scattering atom, and, as may be seen by considering the simple examples of the monatomic gas and the isotropic oscillator, gives a cross section which is formally correct to first order in $\hbar$.

Another case discussed by Vineyard[2] is that in which the atoms diffuse according to the Langevin equation. By means of the real function $\gamma'(\vec{\kappa}, t)$ it is possible to obtain an explicit expression for the cross section:

$$\Gamma'(\vec{\kappa}, \omega) = \frac{2}{\eta} e^{\alpha} \sum_{n=0}^{\infty} \frac{(-1)^n}{n!} \alpha^{n+1} \times \left[\frac{1}{(\alpha+n)^2+\beta^2} - \frac{1}{(\alpha+n+1)^2+\beta^2}\right], \quad (7)$$

where η is the coefficient of viscous damping, and

$$\alpha = k_B T\kappa^2/M\eta^2, \quad \beta = \omega/\eta.$$

The result obtained if the simple diffusion equation is used to derive $G(\vec{r}, t)$ corresponds to the first part of the first term in (7) so that unless both α and β are small, this approximation is not valid. In fact, (7) gives a width for the scattered energy distribution less than that given by both the simple diffusion model and the gas model. This is in agreement with the observations of Pelah et al.[3] on liquid lead. However, (7) does not give a width sufficiently small to explain the results of Turberfield[4] on lead with cold neutrons. These experiments indicate that the atoms of the liquid must make many vibrational oscillations between diffusive jumps, and the results cannot be interpreted on a basis of continuous diffusion.

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LEAD K ABSORPTION EDGE FOR μ-MESON MASS DETERMINATION

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The recent accurate determination of the f_μ/f_p ratio for the μ meson[1] and the comparison of the magnetic moment of the μ meson based on this measurement with the value predicted by quantum electrodynamics[2] depends critically on the mass of the μ meson. It has been shown experimentally that the $3D$-$2P$ transition in μ-mesonic phosphorus lies near the Pb K edge energy.[3] In fact, when considered in detail, it appears that the fine structure splitting of the $3D$-$2P$ transition in phosphorus will cause the lines to straddle the Pb K edge energy.[4] Therefore, it seems possible that one may use the variation of the mass-attenuation coefficient in lead as a function of energy in the K edge region as a very accurate measurement of the mesonic x-ray energy. The detailed shape of the lead K edge must be known precisely both in energy scale and mass-attenuation coefficient. Knowing these transition energies, and accounting for corrections due to vacuum polarization, nuclear size effects, etc., it would be possible to make a precise determination of the μ-meson mass. The transition energies for the mesonic phosphorus lines under discussion are given by[4]

$3D_{3/2} - 2P_{3/2}$: 425.42 m_μ/m_e, relative intensity = 1;

$3D_{5/2} - 2P_{3/2}$: 425.65 m_μ/m_e, relative intensity = 9;

$3D_{3/2} - 2P_{1/2}$: 427.75 m_μ/m_e, relative intensity = 5.

From the quoted "best value" of the μ-meson mass,[5] $m_\mu/m_e = 206.86 \pm 0.11$, the $3D_{5/2} - 2P_{3/2}$ transition would lie at 88 041 ev. The best estimate of the inflection point of the Pb K edge is at 88 014 ev,[6] and its width is of the order of 100 ev. The intent of this Letter is to present then an accurate measurement of the Pb K absorption edge.

A two-crystal spectrometer using the $20\bar{2}3$ planes of quartz as diffracting surfaces was constructed. Angles were measured by use of the precision circle of the Societé Genevoise goniometer of the Johns Hopkins x-ray laboratory.[7] In order to gain comparative freedom from scattering, distances of one meter were used between x-ray source, first crystal, second crystal, and detector. With this arrangement the signal to background ratio was never worse than one hundred to one. A commercial high kilovoltage x-ray tube[8] was used as an x-ray source, and a NaI(Tl) scintillation counter with single-channel pulse-height discrimination detected the radiation. The full width of the (1-1) rocking curve at the Pb K edge wavelength was 5.5″. The use of this narrow window allowed the determination of the edge shape without any appreciable interference due to window width. The "thickness effect" as previously reported[9,10] is negligible in this case, as was shown by measuring the mass-attenuation coefficient near the high side of the edge and varying the thickness of the absorbing foil. No change of mass-attenuation coefficient of more than two percent was detected over an absorber thickness from one-quarter to five absorption lengths. This absence of "thickness effect" is a distinct advantage of the high-resolution two-crystal instruments, and is due to the smaller unbent crystal diffraction widths and the larger dispersion obtainable by the two-crystal method.

The crystal spacing was determined by measuring the diffraction angles for Mo $K_{\alpha 1}$, Ag $K_{\alpha 1}$, and W $K_{\alpha 1}$ radiation. The lattice spacing for the $20\bar{2}3$ planes in quartz at 25°C was found to be (1372.117 ± 0.010) xu.

The Pb K edge determination was made with the diffracted x-ray beam passing through the crystals. As a check, the W $K_{\alpha 1}$ line was measured with: (1) the diffracted beam passing through the crystal; and (2) the diffracted beam in "reflection." No significant difference in diffraction angle could be detected, once the diffraction angle in case (2) was corrected for refraction in the crystal.

The measured shape of the Pb K edge for 98% purity lead foil[11] appears in Fig. 1. The energy scale is known to ±3 ev and the value of the mass-attenuation coefficient at any point is stated with a probable error of two percent. Since the $3D_{3/2}-2P_{1/2}$ transition probably lies entirely on the high absorption side of the Pb K edge, the mass-attenuation coefficient of lead was measured at 88 450 ev and found to be (7.30 ± 0.1) cm^2/gram.

As the two-crystal spectrometer measures the mass-attenuation coefficient for an extremely "good geometry," the mass-attenuation coefficient includes both photoelectric absorption and scattering cross sections. For any particular mesonic x-ray experiment, it is necessary to ascertain the amount of scattered radiation which enters the detector in order to arrive at the appropriate mass-attenuation coefficients for the unavoidable "poor geometry." Unfortunately, present measurements of the attenuation of $3D-2P$ mesonic x rays of phosphorus in lead[3] are not suitable for use in a precise determination of the μ-meson mass. Therefore, new experiments are essential to determine with high precision the attenuation in lead for these mesonic x-ray transitions.

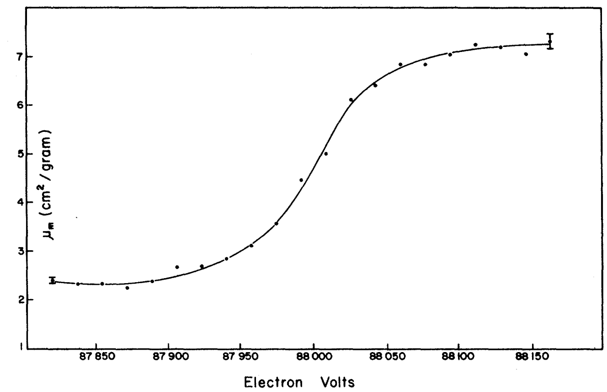

FIG. 1. Pb K absorption edge.

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