COPPER ISOTOPES

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Abstract

The Allison magneto-optic method shows that copper has a third less abundant isotope of atomic weight less than 63.

ALLISON and Murphy[1] have described a magneto-optic method of chemical analysis in which compounds are detected by the time lag of their Faraday effects behind the applied magnetic field. The time lag is measured with respect to that of some reference material which in this experiment is carbon disulfide. The time lags for various compounds may be greater or less than that for carbon disulfide. The time intervals are extremely short and the actual measurements are linear measurements of the path of a light beam or of an electric impulse along a conductor. In the present apparatus, each scale division represents 10^{-9} sec. With carbon disulfide in the comparison cell, the scale reading is 15.00. By subtracting the scale reading for another compound from 15.00, and multiplying by 10^{-9} the differential time lag in seconds of the Faraday effect for the compound with respect to carbon disulfide is obtained.

The time at which the magnetic field becomes effective is determined by the extinction or at least the reduction to a minimum of the light which, passes through the apparatus. In the case of solutions of inorganic compounds there is often more than one setting for minimum light. These minima have been found to be equal in number to the number of isotopes of the cation. The differential time lag is found to be a function of the equivalent weight of each constituent of the compound. For a given anion, the time lag decreases with increasing equivalent weight of the cation.

When solutions, that are at first too dilute to show the effect, have their concentrations increased, it is found that the isotope which is most abundant gives the threshold change of intensity first. This is as expected, but to organize the data consistently it was found necessary to assume that, for a given element, the time lag *increases* with increasing equivalent weights of the isotopes.[2]

Of a large number of elements studied by several investigators employing the magneto-optic method, copper presented the only exception to this rule. The cupric chloride minimum with a time lag of -5.48×10^{-9} sec. (scale reading 20.48) was always obtained with more dilute solutions than the

[1] Allison and Murphy, J. Am. Chem. Soc. **52,** 3796 (1930).

[2] Allison and Murphy, Phys. Rev. **36,** 1097 (1930); Allison, Ind. & Eng. Chem. (Anal. Ed.) **4,** 9 (1932).

minimum with a time lag of -5.66×10^{-9} sec. (scale reading 20.66). The second has the smaller time lag (greater negative value), but the lower weight isotope (63), of the two usually assigned to copper, is the more abundant.[3] Since it did not seem reasonable that copper should behave differently in this respect from other elements, a search was made for other minima.

A cupric chloride solution was carefully examined for additional minima and one found with a time lag of -5.56×10^{-9} sec. (scale reading 20.56).[4] With a solution containing one part of cupric chloride in 10^{12} of water, no minima were observed. As the concentration was increased, the minimum at -5.56×10^{-9} sec. (scale reading 20.56) appeared first, that at -5.48×10^{-9} sec. (scale reading 20.48) followed and that at -5.66×10^{-9} (scale reading 20.66) came last. These minima must then correspond to the isotopes in the order of their abundance, the first to Cu^{63}, the second to Cu^{65} and the last, having the least time lag to an isotope lighter than Cu^{63} and also least abundant.[5] Determinations with cupric sulfate showed its minima appearing in the same order as found for cupric chloride. Other copper compounds were examined and three minima were found for each. The data are given in the following table.

TABLE I. *Scale readings of minima and differential time lag with respect to carbon disulfide for copper compounds.*

	Cl		NO_3		SO_4	
	Scale reading	Seconds $\times10^{-9}$	Scale reading	Seconds $\times10^{-9}$	Scale reading	Seconds $\times10^{-9}$
Cu^{++}	20.48	−5.48	7.35	7.65	14.80	0.20
	20.56	−5.56	7.40	7.60	14.90	0.10
	20.68	−5.68	7.43	7.57	15.00	0.00
Cu^{+}	30.38	−15.38	9.20	5.80	23.24	−8.24
	30.45	−15.45	9.35	5.65	23.40	−8.40
	30.68	−15.68	9.50	5.50	23.50	−8.50

The minima attributed to copper are not given by the corresponding zinc compounds or any other compound that has been examined. Precautions were taken to avoid any possible contamination. The water used was redistilled from Pyrex. All compounds used were C. P. and the cupric sulfate was recrystalized. Cuprous compounds were prepared from cupric by reduction with metallic copper. The minima of cupric chloride and sulfate were determined in solutions whose concentration was a few parts in 10^{12} so that any impurity would have had to be present in as great concentration as the copper

[3] Aston, Nature **112,** 162 (1923); Mulliken, Phys. Rev. **26,** 1 (1925); Hicks, Nature **123,** 838 (1929).

[4] Except for threshold values, obtained as the concentrations are increased, the minima appear the same to the eye, so that the most abundant isotope may be missed as readily as any other.

[5] Dempster, Nature **112,** 7 (1923), reported three isotopes of copper of weight 62, 64, and 66, but Aston, Nature **112,** 162 (1923), found only 63 and 65 and attributed Dempster's lines to zinc. Dempster found his lightest isotope most abundant and the other two of equal intensity which is not in agreement with the findings above.

to produce minima. It seems impossible that any contamination could have been so consistently present in all copper compounds examined, especially in both valences, and not be found in water or any other compound examined.

It is interesting to note that a copper isotope of mass 61 would fit into "The Natural System of Atomic Nuclei" proposed by Urey. The data above indicate merely that the weight is less than 63.

I wish to express my appreciation to Dr. Allison for the use of his apparatus and for his cooperation in the work.