(Gallagher, 1970; Murray, 1979). It is uncertain whether some Cl^- also substitutes for structural OH^-.

The Cl^--rich nature of the Norfolk akaganéite is consistent with its formation in waters of near-marine composition. Surface waters in the lower marsh-sandflat system, which is covered by about 65% of tides, typically contain 18000–19000 ppm Cl^-; porewaters from 10–40 cm below the surface of the lower marsh contain 20000–24000 ppm Cl^- (average seawater = 18986 ppm Cl^-).

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Spencerite from Kabwe, Zambia, and the infrared spectroscopy of the Kabwe zinc phosphates

AMONG a suite of specimens from Kabwe, Zambia (previously known as Broken Hill, Northern Rhodesia) sent to Mr L. Clark and the author for investigation was a small piece consisting mainly of a portion of a very pale greenish hemimorphite nodule with 2–3 mm thick solid walls. The matrix within this hemimorphite nodule had been dissolved away and partly replaced by tiny colourless spiky smithsonite crystals, while colourless thick blades of hopeite to about 5 mm sit on the hemimorphite. Spanning spaces between hemimorphite and hope-ite crystals, and growing around the hopeite are colourless pearly thin lath-shaped crystals to about 7 mm in length, representing the latest generation of mineralization present. The infrared spectrum of these laths indicates that they are the rare zinc phosphate spencerite, $Zn_4(PO_4)_2(OH)_2 \cdot 3H_2O$. Spencerite has only been reported before from two localities, Hudson's Bay mine, Salmo, British Columbia, the type locality (Walker, 1916, 1918), and Turf Pits mine, Grassington, Yorkshire (British Museum (Natural History) specimen, collected by A. W. G. Kingsbury in 1963; see Embrey, 1978). The rarity of spencerite is due to the fact that it is
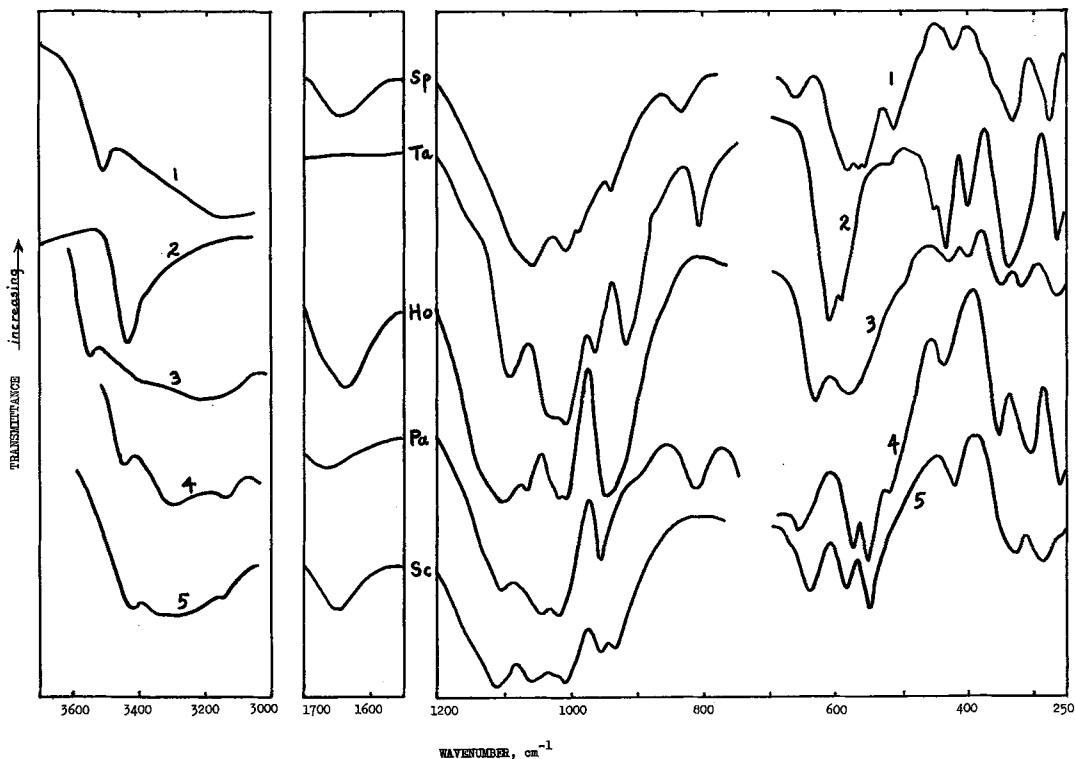
FIG. 1. Infrared spectra of the Kabwe zinc phosphate minerals, measured in Nujol mulls between CsI plates, using a Perkin-Elmer PE 783 precision grating spectrophotometer: 1, Spencerite, British Columbia, off RSWB 68-329; 2, Tarbuttite, Kabwe, off RSWB 82-20; 3, Hopeite, Kabwe, off RSWB 83-3; 4, Parahopeite, Kabwe, off RSWB 83-4; 5, Scholzite, Reaphook Hill, S. Australia, off RSWB 77-35. Spectra of spencerite and scholzite from Kabwe, off RSWB 83-9 and 83-6 respectively were measured under similar conditions (but using KBr plates) over the $4000-400$ cm^{-1} range using a Perkin Elmer 397 spectrophotometer, and gave similar spectra over that range to those shown.

thermodynamically unstable with respect to tarbuttite in aqueous solutions at ambient temperature (Magalhães et al., 1986). Tarbuttite is common at Kabwe, and the spencerite under study must have been formed as a metastable product within the protective confines of the hemimorphite nodule. The type material from British Columbia was also found in cores of protective hemimorphite (Walker, 1916, 1918).

For a fairly recent general account of the mineralisation at Kabwe see Notebaart and Korowski (1980).

The infrared spectrum of the Kabwe spencerite is similar to that of a spencerite from the type locality. The spectrum is quite characteristic, and easily distinguished from those of the related zinc phosphates hopeite, parahopeite, tarbuttite and scholzite, all of which are found at Kabwe, and of course also from the associated silicate hemimorphite, sometimes misidentified visually as a zinc phos-

phate. These spectra are shown in Fig. 1. Wavenumbers of absorption maxima and assignments are tabulated in Table 1. These assignments are based mainly on the known positions of absorption bands for isolated ions (Hertzberg, 1945; Nakamoto, 1978) and on comparison with published assignments for related compounds (see notes to Table 1).

From published X-ray structural data (Chao, 1969; Cocco et al., 1966; Fanfani et al., 1972; Hill and Jones, 1976; Taxer, 1975) it can be seen that in each of these minerals the phosphate ions occupy only one site, and that the PO_4 symmetries are C_1 in each case, although in the case of spencerite (Fanfani et al., 1972) the coordination about the phosphate ions suggests a higher site symmetry, C_2, and the uncertainties in the published P-O distances and O-P-O bond angles overlap, so that C_2 symmetry can indeed be accommodated. Examination of the site splittings of the infrared absorption

Table 1. Positions of infrared absorption maxima, and their assignments, for the Kabwe, Zambia zinc phosphate minerals

Absorption maxima, cm^{-1}, intensities					Assignments
Spencerite	Tarbuttite	Hopeite	Parahopeite	Scholzite	
3510 ms, sp	3430 s, sp	3530 s	3440 ms	~3510 mw, sh	O-H stretch, increasingly hydrogen bonded as wavenumber decreases.
				3420 m	
			3280 s, br	~3300 sm, br	
~3140 s, br		~3160 vs, br	3120 s, br	~3150 m, sh	
1650 mw		1640 s	1680 m, br	1653 m	H-O-H "scissor" in-plane deformation.
		1100 vs	1100 s	1110 vs	
1066 vs	1090 s	1066 sh	1060 sh	1058 vs	PO$_4$ ν_3 unsymmetrical stretch. Metal O-H in-plane bend. Note 1.
1010 vs	1030 vs	1020 s, sh	1046 vs		
992 s, sh	1000 vs	1006 vs	1013 vs	1003 vs	
943 m	955 s	945 s	952 s, sp	955 s	PO$_4$ ν_1 symmetrical stretch. Metal O-H bend. Note 2.
	910 s	933 sh	890 sh		
843 wm	802 ms		805 m		ZnO-H bend? Note 3.
667 wm		633 ms	650 ms	638 ms	Zn-OH$_2$ twist. Note 4.
595 sm	605 s				PO$_4$ ν_4 unsymmetrical bend. Note 5.
580 sm	583 s	580 ms	568 ms	582 ms	
560 sm	525 m		545 s, sp	545 s	Zn-OH$_2$ wag. PO$_4$ ν_4 unsymmetrical bend. Note 6.
515 m		500 w, sh	510 m, sh		
	450 sh, m				Zn-OH$_2$ stretch (?), PO$_4$ ν_2 symmetrical bend. Note 7.
417 wm	435 ms	433 mw	425 m	420 m	
	398 m, sp	400 mw			
340 ms		350 ms	352 ms	~350 sh	Metal-OH$_2$ stretch. Note 8.
	321 ms	318 ms	300 ms	322 ms	Metal-O?
270 ms	260 ms	272 m	260 ms	285 ms	

s = strong, m = medium, w = weak, sh = shoulder, sp = sharp, br = broad, v = very

1. Spencerite, $Zn_4(PO_4)_2 \cdot 3H_2O$.

2. Tarbuttite, Zn_2PO_4OH.

3. Hopeite, $Zn_3(PO_4)_2 \cdot 4H_2O$ (orthorhombic).

4. Parahopeite, $Zn_3(PO_4)_2 \cdot 4H_2O$ (triclinic).

5. Scholzite, $CaZn_2(PO_4)_2 \cdot 2H_2O$.

Notes to Table 1.

1. PO$_4$ ν_3 is at 1031, 999, 967 cm^{-1} in pyromorphite, for example (Levitt and Condrate, 1970). Three maxima expected for C_1 or C_2 symmetry. Metal O-H in-plane bending vibrations are near 1000-1100 cm^{-1}, at lower wavenumbers for bridging O-H (Nakamoto, 1978). Spencerite and tarbuttite both have bridging OH groups.

2. PO$_4$ ν_1 is at 980 cm^{-1} for isolated ion (Hertzberg, 1945), 927 cm^{-1} in pyromorphite (Levitt and Condrate, 1970). Should be one absorption, forbidden and therefore weak, and may be hidden under edge of ν_3 absorption. ZnO-H deformation in adamite is at 885 cm^{-1} (Braithwaite, 1983).

3. A ZnO-H out-of-plane bend in ϵ-Zn(OH)$_2$ is at 830 cm^{-1} and in ZnOHCl and ZnOHF at 855 and 790 cm^{-1} (Srivastava and Secco, 1967), but parahopeite has no non-water OH. The coordinated water rock in hydrated zinc sulphate is at 758 cm^{-1} according to Gamo (1961).

4. The coordinated water twist in hydrated zinc sulphate is at 621 cm^{-1} (Kermarrec, 1964). Absent in the spectrum of tarbuttite, which has no H$_2$O.

5. PO$_4$ ν_4 is at 575, 543 cm^{-1} in pyromorphite (Levitt and Condrate, 1970). Three maxima expected for C_1 or C_2 symmetry.

6. Coordinated water wag in hydrated zinc sulphate is at 541 cm^{-1} (Nakagawa and Shimanouchi, 1964), 555 cm^{-1} (Kermarrec, 1964).

7. PO$_4$ ν_2 is at 436 cm^{-1} in pyromorphite (Levitt and Condrate, 1970). Forbidden, and therefore very weak. Doubly degenerate, with two maxima expected for C_1 and C_2, and one maximum for C_{2v} symmetry. See text. Stretching vibrations of coordinated water to metals such as Zn are also in this region.

8. The Zn-O stretching vibration of coordinated water in hydrated zinc sulphate is at 364 cm^{-1} (Nakagawa and Shimanouchi, 1964). Tarbuttite lacks water.

maxima by degeneracy removal cannot resolve this problem, unfortunately, as both C_1 and C_2 symmetry would involve loss of all degeneracy, giving nine infrared active modes ($1 \times v_1$, $2 \times v_2$, $3 \times v_3$, $3 \times v_4$). The spectra of spencerite, parahopeite and scholzite appear to show only one absorption maximum each in the $PO_4 v_2$ region (at 417, 425 and 420 cm^{-1} respectively) as though their site symmetries were C_{2v} or higher. These absorptions, however, are appreciably stronger than would be expected for this symmetrical and therefore infrared forbidden vibration, and must be derived from some other vibration, possibly a $Zn-OH_2$ stretch, concealing the phosphate v_2 band multiplicity by burial. Tarbuttite has two rather strong bands in this region, of unknown assignment; it lacks coordinated water and the absorption bands are far too strong for phosphate v_2 vibrations.

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Formal definitions of type mineral specimens

TYPE mineral specimens are reference samples for the definition of mineral species. The biological sciences have a long-established system of type specimens, but the formal designation of such samples is a relatively recent matter in mineralogy. Indeed, for a vast number of minerals, some first discovered in antiquity, and many others as recently as this century, there exist no type specimens at all. In many such cases, the best available information comes from designations such as 'original material' on museum catalogues, and on some old labels. Interpretations of labels, however, even if they are in the handwriting of the original describer, should always be treated with utmost caution.

Embrey and Hey (1970) provided a thoughtful discussion of the problems associated with type specimens, and the practices of our colleagues in the biological sciences, and proposed an argument for distinguishing seven kinds of type specimens. We