na; commonly near  $\text{NaAlSi}_2\text{O}_6 \cdot \text{H}_2\text{O}$ ;  $Z = 16$  (e.g. HARTWIG, 1928; COOMBS, 1955);  $D = 2.265 \pm 0.01$ . SAHA (1957) has indicated that synthetic analcimes may range from  $\text{NaAlSi}_3\text{O}_8 \cdot n\text{H}_2\text{O}$ , to  $\text{NaAlSiO}_4 \cdot m\text{H}_2\text{O}$ , presumably with  $Z = 12$  and  $Z = 24$  respectively.

*Ashcroftine.*  $40(\text{KNaCaAl}_4\text{Si}_5\text{O}_{18} \cdot 8\text{H}_2\text{O})$ ;  $D = 2.61 \pm 0.05$  (HEY and BANNISTER, 1933).

*Chabazite.*  $(\text{Ca}, \text{Na}_2, \text{K}_2)_5\text{Al}_{10}\text{Si}_{20}\text{O}_{72} \cdot 36\text{H}_2\text{O}$  to  $(\text{Ca}, \text{Na}_2, \text{K}_2)_{6.75}\text{Al}_{13.5}\text{Si}_{22.5}\text{O}_{72} \cdot 36\text{H}_2\text{O}$ . Alkalis sometimes exceed Ca. STRUNZ (1956) gives  $(\text{Ca}, \text{Na}_2)\text{Al}_2\text{Si}_4\text{O}_{12} \cdot 6\text{H}_2\text{O}$ ;  $Z = 6$ ;  $D = 2.082$ .

*Epistilbite.* STRUNZ and TENNYSON (1956) give  $\text{CaAl}_2\text{Si}_6\text{O}_{18} \cdot 5\text{H}_2\text{O}$ ;  $Z = 3$ . In eight out of fifteen analyses considered by the present writer, there are 15.7 to 16.3  $\text{H}_2\text{O}$  per unit cell, the others showing rather less. We tentatively accept 16  $\text{H}_2\text{O}$  per unit cell, which would make epistilbite a true, higher density, polymorph of heulandite with the approximate range  $(\text{Ca}, \text{Na}_2)_{2.85}\text{Al}_{5.7}\text{Si}_{18.3}\text{O}_{48} \cdot 16\text{H}_2\text{O}$  to  $(\text{Ca}, \text{Na}_2)_{3.5}\text{Al}_7\text{Si}_{17}\text{O}_{48} \cdot 16\text{H}_2\text{O}$ ;  $D$  typically  $2.25 \pm 0.03$ . Ca is dominant over alkalis.

Dachiardite is shown by X-ray powder diffraction to be structurally related to epistilbite. It has a higher alkali content with about  $\text{Si}_{19-19\frac{1}{2}}$  for 48 O.

*Erionite.*  $(\text{Na}_2, \text{K}_2, \text{Ca}, \text{Mg})_{4.5}\text{Al}_9\text{Si}_{27}\text{O}_{72} \cdot 27\text{H}_2\text{O}$ ;  $D$  (calc.) = 2.07 (STAPLES and GARD, 1958).

*Faujasite.* Near  $(\text{Na}_2, \text{Ca})_{1.75}\text{Al}_{3.5}\text{Si}_{8.5}\text{O}_{24} \cdot 16\text{H}_2\text{O}$ ;  $Z = 16$ ;  $D = 1.92$  (cf. STRUNZ, 1955).