TABLE I. Dielectric constant, permeability and $\tan\delta_{\epsilon,\mu}$ of various ferrites at a wavelength of 6.6 cm; thickness of the specimen is 1.5 mm.

Ferrite	ϵ_1	ϵ_2	$\tan\delta_\epsilon$	μ_1	μ_2	$\tan\delta_\mu$
$MgOFe_2O_3$ quenched from 1200°C	9.66	0.174	0.018	1.20	0.974	0.812
$MgOFe_2O_3$ slow cooled	8.53	0.132	0.016	2.84	0.341	0.120
$CuOFe_2O_3$ quenched from 1000°C	9.29	0.520	0.056	1.94	1.240	0.639
$CuOFe_2O_3$ slow cooled	8.65	0.089	0.010	1.38	0.740	0.543
$CoOFe_2O_3$ quenched from 1200°C	9.49	0.045	0.047	1.57	0.211	0.138
$CoOFe_2O_3$ slow cooled	9.00			1.90	0.116	0.061
$NiOFe_2O_3$ quenched from 1200°C	13.40	3.520	0.260	1.74	0.460	0.264
$NiOFe_2O_3$ slow cooled	8.88	0.155	0.017	1.47	2.377	1.620
$MnOFe_2O_3$ quenched from 1200°C	9.30	0.475	0.051	2.31	2.040	0.883

as uniform. The same experiment was also made with a specimen of different size, 1 mm in thickness and 20 mm in diameter, but no effect of the thickness could be observed in the present experiment.

Details will be published in the Scientific Reports of the Research Institute of Tohoku University.

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The Closing of the Proton Sub-Shell at *Z* 58

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NUCLEI containing 2, 8, 20, 28, 50, 82, and 126 neutrons and protons are particularly stable. The extra stability of these nuclei is attributed to the completion of the neutron or proton shells at these numbers. Of the various schemes[1–4] suggested to explain this, the one due to Mayer[5] and Jensen *et al.*[4] seems to fit the data best. They explain the occurrence of these magic numbers on a single particle model with a strong spin-orbit coupling, and the levels responsible for the aforementioned magic numbers are $1s_{1/2}$, $1p_{3/2,1/2}$, $2s_{1/2}$, $1f_{1/2}$, $1g_{9/2}$, $1h_{11/2}$, and $1i_{13/2}$ [Mayer[5]].

There is some dispute about the closing of the shells at N or $Z=20$.[6] On the other hand, there is evidence to show that there is a closing of the shell at N or $Z=40$.[7] On Mayer's scheme, this can happen by the filling up of the sub-shells $2p_{3/2,1/2}$; but with considerations like this, one would expect the systems with 58, 68, 70, 92, 106, 112, 138, and 156 neutrons or protons, in addition to the usual magic number isotopes, to be specially stable because of the filling up of $1g_{7/2}$, $2d_{5/2,3/2}$, $3s_{1/2}$, $1h_{9/2}$, $2f_{7/2,5/2}$, $3p_{3/2,1/2}$, and $1i_{11/2}$, respectively. Besides these, Feenberg and Hammack[2] have suggested, on the basis of the nonoccurrence of stable isotopes with N or $Z=61$, that perhaps there is a closing of the shells $4d$ at N or $Z=60$, giving rise to an extra stable configuration. It seems to us that instances like β-stable $_{51}Sb$ and $_{84}Ac\,C'^{211}$ show that a magic number configuration is not necessarily followed by an unstable one. It seems to us that one should expect the occurrence of extra stable configurations only if the building up of the nucleus of the isotope in question is as regular as, say, the Mayer scheme. An examination of the table of spins and magnetic moments[8] shows that this is not always so. In this connection it is worthwhile emphasizing what Mayer has pointed out, that in the region between N or $Z=50$ and 82, the last odd proton, in contrast to the last odd neutron, is usually found in an orbit of high angular momentum, perhaps due to the Coulomb repulsion tending to concentrate the charge on the periphery of the nuclei. So far as the neutron shells are concerned, the examination of the neutron binding energy values[9] and the results of the mass spectrometer studies[7] suggest the closing of the neutron shells at $N=60$ and 70.

Although it is difficult to say what happens at the neutron numbers 58, 68, 92, 106, 112, and others mentioned above, one can readily say that there is no closing of the proton shell at $Z=92$, and the protons between $Z=83$ and 91 are not filled in the level $1h_{9/2}$; this is based on the fact that the spin of $_{91}Pa^{231}$ is 3/2[8] and that of $_{89}Ac^{227}$ is 3/2.[10] In the case of the closing of the shell there, the spin of at least $_{91}Pa^{231}$ (which would in that case be a nucleus with a hole in the level $1h_{9/2}$) should have been 9/2 as in the case of $_{83}Bi^{209}$.

The case of the element cerium ($Z=58$) is different. In this region the heavier of the two stable isotopes of $_{51}Sb$ and $_{53}I$, and the even N isotopes of $_{55}Cs$ and $_{57}La$ have all spin 7/2, pointing to the fact that the level $2g_{7/2}$ is regularly filled; and after the completion of this sub-shell, the protons start filling the shell $2d_{5/2}$ as is shown by the occurrence of spin 5/2 in $_{59}Pr^{141}$ and $_{63}Eu^{151,153}$.[8]

What one can thus surmise on this point from the evidences of the spin values is corroborated by the results of the mass spectrometer measurements. Duckworth *et al.*[11] have shown, by plotting the average nucleon binding energy (calculated from the packing fraction values) *vs* the mass number, that there is a kink in the curve wherever the nucleus is doubly magic; the kink is interpreted as being caused by a sudden fall in the average nucleon binding energy in the isotopes that follow. This they first showed for $_{14}Si^{30}$, $_{28}Ni^{60}$, $_{40}Zr^{90}$, $_{50}Sn^{120}$, and $_{82}Pb^{208}$; and recently they have shown this for $_{58}Ce^{140}$. We have approached the problem more directly. Instead of relying on the average binding energy, we have sought to calculate the binding energy of the last proton.

On the single particle model one can think of the β^- decay as the neutron in the topmost ground-state level emitting an electron and a neutrino, being converted into a proton, and then making a transition to the proton level, energetically permitted and most allowed. In case the allowed level is not the ground state, there is a subsequent emission of gamma-radiation. Similarly, the positron emission can be thought of as the proton emitting a positive electron and a neutrino, being converted into a neutron, and then making a transition to the neutron level energetically permitted and most allowed. On this basis then, we can write for the maximum energy of the beta-emission (including any gamma-radiation emitted in cascade)[12,13]

$$E_{\beta^-}=B_p(Z+1,A)-B_n(Z,A)-0.75\ \text{Mev}$$
$$E_{\beta^+}=B_n(Z+1,A)-B_p(Z,A)-1.77\ \text{Mev}$$
$$E_K=B_n(Z+1,A)-B_p(Z,A)-0.75\ \text{Mev},$$

where $B_p(Z,A)$ and $B_n(Z,A)$ are the binding energy of the last proton and the last neutron respectively in the isotope (Z,A). B_n and B_p values in the region of Pb have been given by Way,[14] Kinsey *et al.*,[15] and Harvey.[9] By making use of their values and the above formulas, the maximum energies of the betas can be calculated quite accurately. In the region of cerium no proton binding energies are experimentally known; but the neutron binding energies in the following have been measured:

B_n in $_{56}Ba^{137,138,139}$	7.1,[16] 8.7,[16] 5.2[9] Mev, respectively
$_{57}La^{139}$	8.8 or 9.8[16] Mev
$_{58}Ce^{140,142}$	8.7, 6.7 Mev, respectively[16]
$_{59}Pr^{141}$	9.4 or 9.8 Mev.[9]

From these values and the beta-decay data[17] we can calculate with the help of the above formula the B_p values in some of the isotopes in this region. They come out as given below:

B_p in ${}_{57}La^{137,138}$~7 Mev
${}_{58}Ce^{140,142}$~8 Mev
${}_{59}Pr^{140,142}$ = 4.5 and 6 Mev, respectively
${}_{60}Nd^{141}$ ~7 Mev.

The sudden drop in the binding energy values is exactly what is observed for the 51st and the 83rd neutrons and protons, and for the 127th neutron. One can feel, therefore, that the occurrence of a similar situation for the 59th proton is a very strong evidence in favor of the view, suggested from other considerations also, that there is a completion of the proton sub-shell $1g_{7/2}$ at $Z=58$ making ${}_{58}Ce^{140}$ a doubly magic isotope.

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The Ionization Loss of Energy of Relativistic Mu-Mesons in Argon*

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SINCE recent observations with mu-mesons[1] in dispersed media indicate an absence of the relativistic rise in the ionization loss of these particles, we have studied the variation with energy of the ionization loss of cosmic-ray mu-mesons in proportional counters filled to 1.6 atmospheres with a mixture of 97 percent argon and 3 percent CO_2.

Two proportional counters, located one above the other, were employed as an aid in the analysis of the data. A series of Geiger counter telescopes selected those vertically incident mesons which traversed at least 10 cm of Pb and both proportional counters. No path length in the proportional counters deviated from the mean path length (3.75 inches) by more than 1.5 percent. The mesons were divided into four range groups (Table I) by means of Pb absorbers and coincident counter trays, the arrangement of the various components being similar to that of Bowen and Roser.[2] The output of each proportional counter channel was displayed on a meter and photographed along with a system of lights which indicated the range tray coincidences. An important feature is the concurrent registration of data on all four range groups.

Table I. Mean energy loss of four energy groups.

Range in Pb (cm)	Energy limits (Mev)	Counter	Mean energy loss (kev)	
			Calc.	Exptal.[a]
10.3– 30.1	160– 400	Upper	29.9	29.9 ±0.5[b]
		Lower	30.3	30.3 ±0.5[b]
30.1– 63.2	400– 840	Upper	31.3	31.7 ±0.4
		Lower	31.5	32.3 ±0.5
63.2–130.2	840–1800	Upper	33.1	33.2 ±0.4
		Lower	33.6	34.7 ±0.4
130.2–	1800–	Upper	37.3	36.7 ±0.4
		Lower	37.9	37.9 ±0.3

a Standard deviation.
b Normalized to calculated value of mean energy loss.

Several runs have been taken to date, all with similar results. In the table are given the final results for that run in which the greatest amount of Pb absorber was used and the greatest number of particles observed (897). We have compared the mean observed energy loss with that to be expected on the basis of a correction to allow for off scale meter readings from high energy loss fluctuations. This latter correction necessitated that we use the Landau[3] distribution.

Assuming a constant relationship between energy loss and number of ion pairs produced, we conclude that within the limits of accuracy of our measurements, the Bethe,[4] Bloch,[5] and Williams[6] theory of energy loss, as extended by Landau to account for fluctuations in the energy loss, predicts quite accurately our observed rise in energy loss with increasing energy of mu-mesons. This result for an argon-CO_2 mixture, which has previously been obtained for mu-mesons in hydrogen by shamos and Hudes with low efficiency Geiger counters containing hydrogen,[7] is quite contrary to the observations of Goodman, Nicholson, and Rathgeber who used an argon-ethylene mixture. A full report of this work is in preparation.

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Transmission and Spectral Response of Lead Sulfide and Lead Telluride*

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THE spectral response of lead sulfide and lead telluride photoconductive films has been known for some time. These compounds, as well as thallous sulfide and lead selenide, have been found to produce photoconductive layers with sensitivity in the

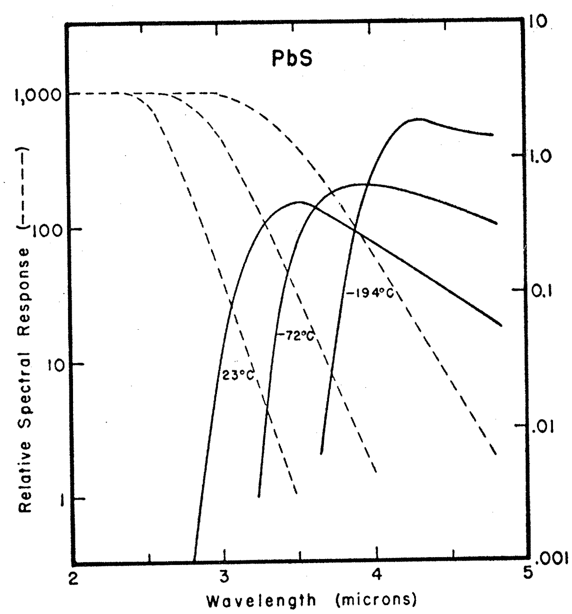

Fig. 1. Transmission of lead sulfide crystal, thickness 0.48 mm. Relative spectral response of lead sulfide photocells.