NOTE ON THE ANOMALOUS THERMAL EFFECT IN QUARTZ OSCILLATOR PLATES

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In a recent paper Lukesh and McCaa[1] have reported an anomalous frequency shift in vibrating quartz plates when exposed to infra-red radiation. It is the purpose of this note to confirm and extend these observations. In the last paragraph of their paper Lukesh and McCaa suggest a tentative explanation of the effect in terms of the thermal strains resulting from the differential exposure. Two observations made by the author some time ago tend to confirm their explanation.

When a vibrating *AT* plate is subjected to a mechanical stress in the X direction, its frequency changes quite appreciably. For example, compressing a $\frac{1}{2}$ inch 5 mc./sec. *AT* plate along the X direction with a force which can be applied directly with the fingers causes a frequency increase of 50 to 100 cycles/sec. The same procedure applied to a *BT* plate causes a decrease in its frequency. The effect in *BT* plates appears to be somewhat less than that in *AT* plates as well as being in the opposite direction. Mechanical stress in the Z′ direction has very little effect on either plate.

Lukesh and McCaa report that irradiating the central region of the blank while shielding the outer zone produces an increase in the frequency of *AT* plates and a decrease in the frequencies of *BT* plates. These results are easily confirmed. However, if the central portion is shielded while the outer zone is exposed, the effect is reversed. This may easily be demonstrated by shielding the central zone of the vibrating plate with a small metal button which also serves for one of the electrodes.

Very often quartz oscillator plates are clamped between electrodes which also serve as mechanical supports. These electrodes must have a thermal coefficient of expansion which approximates that of quartz in the plane perpendicular to the optic axis. Otherwise an hysteresis effect is observed when the temperature is cycled. For example, in *AT* plates clamped between ceramic electrodes, the frequency is found to rise anomalously when the temperature is increased and to drop anomalously when the temperature is decreased. This phenomenon, which is quite troublesome, is caused by the constraining force exerted on the blank by the electrodes which have a much lower coefficient of expansion than the quartz plate. With *BT* plates the effect is reversed.

All these experimental facts are correlated and explained if we assume

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[1] Lukesh, Joseph S., and McCaa, David G., *Am. Mineral.,* **32,** 137–140 (1947).

that exposure of the quartz to infra-red radiation produces localized body heating of the material. Due to the low thermal conductivity of quartz, the expansion resulting from the heating is localized in the exposed region. Thus, exposing the central zone while shielding the outer zone, results in expansion of the central zone against the constraining force supplied by the unexposed outer zone. But lateral compression of the plate is observed to cause a frequency shift in the same sense as that observed when the central zone is irradiated. Hence the hypothesis of Lukesh and McCaa is explained and confirmed.

In our joint paper "Differential thermal analysis of some carbonate minerals," *Am. Mineral.*, **32,** 111–116 (1947), a curve having only an exothermic peak is given for siderite (Fig. 2, p. 114). Since publication several workers in the same field have called to our attention that they most frequently get an endothermic reaction interrupted and followed by the exothermic reaction. Our sample was chosen as the most pure siderite we could obtain. As we point out in paragraph 3, page 115, "The exothermic reaction is a result of the heat balance between the decomposition of the $FeCO_3$ and the immediate oxidation of the resulting FeO to Fe_2O_3." Perhaps a fortuitous combination of pure sample, dilution, and heating rate has suppressed the endothermic reaction which other workers obtain when these conditions are *different.*

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Dr. A. E. Alexander, director of the Gem Trade Laboratory, Inc., New York, has returned from Bahrain Island, Persian Gulf, where at the invitation of the Bahrain government a study was made of genuine pearl fishing methods as practiced by the natives of that area. On his return several days were spent with Mr. B. W. Anderson, director of the Precious Stone Laboratory, London Chamber of Commerce.

The Crystallographic Society has reported election of the following officers: John W. Gruner, University of Minnesota, president; A. Pabst, University of California, who succeeds to president in 1948, vice-president; William Parrish, Philips Laboratories, Inc., Irvington-on-Hudson, New York, secretary-treasurer (1947–49); and Samuel G. Gordon, Academy of Natural Sciences of Philadelphia, and George Tunnell, University of California at Los Angeles, councilors.

Letter to the Editor

X-ray wave-lengths have been expressed in X units. The X unit is defined in terms of the calcite spacing and is nearly 10^{-11} cms., but is now known to differ from 10^{-11} cms. by about 0.2%. During the last twenty-five years X-ray diffraction workers have expressed X-ray wave-lengths and crystal dimensions in terms of a unit which was 1000 X units, but instead of calling it 1000 X units have erroneously called it an Ångström unit. In recent years, the X-ray diffraction groups have agreed to use the term kilo X unit (abbreviated kX) in place of the incorrectly used Ångström unit, until agreement was reached on the best conversion factor to use for converting from *kX* to Ångström units. Agreement on the factor has now been reached.

As secretary of the American Society for *X*-ray and Electron Diffraction, I have been instructed to call the attention of American *X*-ray workers to the following announcement which appeared in the January, 1947, issue of the *Journal of Scientific Instruments*. Because of its importance it is here reproduced in its entirety.

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Murray Hill, N. J.

The Conversion Factor for *kX* Units to Ångström Units

At the annual conference of the *X*-ray Analysis Group of the Institute of Physics in July 1946 it was announced that agreement had been reached concerning the factor for converting measurements in *kX* units to Ångström units. The factor agreed upon, after consultation with the *American Society for X-ray and Electron Diffraction* and Prof. Siegbahn was 1.00202. This factor is probably correct to 0.003%. Since wave-lengths in *X*-units have been measured to an accuracy of 0.001%, the wave-lengths in Ångström units can be taken as accurate to 0.004% in general.

The following is a list of values of wave-lengths in Ångström units of certain emission lines and absorption edges in common use. The column headed $K\alpha$ gives the mean value of $K\alpha_1$ and $K\alpha_2$, $K\alpha_1$ being allowed twice the weight of $K\alpha_2$.

Current values of the physical constants, such as those quoted by Birge in the 1941 volume of the Physical Society's *Reports on Progress in Physics*, should be used in conjunction with these wave-lengths. In particular density ρ is given by the equation

$$\rho = 1.66020\ \Sigma A/V$$

where ΣA is the sum of the atomic weights of the atoms in the unit cell, and V is the volume of the unit cell in A^3.

	$K\alpha_1$	$K\alpha_2$	$K\alpha$	$K\beta_1$	Absorption edge
Cr	2.28962	2.29352	2.2909	2.08479	2.0701
Mn	2.10174	2.10570	2.1031	1.91016	1.8954
Fe	1.93597	1.93991	1.9373	1.75654	1.7429
Co	1.78890	1.79279	1.7902	1.62073	1.6072
Ni	1.65783	1.66168	1.6591	1.50008	1.4869
Cu	1.54050	1.54434	1.5418	1.39217	1.3802
Zn	1.43510	1.43894	1.4364	1.29520	1.2831
Mo	0.70926	0.71354	0.7107	0.63225	0.6197
Rh	0.61326	0.61762	0.6147	0.54559	0.5341
Pd	0.58545	0.58982	0.5869	0.52052	0.5090
Ag	0.55941	0.56381	0.5609	0.49701	0.4855

It is recommended that in any published work the values of the wave-lengths used should be explicitly stated.

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