process, $He^+ + 2He \rightarrow He_2^+ + He$. Substitution of the interaction constants of Massey and Mohr[11] in the Thomson formula gives that the mean lifetime of a He^+ ion in helium at 25 mm Hg is only about 10^{-5} sec.[12] Since the age of the ions studied by Biondi and Brown ranged from 5×10^{-3} to $1\cdot1\times10^{-2}$ sec., it would seem probable that they were indeed He_2^+. In view of the importance of being certain of the nature of the recombination mechanism, it would be useful if this could be verified by means of a mass spectrograph.

The ambipolar diffusion measurements were conducted at lower pressures but the conditions were still such that He_2^+ might well predominate over He^+. Unfortunately the discrepancy between the results of Biondi and Brown and those of Tyndall and Powell[13] cannot be attributed to this, for Meyeratt[14] claims these latter probably also worked with molecular ions. It is difficult to predict the mobility of He_2^+ as certain collision reactions may introduce complications.

Finally I would like to thank Professor H. S. W. Massey for several helpful discussions.

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Microwave Spectra and Molecular Constants of Trifluorosilane Derivatives. SiF_3H, SiF_3CH_3, SiF_3Cl, and SiF_3Br *

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$Si^{28}F_3H$ and $Si^{29}F_3H$. The rotational transitions $J=1\rightarrow2$ and $J=2\rightarrow3$ have been observed for $Si^{28}F_3H$. Precise measurements on the $J=1\rightarrow2$ transition yield: $\nu=28{,}831.90\pm0.10$ mc, $B_0=7207.98$ mc, and $I_B=116.39_4\times10^{-40}$ g cm^2 (with Planck's constant $=6.624_2\times10^{-27}$ erg sec.). With the assumptions, $d_{SiH}=1.55\pm0.05$A and $\angle FSiF=110°\pm1°$, the silicon-fluorine distance, $d_{SiF}=1.555\pm0.005$A, is obtained.

The $J=2\rightarrow3$ transition has been observed for $Si^{29}F_3H$. Failure to detect a hyperfine structure is evidence, but not proof,[1] that the nuclear spin of Si^{29} is $\frac{1}{2}$. Precision measurements are being made on the rotational frequency of this and other transitions. Also, it is expected that measurements can be made on $Si^{30}F_3H$, with Si^{30} in naturally occurring concentrations.

$Si^{28}F_3C^{12}H_3$. Observations of the $J=3\rightarrow4$ and $J=5\rightarrow6$ transitions[2] have been made for $Si^{28}F_3C^{12}H_3$. Precise measurements yield: $\nu=29{,}724.91\pm0.18$ mc for the $J=3\rightarrow4$ transition, $B_0=3715.62$ mc, and $I_B=225.79_4\times10^{-40}$ g cm^2 (with $h=6.624_2\times10^{-27}$ erg sec.). Assuming all angles to be tetrahedral and assuming $d_{SiF}=1.555$A and $d_{CH}=1.10$A, the SiC distance obtained is 1.88A.

$Si^{28}F_3Cl^{35}$ and $Si^{28}F_3Cl^{37}$. The pure rotational transitions, $J=6\rightarrow7$, $7\rightarrow8$, and $8\rightarrow9$, have been observed for $Si^{28}F_3Cl^{35}$ and the $J=7\rightarrow8$ for $Si^{28}F_3Cl^{37}$. A hyperfine structure, which has not yet been completely analyzed, was observed for each transition. The moments of inertia (I_B) are $338._6\times10^{-40}$ g cm^2 and $347._5\times10^{-40}$ g cm^2 for $Si^{28}F_3Cl^{35}$ and $Si^{28}F_3Cl^{37}$, respectively. If $\angle FSiCl$ is taken as 110°30′, as indicated by electron diffraction,[3] the preliminary values, $d_{SiF}=1.55_0$A and $d_{SiCl}=1.99_8$A, are obtained. The SiCl distance thus appears to be shorter than that[4] in SiH_3Cl by about 0.05A.

$Si^{28}F_3Br^{79}$ and $Si^{28}F_3Br^{81}$. The pure rotational transitions $J=15\rightarrow16$ and $16\rightarrow17$ have been observed for $Si^{28}F_3Br^{81}$ and the $J=16\rightarrow17$ for $Si^{28}F_3Br^{79}$. The hyperfine structure has not been completely analyzed. The moments of inertia are $541._4\times10^{-40}$ g cm^2 and $547._3\times10^{-40}$ g cm^2 for $Si^{28}F_3Br^{79}$ and $Si^{28}F_3Br^{81}$, respectively. If $\angle FSiBr$ is taken as 110°30′, as is $\angle FSiCl$ in SiF_3Cl, preliminary figures for the bond distances are obtained as follows: $d_{SiF}=1.55_0$A, $d_{SiBi}=2.15_9$A. The SiBr distance is thus probably some 0.05A shorter than that[5] (2.20$_9$A) in SiH_3Br.

Further work on these molecules is planned to complete the structure determinations and to determine the nuclear couplings and molecular dipole moments.

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[1] From the relation between nuclear quadrupole moment and nuclear shell structure found by Gordy [Phys. Rev. **76**, 139 (1949)] one would not expect a large quadrupole moment for Si^{29}. Because of the symmetry of the tetrahedral bonds to Si, the quantity $(\partial^2V)/(\partial z^2)$ would be very small. Hence, if a hyperfine structure exists for $Si^{29}F_3H$, it might be unresolvable.
[2] Concurrently with our work, Minden, Mays, and Dailey (private communication) have made approximate measurements on the $J=2\rightarrow3$ and $3\rightarrow4$ transitions of SiF_3CH_3. They report several lines caused by molecules in excited vibrational states.
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Multiple Meson Processes and Nucleon Recoil

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AN investigation of the effects of multiple meson processes and nucleon recoil has been carried out with an adaptation of the functional formalism of Fock.[1] An iterative method was employed to deduce from the set of integro-differential equations the explicit interaction $U={}^2U+{}^4U+{}^6U+\cdots$, where

$$ {}^2U=-\int\{G_0^*(\mathbf{k})G_0(\mathbf{k})/\hbar\omega\}d\mathbf{k}, \tag{1}$$

$$ {}^4U=+\int\{G_0^*(\mathbf{k})[H_p, G_0(\mathbf{k})]/(\hbar\omega)^2\}d\mathbf{k}, \tag{2}$$

$$ {}^6U=-\int\{G_0^*(\mathbf{k})[H_p, [H_p, G_0(\mathbf{k})]]/(\hbar\omega)^3\}d\mathbf{k}, \tag{3}$$

$$ G_0(\mathbf{k})=\Sigma_u\, g(2\pi)^{-\frac{1}{2}}\beta_u c(\hbar/2\omega)^{\frac{1}{2}}\exp(-i\mathbf{k}\cdot\mathbf{x}_u). \tag{4}$$

H_p is the Hamiltonian for free nucleons and $\omega=c(\mathbf{k}\cdot\mathbf{k}+\kappa^2)^{\frac{1}{2}}$.

Equation (4) is for a neutral one-mass scalar field with scalar coupling. It may be modified for other types of fields and couplings. ${}^2U$ is the usual second-order interaction. Using this very same formalism but neglecting nucleon recoil, Tomonaga[2] obtained only ${}^2U$. In contrast with previous results by others ${}^4U$, ${}^6U$, ${}^8U$, etc. here are quadratic in the coupling constant. In deriving ${}^6U$ and ${}^8U$ certain questions as to the order of the operators involved in self-energy terms arose which we resolved in view of the symmetry requirements for bosons by assuming that expressions like $[G_{0u}(\mathbf{k}_2), [H_{pu}, G_{0u}(\mathbf{k}_1)]]\psi_0$ may be ignored. Apart from this unsettled point the work was straightforward. We believe it reasonable to anticipate that an indefinite extension of our method or a valid alternative perturbation method will lead to the following conclusions.

(a) The exact interaction is quadratic in the coupling constant.

(b) The results of any development employing power series in the coupling constant must be regarded with very great suspicion. The fact that in electrodynamics such a perturbation method

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