

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 principle³ is effective in removing divergences even from these higher order effects. The relations $\Sigma \xi_i/\gamma_i$ 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-Villars⁴ 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.

¹ V. Fock, *Physik. Zeits. Sowjetunion* **6**, 425 (1934).

² S. Tomonaga, *Prog. Theor. Phys.* **2**, 10 (1947).

³ A. Green, *Phys. Rev.* **75**, 1926 (1949); **73**, 519 (1948).

⁴ W. Pauli and F. Villars, *Rev. Mod. Phys.* **21**, 434 (1949).

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 Meinel¹ at the Lick Observatory and Petrie² 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 N₂ 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.

¹ A. B. Meinel, *Pub. Astr. Soc. Pac.* **60**, 373-377 (1948).

² W. Petrie, *J. Research* (to be published).

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 report¹ this activity was indicated on an alpha-energy vs. mass number plot as Bi²⁰⁸ (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 Bi²⁰⁸ since, according to the systematics of alpha-radioactivity,^{1,2} we would expect the alpha-energy of Bi²⁰⁸ to be even less than that of Bi²⁰⁹ 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 Po²¹⁰ 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 Bi²¹⁰ is the identification of a thallium³ daughter with the properties of Tl²⁰⁶. The half-life obtained was 4.2±0.5 min. in agreement with the reported value for Tl²⁰⁶, 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 Nahum⁶ for Tl²⁰⁶. 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 Tl²⁰⁶.

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 Bi²¹⁰, it should decay to the ground state and directly to Po²¹⁰ 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 Bi²¹⁰ 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 Tl²⁰⁶. 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 Tl²⁰⁶ and the alpha-decay energy of Po²¹⁰. Broda and Feather⁷ 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 Nahum⁶ and of Fajans and Voigt⁴ for the beta-energy of Tl²⁰⁶, 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 Bi²¹⁰ 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 Po²¹⁰ 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 5×10⁴ 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 Helmholtz⁸ relating decay constant to the order of the transition and the transition energy, it would appear impossible to explain the >5×10⁴-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