when augmented by cut-off devices may be used to predict unambiguously a wide range of physical phenomena, is due to a combination of circumstances which is not duplicated in meson theory.

(c) Our generalization principle[3] is effective in removing divergences even from these higher order effects. The relations $\Sigma_\sigma \xi_\sigma^i/\gamma_\sigma$ for $i=0$ and $i=2$ which follow from our generalized field theory for arbitrary meson mass assignments are just the regularization conditions $\Sigma_i C_i=0$ and $\Sigma_i C_i M_i^2=0$. Thus the Pauli-Villars[4] treatment will also be effective here although to a lesser extent since in allowing the masses of the auxiliary particles (including the negative energy bosons) to become infinite some of the milder divergences reappear.

This work was based upon the original quantum field methods of Heisenberg, Pauli, Dirac, Fock and others. It probably can be translated into the Tomonaga-Schwinger invariant methodology which, in meson theory, suffers from significant ambiguities and the use of the unreliable power series method.

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The Near Infra-Red Spectrum of the Polar Aurora

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DURING the past year, infra-red spectra of the aurora have been secured by Meinel[1] at the Lick Observatory and Petrie[2] at the University of Saskatchewan. Low level permitted multiplets of OI and NI are features of the spectra, but it appears that atoms of these elements are not excited to levels with energies greater than around 11.5 ev. The low level forbidden and permitted lines of OII and NII are absent from the spectra, hence it is unlikely that the many faint auroral features which have been attributed to ionized oxygen and nitrogen really arise from these ions. The relative intensities of the OI multiplets indicate that the excitation temperature during an auroral display is of the order of 7000°K. The relative intensities of the NI and OI lines suggest that the ratio of the numbers of nitrogen and oxygen atoms in low energy levels is of the order of 1.5. This result is of interest and must be considered in any theory of atmospheric ionization.

A number of N_2 bands of the first positive system are present in the infra-red auroral spectrum. These bands show structure, but higher resolution is needed to measure the several maxima which can be seen.

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A Possible Isomeric State of RaE*

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THE neutron irradiation of bismuth at high neutron flux has produced a new bismuth alpha-emitter of very low activity which can best be assigned to Bi^{210m}, an isomeric state of RaE. In a previous report[1] this activity was indicated on an alpha-energy *vs.* mass number plot as Bi^{208} (with the mass number in question) on the assumption that it was formed by a $(n,2n)$ reaction from the relatively small number of fast neutrons. The alpha-particle energy of this new activity is 5.03±0.05 Mev as determined in an ionization chamber coupled to a pulse-height analyzer. This value for the energy is one of the arguments against the assignment to Bi^{208} since, according to the systematics of alpha-radioactivity,[1,2] we would expect the alpha-energy of Bi^{208} to be even less than that of Bi^{209} which itself must be about 4 Mev or less. In addition, the bismuth alpha-emitter was not noted following the irradiation of lead with 20-Mev deuterons although an extremely long half-life could explain this.

The alpha-activity was observed by allowing the irradiated bismuth to stand for six months until all of the 5-day RaE had decayed after which it was rigorously purified, first from the great alpha-activity of Po^{210} present and then from all other possible alpha-activities. To reduce any extraneous beta- and gamma-activity that might be present, special purification from such elements as silver was performed in addition to purification from heavy elements. The bismuth finally reached a constant specific activity of 1.9±0.1 alpha-disintegrations per minute per milligram and 2.0±0.2 electrons or beta-particles.

The principal experimental evidence that this alpha-emitter is an isomer of Bi^{210} is the identification of a thallium[3] daughter with the properties of Tl^{206}. The half-life obtained was 4.2±0.5 min. in agreement with the reported value for Tl^{206}, 4.23 min.[4,5] There was available insufficient activity to determine the beta-particle energy precisely but through a factor of ten in absorption, the absorption curve looks like that reported by Krishnan and Nahum[6] for Tl^{206}. Within the experimental uncertainty of about 10 percent then, all of the radioactivity of the Bi^{210m} may be explained by the alpha-particles for Bi^{210m} in equilibrium with its 4-min. beta-emitting daughter Tl^{206}.

It is recognized that the assignment of this activity to Bi^{210m} will imply extraordinary half-life energy relationships for modes of decay other than alpha-emission. If it is a metastable state of Bi^{210}, it should decay to the ground state and directly to Po^{210} by β^--emission. Indeed, if we accept the data to be discussed, this nucleus should also be unstable with respect to RaD. It is possible to calculate these decay energies from the alpha-energies of the two states of Bi^{210} and known beta-energies and to set some lower limits on the half-lives for the different processes.

Let us first consider the isomeric transition energy, that is the difference between Bi^{210m} and RaE, the ground state. This can be obtained by comparing the alpha-energies of the two states making the assumption that both alpha-transitions go to the ground state of Tl^{206}. The alpha-decay energy for Bi^{210m} as determined in the present study is 5.12±0.05 Mev. That for RaE can be calculated by closing a cycle involving the beta-decay energies for RaE and Tl^{206} and the alpha-decay energy of Po^{210}. Broda and Feather[7] who discovered the alpha-branching of RaE made this calculation arriving at the decay energy 4.86 Mev for the alpha-decay of RaE; but in re-evaluating the data of Krishnan and Nahum[6] and of Fajans and Voigt[4] for the beta-energy of Tl^{206}, we have selected 1.63±0.10 Mev which revises the alpha-energy of RaE to 4.94±0.10 Mev. The energy difference between the isomeric states of Bi^{210} would then be 0.18±0.11 Mev. The unobserved beta-decay energy of Bi^{210m} is accordingly 1.35 Mev and the electron-capture energy to RaD 0.1 Mev.

The alpha-half-life for Bi^{210m} is not known other than that it must be greater than 25 years based on observation of the alpha-activity over a period of 15 months. From the failure to find Po^{210} growing into the sample which would result from both the isomeric transition and beta-decay, it is possible to say that these decay modes are at least 2000 times slower than the alpha-decay and therefore have minimum half-lives of 5×10^4 years.

It is obvious that the most stringent requirement in explaining the long half-lives will be demanded by the isomeric transition. Using the expression and conventions given by Segrè and Helmholz[8] relating decay constant to the *order of the transition* and the transition energy, it would appear impossible to explain the $>5\times10^4$-yr. half-life if the transition energy is as great as 0.18 Mev even if one assumes a fifth-order transition. However, if the

transition energy is 0.07 Mev, the calculated half-life can become sufficiently long.

With the uncertainties still existing in this study, it is not considered profitable to attempt to assign spin numbers to the different nuclear states in these transitions nor to interpret such states in terms of the newer considerations of shell structure. It is perhaps worth pointing out that other cases of nuclear isomerism in odd-odd nuclei have been found in the heavy element region, for example, $Am^{242}-Am^{242m}$ and $UZ^{234}-UX_2^{234}$.

* This work was performed under the auspices of the U. S. AEC.
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A Confirmation of the Workman-Reynolds Effect

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THE recent discovery by Workman and Reynolds[1] of the formation of a large electrical potential as water containing small quantities of certain salts is in the process of freezing has impressed the writer as being a phenomenon of great importance in the field of meteorology and physical chemistry.

Having attended the meeting in Washington in 1949 when the effect was first described to meteorologists and noting the skepticism voiced at the conclusion of the paper by certain of the audience, it was decided by the writer to check the experiments by an independent investigation.

A simple electrometer and freezing unit was constructed following, in general, the description of the apparatus described[2] in a report issued by Workman and Reynolds.

The electrical effects as described in this report were immediately observed using a good grade of laboratory distilled water containing a 1×10^{-5} molar concentration of NH_4I. Lack of time has thus far prevented a complete survey of the many salts on which data have accumulated, but it is felt that a sufficient variety of salts has been studied to confirm their claims without question, both as to voltage magnitude and sign of the current flow generated in the freezing process. The peculiar structural detail of the curves produced by a specific salt has also been checked.

It is interesting to note that the molar concentrations of the dilute electrolytes which give the maximum effects are in the same range as those we use to obtain good monomolecular reactions in surface chemistry.[3]

TABLE I. Electrical potentials developed in the freezing of salt solutions.

Approx. molar concentration (with respect to salts in the sea water)	Max. potential
5×10^{-2} molar	0.0 volt
5×10^{-3}	+0.2
2.5×10^{-3}	+12.
1×10^{-3}	+11.
5×10^{-4}	+16.5
5×10^{-5}	+15.0
2.5×10^{-5}	+4.5
5×10^{-6}	0.0

In addition to the salts studied which included NaOH, CsF, NH_4I $Ba(CO_3)_2$, NaCl, and NH_4CO_3, two samples of sea water from the Atlantic near Bermuda and northwest of Puerto Rico were used. These were essentially similar. The results from the latter are shown in Table I.

The extreme simplicity of the experiment and the very important implications of the Workman-Reynolds effect as it pertains to the development of lightning in thunderstorms and as a possible new method for microchemical analysis suggests that a careful study of its physical and chemical nature should be actively pursued.

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Statistics of the Three-Dimensional Ferromagnet

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SINCE Kramers' variational method[1] appeared to be so much superior to other methods in approximating the partition function of the two-dimensional ferromagnet, it was felt to be worth while to use the same method for the three-dimensional case.[2] We have used a simple cubic Ising model[3] with only nearest neighbor interaction. It turns out that now the partition function has to be approximated in two steps, both involving the variational principle. We shall denote by J the interaction energy, i.e., the difference in energy between a situation where two neighboring spins are parallel or antiparallel. If we restrict ourselves to the case where no magnetic field is present, the total energy of the system is given by

$$E=-\tfrac{1}{2}J\sum\mu\mu', \tag{1}$$

where the summation extends over all nearest neighbor pairs in the crystal. The quantities μ and μ' can take on the values $+1$ and -1, corresponding to the two possible directions of the spins. The partition function f is now given by

$$f=\sum_{\mu=\pm1}\exp(K\sum\mu\mu'), \tag{2}$$

where the summation is extended over all spins in the crystal and where

$$K=J/2kT. \tag{3}$$

By the same method as used by Kramers and Wannier,[1] one can show that the partition function will be given by the largest eigenvalue of the matrix

$$H(\mu_{ij},\mu_{ij}')=\exp[K\sum_{i,j}\mu_{ij}\mu_{ij}'+\tfrac{1}{2}K\sum_{ij}(\mu_{ij}\mu_{ij+1}+\mu_{ij}\mu_{i+1j}+\mu_{ij}'\mu_{ij+1}'+\mu_{ij}'\mu_{i+1j}')], \tag{4}$$

where the μ_{ij} denote the spins in one plane and μ_{ij}' the spins in the next plane: the problem is reduced from a three-dimensional problem to a bi-planar problem. The largest eigenvalue of $H(\mu_{ij},\mu_{ij}')$ can be approximated by the Ritz method, and it turns out that one then has to use the Ritz method once more in order to find a solvable equation. Detailed calculations will be published elsewhere but we may mention here that one finally has to evaluate the partition functions of crystals consisting of 4, 2, and 1 neighboring linear chains which leads to 16th, 4th, and 2nd degree equations.

For high temperatures, the equations can be simplified and one can solve the equations either by numerical methods, the