Where CO.NH groupings functionate in such constructions it should be possible to replace hydrogen in such amide groupings with methyl by action of this reagent. The hydrolysis of the products of alkylation should lead to the formation of methyl derivatives of known constitution, thereby contributing new knowledge regarding the constitution of the parent substances. The final results of our researches will be published in the *Journal of the American Chemical Society.*

ABSORPTION OF SHORT X-RAYS BY ALUMINIUM AND COPPER

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1. In 1914 one of us presented to the American Roentgen Ray Society and to the American Physical Society descriptions of methods of measuring the average or "effective" wave-length of a beam of X-rays, without the use of an X-ray spectrometer. Mr. Hunt and one of us[1] have shown that even if a constant voltage (from a storage battery, for instance) drives a current through an X-ray tube the resulting X-rays are not monochromatic but contain X-rays covering a considerable range in the spectrum, that depends upon the absorption of the matter through which the rays pass, as well as upon the voltage applied. We define the term "effective" wave-length to mean the wave-length that has the same absorption in a given case as that of the whole beam. For many purposes this "effective" wave-length appears to be an important wave-length to know. The methods of estimating it described in 1914 were based upon a measurement of the absorption of the beam of X-rays in aluminium or copper and the determination of the wave-length from a curve giving the relation between the absorption of monochromatic X-rays and their wave-lengths. Curves were drawn from all the data available at the time representing this relation. It was proved that over a very wide range of wave-lengths, namely, from about 3 ångströms down to .35 of an ångström, the relation between the mass coefficients of absorption and the wave-lengths could be reasonably well represented by the equation

$$\frac{\mu}{\rho} = 14.9 \, \lambda^3, \tag{1}$$

where $\frac{\mu}{\rho}$ is the total mass coefficient of absorption and λ is the wave-length in ångströms.

Since 1914 Hull and Rice[2] and Richtmyer[3] have measured the co-efficients of absorption in aluminium and copper for wave-lengths lying between .75 and .135. They find that the relation between the mass co-

efficient of absorption and the wave-length may be expressed approximately by an equation of the form

$$\frac{\mu}{\rho} = k\lambda^3 + s. \tag{2}$$

Hull and Rice give for the constants k and s: $k = 14.9$ and $s = .12$ for aluminium; and $k = 150$ and $s = .12$ for copper, the range of wave-lengths lying between .392 and .147.

Richtmyer gives the following values for the constants k and s: for aluminium $k = 14.5$ or 14.3 and $s = .15$ or .16; and for copper $k = 147$ and $s = .5$.

2. As a great deal of work is now being done on X-rays of wave-lengths shorter than .135, we have undertaken to extend the measurements of the absorption in aluminium and copper to cover the range of these shorter waves. We have measured the mass coefficients of absorption for aluminium and copper for wave-lengths from .165 to .095.

In making these measurements we have used a Coolidge X-ray tube with a Tungsten target, excited by the high tension, constant voltage generating plant that has been described elsewhere. The constant voltage employed for these short waves amounted to about 160,000 volts. The X-ray spectrometer employed has been described also, together with the methods of protecting it against stray radiation, etc. This protection against stray radiation becomes of very great importance for the shorter, penetrating rays. It is sufficient to call attention to the fact that the X-ray tube with its generating plant was in one room and the spectrometer in an adjoining room, and that thick lead plates were fastened to the wall between the two rooms for additional protection. Further, the entire spectrometer was in a zinc box that completely surrounded it.

3. In making measurements of the coefficients of absorption we set the spectrometer to reflect a given wave-length into its ionization chamber. We then measure the ionization current with a plate of the absorbing substance placed between the X-ray tube and the hole in the wall through which the X-rays pass to the spectrometer. We next measure the ionization current with this plate removed. From each of these currents must be subtracted the current due to scattered radiation and to the natural leak in the instrument. This correction we estimate by turning the crystal of the spectrometer into such a position that it does not reflect rays into the ionization chamber, and measuring the ionization currents both with and without the absorbing plate in place. Subtracting the correction currents from the currents obtained with the crystal in its proper position, we get the fraction of radiation passing through the absorbing substance, and from this we calculate the mass coefficient of absorption in the usual way.

Aluminium plates of density 2.70 and plates of pure copper of density 8.92 were employed.

The following table contains the data obtained:

λ	$\frac{\mu}{\rho}$	
	ALUMINIUM	COPPER
.1653	.218	1.015
.1477	.194	.745
.1381	.189	.631
.1290	.182	.538
.1124	.167	.399
.0951	.161	.299

Our data agree very well with the values obtained by Richtmyer for wave-length .135.

4. In the figure we have plotted the mass coefficients against the cubes of the wave-lengths. Points marked (+) represent our measurements. Those marked (⊙) represent Richtmyer's data.

It appears that neither curve should be regarded as strictly a straight line. Both curves bend downward in the region of the shorter wave-lengths. Owing to this curvature it is impossible to estimate with certainty the points at which the curves strike the axis of zero wave-length. Extrapolations of this kind may lead to quite erroneous conclusions. The curves, however, appear to be pointing toward the values .146 for aluminium and .13 for copper at zero wave-length.

According to the usual method of analyzing coefficients of absorption into fluorescent and scattering coefficients these may be regarded as mass scattering coefficients for aluminium and copper, respectively. It is quite possible, however, that, according to some of the recent conceptions of absorption, this division of the coefficients into fluorescent and scattering coefficients may be somewhat artificial.

5. The following equations represent approximately the coefficients of absorption that we measured in the region of short wave-lengths:

$$\text{For aluminium } \frac{\mu}{\rho} = 15.5 \, \lambda^3 + .147$$

$$\text{For copper } \frac{\mu}{\rho} = 193 \, \lambda^3 + .13 \tag{3}$$

It will be noticed that the mass scattering coefficient for aluminium does not differ appreciably from that obtained by Richtmyer, and that the mass scattering coefficient for copper agrees well with that given by Hull and Rice. The coefficients of the terms containing the cube of the wave-length, however, are each larger than the corresponding quantities deduced by Hull and Rice and Richtmyer from their experiments on longer waves.

6. Evidently by means of the relation between the absorption and the wave-length it becomes possible in any practical case to determine the "effective" wave-length for a beam of X-rays by simply measuring the fraction of the radiation that passes through a plate of aluminium or a plate of copper. The details of such experiments will be given elsewhere. It is sufficient to note here that owing to the rapid change of absorption

The Mass Coefficients of Absorption of X-Rays.   Aluminium and Copper

The Cube of the Wave Length, λ^3.
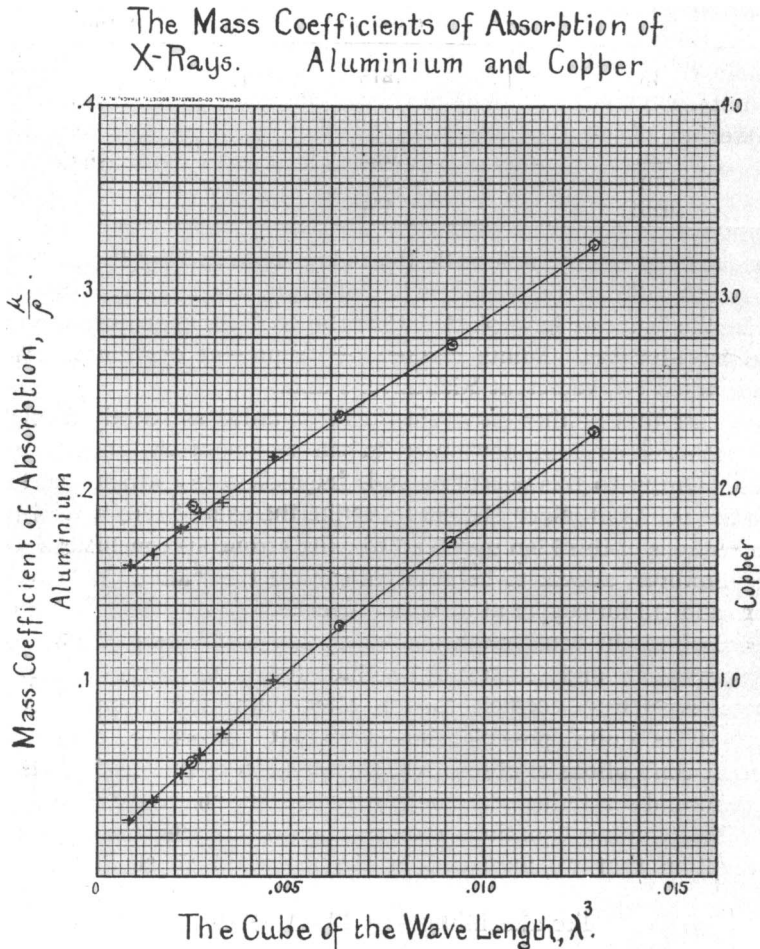
with wave-length, copper should be used for estimating the wave-length of short rays, whereas aluminium is better for longer ones.

In certain practical cases (in radio-therapy, for instance) another method of estimating the "effective" wave-length appears to be preferable. This consists in determining by means of an ionization chamber, a photographic plate or a fluorescent screen the thickness of aluminium that is

equivalent to a given thickness of copper. The ratio of the equivalent thicknesses of aluminium and copper changes a great deal in this short wave-length region of the X-ray spectrum. In the neighborhood of wave-length .3, for instance, an aluminium plate must be twenty-eight times as thick as a copper plate in order to absorb the same fraction of X-radiation. For wave-length .095, however, a plate of aluminium only 6 times as thick as a plate of copper will absorb the same fraction of X-radiation. The estimate of the equivalent thickness of aluminium and copper can be made comparatively easily and rapidly, so that the method furnishes a good means of determining the "effective" wave-length of a beam of X-rays during a treatment with them.

The curve giving the relation between the equivalent thickness and the wave-length will be published in a technical journal. The equivalent thickness for a given short wave-length can be calculated, of course, from equations (3), by dividing the linear coefficient of absorption for copper by that for aluminium.

The coefficient of absorption of a beam of rays that is not monochromatic usually (but not always) decreases as the rays pass through matter. If one measures the coefficient of absorption of such a beam, the results give a kind of average coefficient of absorption for the rays, as they travel through the absorbing material. Similarly, the above-mentioned methods of measuring the "effective" wave-lengths furnish a kind of average value for the "effective" wave-length of the beam as the rays pass through the plates.

[1] *Ithaca, Physic. Rev.,* August 1915, p. 166.
[2] *Ibid.,* Sept. 1916, p. 326.
[3] *Ibid.,* July 1921, p. 13.

THE EFFECTIVE TEMPERATURE OF 16 STARS AS ESTIMATED FROM THE ENERGY DISTRIBUTION IN THE COMPLETE SPECTRUM

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1. *Introductory Statement.*—Data on the spectral energy distribution of stars as related to that of a black body are very meager. They are the results practically of the spectrophotometric measurements of Wilsing,[1] and of Nordmann,[2] and the spectral energy curves determined photographically by Plaskett,[3] all of which relate to the visible spectrum.

The various methods used to obtain stellar temperatures give different results. For example, Plaskett (loc. cit.) obtained an effective temperature of 6800° K for γ *Cassiopeiae* (Class Bop) by considering the continuous spectrum and 10,600° K by considering the bright line spectrum.