TABLE I. Calculated photo-disintegration cross sections of the deuteron (units of 10^{-28} cm²).

Deuteron binding energy	Theory[a]	Meson mass	σ_m	σ_e	σ $(=\sigma_m+\sigma_e)$	$\left[\frac{\sigma(0)}{\sigma(\pi/2)}\right]_{\text{c.m.}}$	$\left[\frac{\sigma(0)}{\sigma(\pi/2)}\right]_{\text{lab}}$
2.187 Mev	*N*	200	3.47	10.18	13.65	0.185	0.214
2.187 Mev	*O*	200	3.47	9.28	12.75	0.200	0.230
2.187 Mev	*MR*	200	3.47	9.06	12.52	0.203	0.235
2.187 Mev	*N*	300	3.62	7.77	11.40	0.237	0.274
2.187 Mev	*O*	300	3.62	7.57	11.19	0.242	0.279
2.187 Mev	*MR*	300	3.67	7.50	11.17	0.246	0.284
2.237 Mev	*N*	200	3.75	8.07	11.82	0.236	0.276
2.237 Mev	*O*	200	3.75	7.39	11.14	0.253	0.295
2.237 Mev	*MR*	200	3.75	7.22	10.96	0.257	0.300
2.237 Mev	*N*	300	3.92	6.21	10.13	0.296	0.346
2.237 Mev	*O*	300	3.92	6.04	9.96	0.302	0.353
2.237 Mev	*MR*	300	3.97	5.99	9.96	0.307	0.358

[a] *MR* denotes the Møller-Rosenfeld theory, *N* the corresponding neutral theory, and *O* the case of no ^3P-interaction (see reference 1).

gallium[2] the calculations have been extended to 2.52 Mev. Table I gives the calculated values of the photomagnetic and photoelectric cross sections (σ_m and σ_e) in 10^{-28} cm² as a unit and the intensity ratio $\sigma(0)/\sigma(\pi/2)$ in the center-of-mass system (c.m.) as well as in the laboratory system (lab.). The average ratio $[(\sigma(0)+\sigma(\pi))/2\sigma(\pi/2)]_{\text{lab}}$ is about one percent higher than $[\sigma(0)/\sigma(\pi/2)]_{\text{c.m.}}$.

The present work was carried out during a stay at the Royal Institute of Technology, Stockholm, which was made possible by a grant from the Swedish Atomic Energy Committee.

[1] I. F. E. Hansson and L. Hulthén, Phys. Rev. **76**, 1163 (1949).
[2] Snell, Barker, and Sternberg, Phys. Rev. **75**, 1290 (1949).

An Anomalous Effect Observed in Self-Quenching Counters Containing Neon

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IN the course of some experiments on self-quenching Geiger counters which are to be reported elsewhere, the following phenomenon was observed. Counters filled to 10 cm total pressure with neon-quenching constituent mixtures containing less than 0.1 percent of ethyl acetate or butane exhibited a Geiger plateau region at a higher voltage across the counter than a preceding region of continuous discharge. The counter characteristics from this point on are observed to follow the usual pattern.

As the partial pressure of the quenching constituent is decreased below the point where the above phenomenon sets in, the continuous discharge region preceding the plateau becomes longer while the plateau itself grows shorter, until the latter completely disappears. The starting potential for counters of 0.95 cm cathode radius in this region is between 250 and 300 volts. The effect is most striking with ethyl acetate, and less so with butane. It also occurs to a limited extent with methane, though at a higher partial pressure of this quenching gas.

In counters of smaller cathode radius the effect either does not occur at all or does so only to a limited extent. A counter of 0.14 cm cathode radius does not exhibit this "late plateau" at all, self-quenching action having apparently ceased before a low enough partial pressure of quenching constituent had been reached. A counter of 0.25 cm cathode radius exhibits a region of multiple discharges at a lower voltage across the counter than the plateau region which comes after it but does not have a region of continuous discharge at this lower voltage. Counters having cathode radii of 0.64, 0.95, 1.27, and 1.84 cm all exhibit this "late plateau" effect. In the counter of 0.95 cm cathode radius, however, the phenomenon is more striking than in the counters of both larger and smaller dimensions.

This effect has not been observed at all in counters containing self-quenching gas mixtures in which either argon or helium is the noble gas component.

Further investigation of this phenomenon is now under way in this laboratory and the results will be reported in detail at a later date.

Differential Identities in Three-Field Renormalization Problem

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MATTHEWS[1] has pointed out that for renormalization to be effective for the combined interaction of charged spinless mesons (scalar interactions), nucleons and electromagnetic field, certain conditions must be satisfied, and has verified these conditions to the lowest order by direct calculation. Here a more general proof is attempted.

Following Dyson[2] we define $\Sigma_P^*(p)$ as the function arising from adding together all integrals corresponding to proper self-energy parts inserted into a proton line of momentum p. Besides the self-energy part consisting of a single point, there are in fact just two irreducible self-energy parts, one arising from the proton's interaction with the electromagnetic field, the other from its interaction with the meson. Define $\Sigma_M^*(p)$ as the corresponding function for meson self-energy graphs. Let $\Lambda_\mu^a(p, p')$ be the function arising from adding together integrals corresponding to proper vertex parts with one external photon and two proton lines, while $\Lambda_\mu^b(p, p')$ stands for vertex parts with one photon and two meson lines. Also let $\Theta_{\mu\nu}(p, p', q)$ be the function arising from adding integrals corresponding to proper C parts (parts with two external meson and two photon lines) defined as capable of replacing the factor $\delta_{\mu\nu}$ from a four-vertex.

From general considerations $\Sigma_M^*(p)$ is at most quadratically, $\Sigma_P^*(p)$ and $\Lambda_\mu^b(p, p')$ are at most linearly, $\Lambda_\mu^a(p, p')$ and $\Theta_{\mu\nu}(p, p', q)$ are at most logarithmically divergent. From invariance considerations their forms are

$$\begin{aligned}
&\Sigma_P^*(p)=(A-2\pi i\delta\kappa_0)+B(p\gamma-i\kappa_0)+S_c(p)(p\gamma-i\kappa_0)\\
&\Sigma_M^*(p)=(A'+\pi i\delta\kappa_0^2)+C(p^2+\kappa^2)+\Pi_c(p)(p^2+\kappa^2)\\
&\Lambda_\mu^a(p, p')=L^a\gamma_\mu+\Lambda_{\mu c}^a(p, p')\\
&\Lambda_\mu^b(p, p')=L^b(p_\mu+p_\mu')+M^b(p_\mu+p_\mu')(p^2+\kappa^2+p'^2+u^2)\\
&\qquad\qquad\qquad+\Lambda_{\mu c}^b(p, p')\\
&\Theta_{\mu\nu}(p, p', q)=R\delta_{\mu\nu}+\Theta_{\mu\nu c}(p, p', q)
\end{aligned}$$

$$\text{where}\quad S_c(p)=\Lambda_{\mu c}^a(p, p)=0 \quad\text{for}\quad i\gamma p+\kappa_0=p^2+\kappa_0^2=0$$

$$\Pi_c(p)=0 \quad\text{for}\quad p^2+\kappa^2=0,\quad \Lambda_{\mu c}^b(p, p')=\frac{\partial\Lambda_{\mu c}}{\partial p_\nu}=\frac{\partial\Lambda_{\mu c}}{\partial p_\nu'}=0$$

$$\text{for}\quad p=p'\quad p^2+\kappa^2=0 \quad\text{and}\quad \Theta_{\mu\nu c}(p, p', q)=0 \quad\text{for}\quad p=p'\quad q=0\quad\text{and}\quad p^2+u^2=0.$$

The possible divergent constants B, C, L etc., are double power series in e and f.

In order to prove our identities, we extend the differential identity $-(1/2\pi)(\partial S_F(p)/\partial p_\mu)=S_F(p)\gamma_\mu S_F(p)$ first given by Ward.[3] For mesons, we have

$$-(1/2\pi i)(\partial\Delta_F(p)/\partial p_\mu)=\Delta_F(p)2p_\mu\Delta_F(p).$$

The insertion of an external photon line (with its energy-momentum set equal to zero) in a charged meson line is described correctly by a single differentiation. The important extension is that a second differentiation of the above with respect to p_ν describes not only the insertion of another photon three-vertex on the same meson line but also the complication of the first three-vertex into a four-vertex. Even while dealing with the three-field problem we can always arrange that the momentum p should follow the charge in any connected graph, so that the internal lines corresponding to neutral particles (neutrons and photons) do not get differentiated. (With certain conditions, closed charged loops inside neutral lines give no extra divergence. This also leads to the finiteness of all neutron magnetic moment graphs, pointed out by Matthews as essential for renormalization to go through.)

By use of the above technique we easily get the following identities:

$$\Lambda_\mu{}^a(p,p) = -(1/2\pi)\partial\Sigma_P{}^*(p)/\partial p_\mu,$$
$$\Lambda_\mu{}^b(p,p) = -(1/2\pi i)\partial\Sigma_M{}^*(p)/\partial p_\mu,$$
$$\Theta_{\mu\nu}(p,p,0) = \tfrac{1}{2}\partial\Lambda_\mu{}^b(p,p)/\partial p_\mu,$$

so that

$$L^a = -B/2\pi, \quad L^b = R = -C/2\pi i,$$

while M^b is finite. The procedure above covers reducible as well as irreducible graphs.

To have a complete proof of renormalization one still must take account of scattering of mesons by mesons (M parts) and also of considerable overlaps between vertex and C parts. It has been verified, however, that the three-field mixture introduces no great complexities besides those associated with mesons in the electromagnetic field. Work on the complete problem is in progress.

After the above work was completed, the author received a communication from Mr. F. J. Dyson, proving similar identities for interaction of mesons with electromagnetic field, from general arguments of gauge invariance.

Acknowledgments are due Dr. P. T. Matthews, for suggesting the investigation and numerous discussions, and Dr. N. Kemmer for continual help and encouragement.

[1] P. T. Matthews, Phys. Rev. (to be published).
[2] F. J. Dyson, Phys. Rev. **75**, 1736 (1949).
[3] J. C. Ward, Phys. Rev. **77**, 293 (1949); **78**, 182 (1950).

Isotope Effect and Lattice Properties in Superconductivity*

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IN a recent communication,[1] Serin, Reynolds, and Nesbitt have suggested that the isotopic dependence of the superconducting transition temperature in mercury can be expressed by the approximate relation $M^{\frac{1}{2}}T_c$ = constant, where M is the average atomic mass and T_c is the transition temperature. From this they have inferred that the ratio of the Debye temperature to the transition temperature is a constant for each of the different isotopes.

It should be pointed out, however, that the data represent a relatively small spread in M and T_c and consequently in trying to fit a relation of the form $M^\alpha T_c$ = constant, one finds that the product is approximately constant, to the degree noted by Serin, Reynolds, and Nesbitt, for a comparatively large range of α's. We have examined all of the available data on the isotopes of mercury for the purpose of determining the best value of the exponent. These data are given in Table I and are plotted for mercury in logarithmic form in Fig. 1. A least-squares fit of the best straight line to the points of Fig. 1 yields a slope of 0.378 $\pm$0.021. A line of slope $\frac{1}{2}$ is shown for purposes of comparison.

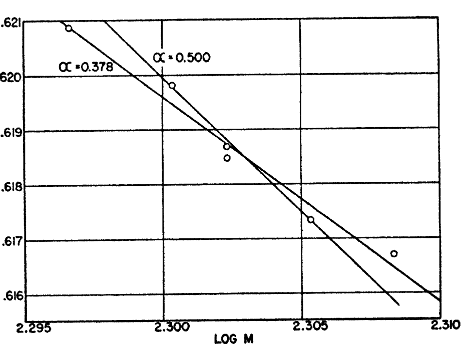

FIG. 1. Plot of $\log T_c$ *vs.* $\log M$ for mercury.

TABLE I. Isotope effect on the transition temperature.

Element	M	T_c
Hg^{198}	198.0	4.177[a]
Hg^{199}	199.7	4.167[b]
Nat. Hg	200.6	4.154[b]
Nat. Hg	200.6	4.156[a]
Hg^{202}	202.0	4.147[b]
Hg^{204}	203.4	4.137[b]
Sn^{124}	123.1	3.662[c]
Nat. Sn	118.7	3.715[d]

[a] E. Maxwell, Phys. Rev. **78**, 477 (1950).
[b] Serin, Reynolds, and Nesbitt, Phys. Rev. **78**, 813 (1950).
[c] E. Maxwell, Phys. Rev. **79**, 173 (1950).
[d] E. Laurmann and D. Shoenberg, Proc. Roy. Soc. **A198**, 560 (1949).

TABLE II. Possible theoretical relations of the form $M^\alpha T_c$ = constant.

Physical quantity assumed constant	Relation between M and T_c
Thermal energy of the lattice[a]	$M^{3/8}T_c$ = const.
Ratio of thermal energy to zero-point energy[a]	$M^{1/2}T_c$ = const.
Mean square linear momentum[a]	$M^{5/8}T_c$ = const.
Mean square thermal velocity[a]	$M^{1/8}T_c$ = const.
Ideal part of normal conductivity just before transition[b]	$M^{2/5}T_c$ = const.

[a] From the Debye theory.
[b] A. Sommerfeld and H. Bethe, *Handbuch der Physik* (Springer, Berlin, 1933), Vol. 24, part 2, p. 529, Eq. (37.16).

Recent results[2] on the isotope effect in Sn^{124} tend to reinforce this conclusion. One finds a value of 0.394 for the exponent using the data for tin in Table I.

We may ask whether the equation, $M^{0.378}T_c$ = constant, corresponds to the invariance of any significant physical quantity.[3] In Table II we list the relation between M and T_c which would hold if various quantities have critical values (independent of the particular isotope) at the transition temperature. From a purely empirical point of view the total thermal energy of the lattice is indicated as a first choice and the ideal part of the normal conductivity as a second. Evidently more experimental data are needed.

* Supported in part by the ONR.
[1] Serin, Reynolds, and Nesbitt, Phys. Rev. **78**, 813 (1950).
[2] E. Maxwell, Phys. Rev. **79**, 173 (1950).
[3] This constant is not the same for all elements, of course.

Ionization Chamber Bursts at Very High Altitudes

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AN investigation is being conducted to study the atmospheric absorption and the latitude dependence of the radiation which produces high energy nuclear disintegrations in the upper part of the atmosphere. The balloon-borne instruments which are being used throughout the projected series of measurements, contain a cylindrical electron-collection ionization chamber 20 cm long and 6.4 cm in diameter filled with pure argon at a pressure of 5 atmospheres. The ionization pulses are amplified and fed into a radio transmitter keying circuit which is biased to respond to pulses exceeding a preset amplitude. Each chamber contains