previous determinations have been somewhat ambiguous, as is evidenced by the fact that Auger's[1] data have been interpreted to give a ten percent latitude effect for the soft component by Heisenberg[2] and a zero percent latitude effect by Heitler.[3]

We have paid particular attention to the estimates of probable errors in our calculations, based on the individual probable errors of the individual intensities of the components as measured in the high latitudes and at the equator. The probable errors of the intensities are estimated in the usual manner from the total number of counts obtained for a given condition. The probable errors are derived for the determination of the latitude effects using standard statistical concepts.

In Table I we have summarized the results for the separate telescopes and for the combined results. It is interesting to note that the latitude effects for the total radiation and the hard component are smaller than have been reported previously. (Arley[4] summarizes previous results as indicating a sea level latitude effect of from 10 to 20 percent.) Of greater interest, however, is the fact that our data strongly indicate the existence of a sea level latitude effect for the soft component whose magnitude is of the same order as that for the hard and total radiation.

If the soft component is defined as that radiation which is absorbed in 10 cm of lead, the radiation is largely restricted, except for Auger showers, to that which is formed below one kilometer from the earth's surface, by mesotron decay and knock-on processes from the mesotron component existing near sea level, rather than pair formation having to do with primary electrons or with electrons produced near the top of the atmosphere. It is not surprising to us, therefore, to find the latitude effects of the hard and soft components of comparable magnitude.

* Supported by funds from Navy Contract N6ori-144 and from the National Geographic Society, also by airplane services from the U. S. Army Air Force.

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Total Cross Sections of Nuclei for 90-Mev Neutrons

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GOOD geometry neutron attenuation measurements have been made, using the 184-inch cyclotron as a neutron source and carbon disks as detectors. The line-up of equipment was as follows:

1. Source: This was a $\frac{1}{2}$-in. Be target inside the cyclotron traversed by 190-Mev deuterons, giving neutrons of 90-Mev mean energy and an energy distribution having a width of about 27 Mev between points of half-maximum intensity.[1,2]

2. Neutron window in tank wall in line of neutron beam: This window is of spun aluminum, $\frac{1}{8}$ in. thick$\times$32-in. diameter, and its purpose is to reduce the amount of scattering material in the path of the beam.

3. Detector: A carbon disk $\frac{1}{8}$ in. thick$\times 1\frac{11}{16}$-in. diameter was placed 17 feet from the source. This had the 20.5-min. C^{11} induced in it by the $(n, 2n)$ reaction; the activity was of the order of a few thousand counts per minute after a 1.5-minute exposure.

4. Scattering blocks: These were $2\frac{1}{2}$ in. in diameter and of various lengths and were placed about midway between source and detector.

5. Monitor: A carbon disk similar to the detector was placed between the source and the scattering block.

Source, monitor, scatterer, and detector were lined up accurately with the aid of a cathetometer. Each measurement consisted of a determination of the ratio (detector activity/monitor activity) with G-M counters. This was done with no scatterer (blank), with a very long copper scatterer (background), and with the scatterer whose attenuation was being measured. The background, arising from scattering in the window, sample supports, and other surrounding material, was 6 percent of the blank. Absorption curves were run on paraffin, carbon, aluminum, and copper, and these were exponential as far as they could be followed accurately in the presence of the background (to about 1/20 of the initial intensity). The most accurate cross-section measurements were made with scatterers about one mean free path long, on which repeated measurements were made to improve the statistics. The spread found in these individual measurements was what was expected from the number of counts taken.

Li, Be, C, Mg, Al, Cu, Zn, Sn, Pb, and U were done as the elements. H was done by taking the difference between carbon and paraffin blocks having about the same attenuation, the readings being taken alternately on the two blocks. The difference $D-H$ was found by a similar direct comparison of heavy and light water contained in thin-walled aluminum cells. O, N, and Cl were computed from the attenuations in water, melamine, and carbon tetrachloride. The statistical mean errors in the direct measurements are 1 percent, and greater than this in the difference measurements; the quoted mean errors include an additional 1 percent added to allow for other possible sources of error. A computed correction has been made for the error caused

TABLE I.

Substance	Total cross section (barns) (10^{-24} cm^2)
H	0.083 ±0.004
*D	0.117 ±0.005
Li	0.314 ±0.006
Be	0.431 ±0.008
C	0.550 ±0.011
N	0.656 ±0.021
O	0.765 ±0.020
Mg	1.03 ±0.02
Al	1.12 ±0.02
Cl	1.38 ±0.03
Cu	2.22 ±0.04
Zn	2.21 ±0.04
Sn	3.28 ±0.06
Pb	4.53 ±0.09
U	5.03 ±0.10

* The difference $D-H$, which may be interpreted roughly as the $n-n$ cross section, is good to ±0.003.

by neutrons diffracted into the detector by the scatterers; its greatest value is about 3 percent. The results are given in Table I.

If these cross sections are expressed in terms of a collision radius R, were $\sigma=2\pi R^2$, and plotted against $A^{\frac{1}{3}}$ as done by Sherr,[3] it is seen that the values from Li to U lie on a nearly smooth curve, and are all below Sherr's line $[R=(1.7+1.22A^{\frac{1}{3}})\times10^{-13}\text{ cm}]$ for 25-Mev neutrons. The difference becomes less for the heavier nuclei, as if the values are tending to approach a line near his. One possible interpretation is to say that the lighter nuclei are partially transparent, and approach opacity with increasing A. Dr. Serber has shown[4] that such an interpretation is well justified. An empirical formula that fits the data from Li to U very well is: $R=(0.5+1.37A^{\frac{1}{3}})[1-\exp(-0.49A^{\frac{1}{3}})]\times10^{-13}$ cm. This formula is not intended to have any theoretical significance, but may be useful for purposes of interpolation. From Li to O, the cross sections are nearly proportional to A. A complete account of this work will be published later.

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The Uncertainty Principle and the Yield of Nuclei Formed in Fission

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A RECENT letter by Dempster[1] discussed the yield curve[2] for the nuclei formed in fission from the standpoint of the liquid-drop model. As an alternative, the hypothesis is here advanced that the yield curve is related to the Heisenberg uncertainty principle in much the same ways as the line breadth of atomic spectra.[3]

Just before the moment of separation of the two fragment nuclei, produced by the fission process, nucleons may be pictured as passing through the area of contact caused by the "thermal" agitation of the particles forming the nucleus. The quantum-mechanical waves associated with these particles have an extent comparable with that of the nuclei themselves, and thus the time for a wave to pass the contact surface will be Bethe's[4] "characteristic nuclear time," 3×10^{-22} sec. The uncertainty in the time of final break between the fragments must be of a comparable magnitude.

From the width of the yield curve at half-maximum and Dempster's curve connecting the masses of the fragments with the energy a value, $\Delta E\approx18$ Mev, is obtained for the uncertainty in the energy. The use of the relation

$$\Delta E\Delta t\approx h/2\pi$$

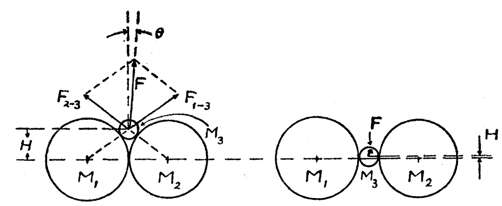

FIG. 1. Curve A gives the experimentally observed fission yields on a logarithmic scale. Curve B is calculated assuming cores of 60- and 16-mass units for the heavy and light fragments, respectively. Curve C gives the calculated yields when all nucleons have equal probability of being in either fragment.

then gives $\Delta t\approx3.6\times10^{-22}$ sec., in reasonably good agreement with the value postulated above.

This suggests the possibility that some of the nucleons, at least, have wave functions giving them an appreciable probability of being in either fragment at the time of fission, and that the yield curve is the net result of the various probabilities for the nucleons involved. The yield curve itself gives a clue as to the number of nucleons involved. Since the difference between the two maxima of the curve is 44 mass units, we assume "cores" for the two fragments differing by that amount, taking for the heavy fragment a core of mass number 60 (the nucleus having the largest known negative packing fraction[5]) and for the light fragment mass number 16. The remaining 158 nucleons are assumed to have equal probability of being in either fragment. Figure 1 shows a curve calculated from the well-known theory of combinations and based on the above assumptions along with the observed curve. The calculated curve gives a value of 6.3 percent at the maxima and underestimates the yield near the maxima while overestimating it in more remote regions. This may arise because neutrons and protons are not distinguished in the calculation. The curve which would be obtained when all nucleons have equal probability of being in either fragment is also shown for comparison.

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Microwave Spectrum Frequency Markers*

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MEASUREMENT of the separation of the satellites of NH_3 microwave spectrum lines exhibiting quadrupole splitting has been reported by Strandberg and others,[1] and subsequently by Watts and Williams.[2] In their experiments the microwave oscillator was frequency modulated by the application of a variable intermediate frequency component of known frequency to the reflector voltage. This caused the microwave oscillator simul-