TABLE I. Yields relative to $N^{14}(\gamma, n)N^{13}$ yield as unity.

Reaction	Product half-life	Product betas and energies (Mev)	Relative yield 100 Mev	Relative yield 50 Mev
$_{24}Cr^{50}(\gamma, n)_{24}Cr^{49}$	42 min.	$\beta^+1.45$	13	12
$_{26}Fe^{54}(\gamma, n)_{26}Fe^{53}$	8.9 min.	β^+[a]	15	15
$_{28}Ni^{58}(\gamma, n)_{28}Ni^{57}$	36 hr.	$\beta^+0.67$ K[b]	>6.3	>6.0
$_{29}Cu^{65}(\gamma, n)_{29}Cu^{64}$	12.8 hr.	$\beta^+0.66(15\%)$ $\beta^-0.58(32\%)$ K[c,d] (53%)	41	32
$_{30}Zn^{64}(\gamma, n)_{30}Zn^{63}$	38 min.	$\beta^+0.5(1\%)$ 1.4(7%) 2.4(85%) K[e] (7%)	26	26
$_{32}Ge^{76}(\gamma, n)_{32}Ge^{75}$	89 min.	$\beta^-1.1$	54	
$_{53}I^{127}(\gamma, n)_{53}I^{126}$	13 days	$\beta^-1.1$ K	>29	>30
$_{59}Pr^{141}(\gamma, n)_{59}Pr^{140}$	3.5 min.	$\beta^+2.40$	73	76
$_{32}Ge^{74}(\gamma, p)_{31}Ga^{73}$	5 hr.	$\beta^-1.4$	2.5	
$_{32}Ge^{70}(\gamma, pn)_{31}Ga^{68}$	68 min.	$\beta^+1.9$	3.4	

[a] Energy not known but self-absorption of betas found to be small in this case.
[b] The writer is indebted to Dr. G. Friedlander for the information that Ni^{57} decays by K-capture as well as by positron emission.
[c] H. Bradt *et al.*, Helv. Phys. Acta **19**, 219 (1946).
[d] C. S. Cook and L. M. Langer, Phys. Rev. **74**, 1241A (1948).
[e] Huber, Medicus, Preiswerk, and Steffen, Helv. Phys. Acta **20**, 495 (1947).

(γ, n) reaction induced by 100-Mev and by 50-Mev x-rays.[1] For reactions studied on nuclides of mass number less than 60, the (γ, n) yield values relative to the yield of the reaction $N^{14}(\gamma, n)N^{13}$ vary from 1 to 6; in the range of mass numbers between 60 and 120 yield values vary from 33 to 46. The one (γ, n) reaction investigated above mass number 121, $Re^{187}(\gamma, n)Re^{186}$, has a yield of 85.

Further work has now been done with (γ, n) reactions in the vicinity of mass number 60. Measurements have been made also on two additional (γ, n) reactions in heavy elements. Incidental to this work, data on two other reactions have been obtained. The experimental method, which has been described in detail,[1] depends upon the measurement of the radioactivity of product nuclei. New results are summarized in Table I. The yield of the reaction $N^{14}(\gamma, n)N^{13}$ has been taken as unity at each x-ray energy.

To avoid the possibility that yield values for the first two reactions listed might be in error because of the production of Cr^{49} and Fe^{53} by $(\gamma, 3n)$ processes from Cr^{52} and Fe^{56}, whose abundances are roughly 15 times those of Cr^{50} and Fe^{54}, materials enriched[2] in Cr^{50} and in Fe^{54} were used for targets. It has been assumed that the measurement of the Cr^{49} and Fe^{53} activities was not complicated by the decay of daughters V^{49} and Mn^{53} in the two cases, respectively. This assumption is in agreement with what is known about V and Mn activities; if, however, the half-lives of V^{49} and Mn^{53} are short compared with those of Cr^{49} and Fe^{53}, the yield values in these two instances are too large by a factor 2. The yield values in the Ni and I cases are lower limits because of uncertainties in the decay schemes of Ni^{57} and I^{126}. The data for the three reactions in which isotopes of Ge are parents were obtained by measurement of chemically separated Ga and Ge fractions from a bombarded sample of pure GeO_2. The time elapsed between end of bombardment and measurement of activity was too great to permit observation of 20-minute Ga^{70}. The yield value for the reaction $Ge^{76}(\gamma, n)Ge^{75}$ may be perhaps 10 percent large if Ga^{75}, the product of a (γ, p) reaction, is short-lived compared with Ge^{75}.

The data for the Cr, Fe, and Ni(γ, n) reactions would make it seem that the increase in the (γ, n) yields in the vicinity of mass number 60 occurs over a range of mass numbers perhaps as great as 15. The yield for the reaction $Pr^{141}(\gamma, n)Pr^{140}$ is high compared with yields for lighter nuclides. This is true also for the Re reaction previously studied; it may be that (γ, n) yields values will show another general increase in the vicinity of mass number 130. The correlation between (γ, n) yields with 50-Mev and with 100-Mev x-rays is not unexpected; it has been found that quanta having energies greater than 50 Mev do not contribute very much to the (γ, n) yields in the two cases thus far investigated.[3,4]

The yield for the only (γ, pn) reaction investigated is of the same order as (γ, p) yields. It may be pointed out in comparison that in the three $(\gamma, 2n)$ cases for which data are available yields are at least a factor 10 smaller than (γ, n) yields at corresponding mass numbers and, moreover, that the known $(\gamma, 2p)$ yields are smaller by a factor approximately 20 than (γ, p) yields.[1]

The writer is indebted to Dr. G. Friedlander for stimulating discussions. He wishes to express his appreciation to Dr. E. E. Charlton for his cooperation and to Mr. G. Jaffe for his valuable assistance.

* Present address: Department of Chemistry, University of Wyoming, Laramie, Wyoming.

[1] M. L. Perlman and G. Friedlander, Phys. Rev. **74**, 442 (1948).
[2] The isotopically enriched materials were produced by the Carbide and Carbon Chemicals Corporation, Y-12 Plant, Oak Ridge, Tennessee, and were obtained on allocation from the Isotopes Division, U. S. Atomic Energy Commission.
[3] G. C. Baldwin and G. S. Klaiber, Phys. Rev. **73**, 1156 (1948).
[4] J. L. Lawson and M. L. Perlman, Phys. Rev. **74**, 1190 (1948).

Dielectric Constant of Barium Titanate at High Temperatures

SHEPARD ROBERTS
Research Laboratory, General Electric Company, Schnectady, New York
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FOR some time it has been thought that the dielectric constant of barium titanate at temperatures above the Curie point (120°C) could be accurately represented by the Curie-Weiss law.[1–4]

$$K = C/(T - T_c), \tag{1}$$

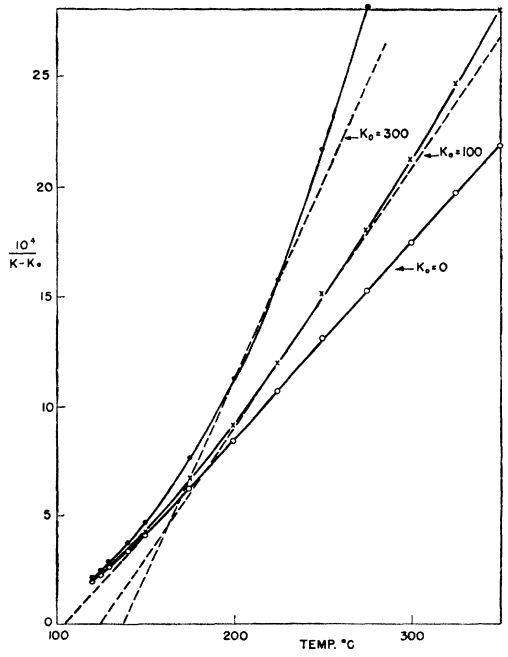

FIG. 1. Reciprocal of $(K - K_0)$ *versus* temperature for different values of K_0

TABLE I. Dielectric constant (K) and loss ($\tan\delta$) of barium titanate at one megacycle.

Temp. °C	K	$\tan\delta$	Temp. °C	K	$\tan\delta$
25	1525	0.009	150	2450	0.002
50	1413	0.011	175	1610	0.001
75	1440	0.010	200	1190	0.001
100	1750	0.014	225	933	0.002
110	2450	0.016	250	761	0.002
115	5070	0.013	275	656	0.007
120	5070	0.009	300	572	0.016
125	4430	0.006	325	506	0.040
130	3820	0.004	350	457	0.087
140	2970	0.003			

where C and T_c are parameters suitably chosen to fit the experimental data and T is the temperature.

However, a new parameter has been introduced in this equation in a more recent article.[5]

$$K=K_0+C/(T-T_c), \tag{2}$$

where K_0 is thought to be the dielectric constant of barium titanate at extremely high or extremely low temperatures. A value of 350 was quoted for K_0, since the dielectric constant reached this value at temperatures near absolute zero. Previously published data, extending only to about 200°C, may be interpreted by either equation since the choice of K_0 is not critical in this range of temperature. The object of the present note is to report measurements of dielectric constant of barium titanate up to much higher temperatures and from these data to determine the value of K_0 directly.

Table I shows results of measurements of dielectric constant and loss of barium titanate ceramic at temperatures up to 350°C. The frequency was one megacycle and the sample was of commercial purity.

In order to find the value of K_0, which most closely fits the experimental data, the reciprocal of $(K-K_0)$ is shown plotted *versus* temperature for different values of K_0 (see Fig. 1). According to Eq. (2), the points corresponding to the correct choice of K_0 should lie on a straight line. This occurs when $K_0=0$ and clearly fails when $K_0=100$ or 300. The line determined by the experimental data, assuming $K_0=0$, is so accurately straight that one can estimate the value of K_0 to be less than 10, if it exists at all, a value quite negligible compared to the dielectric constant measured at ordinary temperatures.

These results at a frequency of one megacycle indicate that Eq. (1) gives a perfectly satisfactory interpretation of the experimental data for temperatures above 150°C. For temperatures nearer the Curie point, there are slight deviations which are not consistent with either equation.

[1] D. F. Rushman and M. A. Strivens, Trans. Faraday Soc. **42A**, 231 (1946).
[2] B. Wul, J. Phys. U.S.S.R. **10**, 95 (1946).
[3] S. Roberts, Phys. Rev. **71**, 890 (1947).
[4] G. H. Jonker and J. H. Van Santen, Chem. Weekblad **43**, 672 (1947); Nature **159**, 334 (1947).
[5] W. P. Mason and B. T. Matthias, Phys. Rev. **74**, 1622 (1948).

Fission Fragment Energies in U^{235} and U^{233}

D. C. BRUNTON AND G. C. HANNA
Chalk River Laboratory, National Research Council of Canada, Chalk River, Ontario, Canada

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MANY measurements have been made of the energy distribution of fission fragments.[1–7] Among these, several experiments[3–5] have used a coincident pulse technique. In particular, Deutsch and Ramsey[5] have compared the energy distributions from U^{235} and Pu^{239}. The present experiments were undertaken to extend this comparison to U^{233} and to improve the statistical accuracy of the results.

A double "back-to-back" ionization chamber was used with a thin source mounted on the common cathode. Electron collection was employed with Frisch grids shielding the collecting electrodes.[8] Fragments in a small energy interval were selected from one side of the chamber by an electronic "gate" and the energy distributions of the coincident fragments from the other side were recorded on a thirty-channel pulse analyzer.[9] Energy measurements were made at the collecting electrode (to eliminate the effects of any amplifier non-linearity) by comparison with artificial pulses fed in at this point from a pulse signal generator. The absolute energy calibration of the signal generator was obtained by using the natural α-particles from the sources and assuming that the mean energy spent per ion pair in argon is the same for fission fragments and α-particles.

TABLE I. Slow neutron fission in U^{235}.

	Jentschke and Prankl	Flammersfeld, Jensen, and Gentner	Jentschke	Deutsch and Ramsey	Fowler and Rosen	Present experiment
Most probable energy of light group (Mev)	91	92	92.5	94	92.5	92.7
Most probable energy of heavy group (Mev)	57	59	65	60	61.2	59
Ratio of most probable energies	1.60	1.56	1.47	1.57	1.51	1.57
Most probable mass ratio of coincident pairs (on an equal ratio-interval curve)	—	—	—	1.49	—	1.485
Width at half-maximum of high energy peak (Mev)	17	15	13	12	15	12
Width at half-maximum of low energy peak (Mev)	22	19	20	19	24.5	20
Ratio of peak heights	1.3	1.22	1.49	1.57	1.46	1.37
Foil thickness (mg/cm²)	~0.03	~0.01	0.04	0.012	0.029	0.014

The fission source was a collodion film of ~14 μg/cm² containing 3–5 μg/cm² of U dissolved in it and mounted on a 0.01" collimator plate with 0.01" collimator holes. Thus the fragments were collimated in only one chamber but the counting of only coincidence pulses effectively produced an equal collimation in the other chamber. The neutron source was the thermal column of the Chalk River pile.

The energy distribution was measured, first with the energy gate wide open so that the whole range of fission energies was recorded. The result was the usual double-humped curve. Then the energy gate, 5 Mev wide, was set on the low energy end of the distribution and the coincident pulses recorded. The position of the gate was increased in 5-Mev steps to cover the whole spectrum and in each case the corresponding distribution recorded.

The results of these gated runs are interesting. When the gate is set on the heavy fragment group, the energy distribution of the corresponding light group is almost independent of the

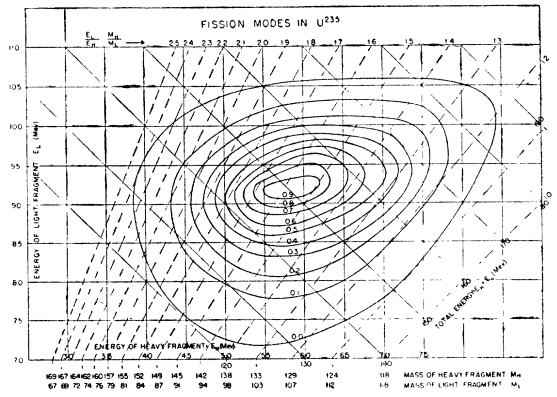

FIG. 1. Contour diagram for the fission modes in U^{235}.