representing dipole and quadrupole interference terms. This is the same expression obtained for copper and cobalt. The solid line drawn through the experimental points of Fig. 1 is taken from the expression

$$(\sin\theta+0.25\sin\theta\cos\theta)^2$$

for the asymmetric component. Thus the amount of quadrupole absorption at these energies in carbon, about 1 percent in intensity, is less than that in copper and cobalt by a factor of 4.

The above analysis is considerably strengthened in the case of the $C^{12}(\gamma, p)B^{11}$ reaction in that the spins and parities of the initial and final states are known. From energetics considerations, only two levels of the residual B^{11} nucleus are involved, the ground level and the first excited level with 2.14 Mev of excitation. Transitions to the level at 4.46 Mev would yield protons of insufficient energy to reach the detectors. Transitions to the ground level of B^{11}, most probably a $p_{3/2}$ level,[3] could satisfy all conditions of conservation of angular momentum and parity for dipole-quadrupole interference and for the observed symmetric component. Transitions to the first excited level of B^{11} would also satisfy these conditions with a spin of $\frac{1}{2}$ or $\frac{3}{2}$ for this level.

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Absorption Coefficients of Gamma-Rays

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RECENTLY published measurements of the absorption coefficients of gamma-rays in the energy range from 0.3 to 2.8 Mev have, on the whole, confirmed the values calculated from theory. However, in the case of the radiation from Co^{60} (mean energy 1.25 Mev) Davisson and Evans[1] reported values of the total absorption coefficients for lead and tantalum which were 2 percent and 5 percent less than the theoretical values; while Shimizu, Hanai, and Okanoto[2] reported values which were between 3 percent and 5.5 percent less than the theoretical values for 6 elements with atomic numbers between 73 and 81.

I have recently measured absorption coefficients for C, Al, Cu, Mo, Ag, W, Pb, U, and H_2O, using the isotopes Hg^{203}, Cr^{51}, Ru^{103}, Rb^{86}, Co^{60}, and K^{42} as sources of gamma-radiation. The arrangement of apparatus and the method of measurement were very similar to those described by Shimizu, Hanai, and Okamoto. Corrections were applied for the effect of bremsstrahlung and Compton scatter from the source, and for Compton scatter and Rayleigh scatter from the absorber. The standard deviations in the corrected values of the absorption coefficients were between 0.5 percent and 1 percent in most cases, but were only 0.3 percent for the measurements made with Co.[60]

The theoretical values of the absorption coefficients were calculated in the usual way, from the Klein-Nishina formula for the Compton scatter coefficient, from Hulme *et al.*[3] for the photoelectric coefficient, and from Bethe and Heitler[4] for the pair production coefficient.

The measured and calculated values of the total electronic absorption coefficients are given in Table I, together with the standard deviations in the measured values due to experimental errors, and the possible errors in the theoretical values due to uncertainties in the values of the quantum energy. The values have all been multiplied by 10^{25}.

The measured values for elements of low atomic number agree, within the limits of the experimental errors, with the theoretical values, thus verifying the Klein-Nishina formula. On the other hand, the measured values for W, Pb, and U at the higher energies are significantly smaller than the theoretical values. There are no anomalous values, however. If the Klein-Nishina formula for Compton scatter and the Bethe and Heitler values of the pair production coefficient are assumed to be correct, the results indicate that the calculations of Hulme *et al.* for the photoelectric coefficient are in error by the amounts given in Table II. These amounts are the weighted means of the differences between the experimental and the theoretical values of the photoelectric coefficient for all the absorbers at each quantum energy.

A fuller account of this work is in preparation.

TABLE I. Measured and calculated values of $_e\mu\times10^{25}$, with the standard deviations. The experimental value for each absorber is listed first, with the theoretical value directly below. The γ-ray energies in the headings are in Mev. The numbers following ± are the standard deviations in the last two decimal places quoted.

	Hg^{203} 0.279	Cr^{51} 0.325	Ru^{103} 0.496	Rb^{86} 1.076	Co^{60} 1.1715 / 1.3316 ±10	K^{42} 1.51
Abs.						
H_2O	3.580±80	3.520±25	2.920±21	2.065±19	1.890±08	1.701±14
	3.631±05	3.429±11	2.902±04	2.037±03	1.885±02	1.713±06
C	3.720±40	3.476±25	2.879±16	2.032±13	1.874±06	1.697±16
	3.631±05	3.429±11	2.902±04	2.037±03	1.885±02	1.713±06
Al	3.693±81	3.473±19	2.876±21	2.052±13	1.893±05	1.714±17
	3.660±05	3.446±11	2.908±04	2.038±03	1.887±02	1.717±06
Cu	4.213±63	3.819±28	2.972±23	2.064±16	1.898±06	1.717±13
	4.151±10	3.773±18	3.013±05	2.055±03	1.901±02	1.733±06
Mo	···	···	3.268±19	2.105±20	1.945±06	···
			3.297±07	2.105±03	1.940±02	
Ag	6.234±78	5.331±45	3.454±20	2.154±13	1.959±05	1.766±14
	6.383±33	5.239±48	3.476±08	2.138±04	1.966±02	1.788±06
W	···	···	5.336±29	2.483±22	2.245±07	···
			5.490±22	2.521±05	2.264±03	
Pb	19.05±28	14.06±08	6.345±26	2.704±14	2.403±06	2.120±16
	18.94±16	13.76±22	6.491±29	2.728±06	2.425±03	2.143±11
U	···	18.10±14	8.026±32	3.027±23	2.641±09	2.303±12
		18.15±30	8.114±40	3.061±07	2.688±03	2.343±12

TABLE II. Values of $[(_e\tau_{expt}-{}_e\tau_{theor})/{}_e\tau_{theor}]\times100$, with standard deviations.

E(Mev)	0.279	0.325	0.496	1.076	1.1715 / 1.3316	1.51
% Error	−1.5±1.8	+1.9±2.1	−3.2±0.8	−3.5±1.5	−5.0±0.8	−6.8±2.3

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Investigations of Complex Structure in Alpha-Emission with Nuclear Emulsions*

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A STUDY has been made, utilizing the method of photographic emulsions, of the conversion electrons accompanying the complex alpha-group structure in a number of nuclides. These conversion electrons, coincident in origin with the alpha-particles, were identified in Ilford G-5 nuclear emulsions. Energies of the electrons were approximated from their range and this, together with postulation of the shell of conversion (or binding energy) of the electrons, allowed calculation of the gamma-ray energy or nuclear energy level separation. The percentage of alpha-particles having such conversion electrons associated with them represent a lower limit to the alpha-decay leading to the

TABLE I. Conversion electrons accompanying alpha-decay.

Isotope	Alpha-events observed	% having conversion electrons	Electron energies (kev)	Shell of conversion	Gamma-energy (kev)
Cm^{242}	5250	23±3	25±5(19%)	*L*	~45
			40±5 (4%)	*M*	~45
Am^{241}	2600	56±5	⩽20(12%)		several levels,
			20–35(31%)		highest at least
			35–60 (9%)		65 kev above the
			two electron coincidences (4%)		ground level
Pu^{239}	8100	12±2	30±5	*L*	~50
			45±5	*M*	~50
			20±5	*L*	~35
			30±5	*M*	~35
			100±20(0.5%)		origin uncertain
Pu^{238}	5700	23±3	20±5	*L*	~40
			35±5	*M*	~40
Pu^{236}	7000	20±3	25±5(17%)	*L*	~45
			40±5 (3%)	*M*	~45
Np^{237}	3500	80±5	⩽20(10%)		several levels,
			20–40(38%)		highest at least
			40–65(20%)		65 kev above the
			two electron coincidences (11%)		ground level
			three electron coincidences (1%)		
U^{238}	6300	22±3	25±5	*L*	~45
			40±5	*M*	~45
U^{235}	9700	27±3	30±5(23%)	*L*	~50
			45±5 (4%)	*M*	~50
U^{232}	8000	30±3	40±5	*L*	~60
			55±5	*M*	~60
Th^{232}	5100	24±3	35±5	*L*	~55
			50±5	*M*	~55
Sm^{147}	7500	0			

corresponding nuclear energy level since the unconverted gamma-rays are not measured by this technique.

Fresh plates were ordered frequently and used within three to eight weeks after the time of manufacture in order that no eradication of electron background (with associated densitization of the emulsion) would be required. Because of residual acidity left in the emulsion with the radioactivity through use of citrate or acetate complexing agents (to aid penetration of the radioactivity into the emulsion), a 30-minute presoaking of the plates in dilute Na_2CO_3 solution preceded normal development with Eastman D-19 solution. The customary period of exposure was 66 hours; where the daughter was a beta-emitter of sufficiently short half-life, appropriate corrections were made in the percentages of electron abundance. Alpha-particle emitting contaminants were negligible (0–1 percent) in all cases except U^{238} for which an isotopically enriched sample was used and appropriate corrections made for U^{234} and U^{235}. Close agreement was found between the present results and those of Asaro and co-workers in earlier work on the two nuclides Cm^{242} [1] and Pu^{238} [2] using the alpha-magnetic spectrometer; this was regarded as indicating satisfactory efficiency of the emulsion method in estimating both electron abundances and energies.

The results are summarized in Table I, where the gamma-ray energies are probably accurate to about 5 kev. As can be seen, in the case of the even-even emitters, the alpha-decay in every case divides between the ground state and one higher energy level of the daughter nucleus. Since the conversion coefficient for the gamma-ray seems to be high for all such daughter nuclei of the even-even type where this has been measured, it seems reasonable to assume that the percentages of conversion electrons listed in Table I correspond essentially to the percentages of the alpha-decays to the level above the ground state. For all the even-even nuclides both the low and high energy alpha-particle groups obey the relationship between energy and half-life quite well; that is, neither group exhibits appreciably the hindered decay characteristic of nuclides containing odd nucleons.[3,4] On the other hand, each of the nuclides with odd nucleons exhibits alpha-decay to several energy levels with widely varying percentages; for these, the decay to one of the excited states is in each case less hindered than the corresponding decay to the ground state, in agreement with the view that the conditions for the assembly of the outgoing alpha-particle can be more favorable in certain instances when the highest lying odd nucleon need not be included.[3]

Results similar to those presented here have been reported for U^{238} [5,6] and Pu^{239} [7] using the same technique.

This work will be reported in more detail in a forthcoming publication.

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Mass of V^{50}†

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HESS and Ingham[1] and Leland[2] have found recently that vanadium has a naturally occurring odd-odd isotope at mass 50, having an abundance of 0.24 percent. Titanium and chromium also have isotopes at mass 50, and the question of radioactivity of V^{50} immediately arises. At least one unsuccessful search[2] for activity has been reported. One reason for the lack of an observable activity could be small energy differences between V^{50}, Cr^{50}, and Ti^{50}. In order to investigate the energy differences, I have determined the masses by the doublet method using a double-focusing mass spectrometer.[3,4]

The technique used in measuring the V^{50} doublet is the same as was used for other metals in this mass region. A normal vanadium metal sample of about 0.5 mg, was spot welded to a tungsten ribbon. The ribbon was then mounted in the source and heated, evaporating vanadium which was ionized by an electron beam. The comparison peak was a fragment C_4H_2 obtained from butadiene. The average of five runs yields a mass difference

$$C_4H_2-V^{50}=683.6\pm1.2\times10^{-4}\text{ amu.}$$

Each run consisted of 10 separate doublet tracings and required a small correction for C^{13} which was never greater than 0.07 percent of the doublet difference. Several hydrogen mass doublets ($C_4H_3-C_4H_2$) measured during the same period had an error less than 0.03 percent. Using $H^1=1.008146\pm3$ and $C^{12}=12.003842\pm4$ we compute the mass of V^{50} as 49.96330 ± 12.

The mass doublets $C_4H_2-Cr^{50}$ and $C_4H_2-Ti^{50}$ were measured under the same experimental conditions as the doublet $C_4H_2-V^{50}$. Four runs were made for each of these doublets and the results obtained agreed closely with those previously found.[5] The new data combined with the old yield

$$C_4H_2-Ti^{50}=709.27\pm0.27;$$
$$C_4H_2-Cr^{50}=696.34\pm0.46.$$