of relativistic terms affects the nature of the plane wave solutions quite radically. A note will be submitted deriving the relativistic equation and its solutions.

The remarks of Roberts concerning growing waves in a cylindrical pipe filled with electrons moving parallel to the axis and upon traveling wave tubes seem to be based upon a misconception. It is stated that Ramo[3] in a discussion of this problem failed to discover a set of waves with negative attenuation. Ramo pointed out that two types of wave exist in such a tube; there are two "space charge" waves moving roughly with the electron stream velocity and two fast "field" waves. The latter solutions according to Ramo are cut off at a certain frequency. This is not strictly correct in the sense that the solutions below this frequency are not pure exponentials. However, such solutions are simply cut-off modes in the pipe perturbed by the electron stream, one increasing and decreasing in the direction of electron flow. The direction of power flow is opposed to the electron flow for these "field" waves. If a situation were to prevail in which the wave increasing in the direction of electron motion dominated the other three waves, clearly power would have to be supplied at the high level end. J. R. Pierce has shown in some unpublished calculations on traveling wave tubes, where a backward increasing wave may also exist, that it is possible by modulating the input stream and arranging the boundary conditions at the two ends of the tube correctly to obtain the four waves excited in such a way that the signal level at the upstream end is greater than that at the downstream end and power flows against the electron flow. However, the gain in such cases is very small compared to the exponential increase of the single backward cut-off wave and bears no simple relation to it. It is clear that the enormous gains cited by Roberts for the single wave would be quite unobtainable in practice. The use of retarding structures to produce approximate synchronism between the circuit wave and electron stream, with a consequent wave showing gain and power flow in the direction of electron flow is not simply a superfluous complication.

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A Naturally Occurring Odd-Odd Isotope of Vanadium

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As part of a program to investigate the isotope abundances of the heavier elements, an isotope of vanadium of mass 50 having an abundance of 0.23±0.01 percent was discovered. The instrument used in the investigation was a 60 degree mass spectrometer of a design similar to one already described by Nier.[1] V^+ ions were obtained by electron bombardment of vanadium vapor produced by evaporation of the metal placed on a heated tungsten filament. That the isotope at mass 50 is actually vanadium and not due to an impurity is indicated by the following observations. (1) The ratio of the mass 50 peak to V^{51} remained constant while varying the temperature of the tungsten filament and consequently the rate of vanadium evaporation. Figure 1 shows the results obtained with two separate samples of vanadium. The intensity ratio of V^{51} to mass 50 is plotted against intensity of V^{51}. The scattering of the points is due to measurement errors introduced by time fluctuations in the vanadium vapor supply. It is seen that over the range of 20 in intensity covered, the ratio remained constant at about 425. (2) As indicated in Fig. 2, the variation in intensity of the mass 50 peak with energy of electrons producing the ions is the same as the variation characteristic of vanadium. (3) The mass spectrum in the region surrounding masses 50 and 51 was void of peaks, thereby indicating the absence of impurities such as hydrocarbons or chromium and titanium which also have isotopes of mass 50. (4) Doubly charged ions were observed which gave the same ratio of intensities, namely $51^{++}/50^{++}$ equal to 425.

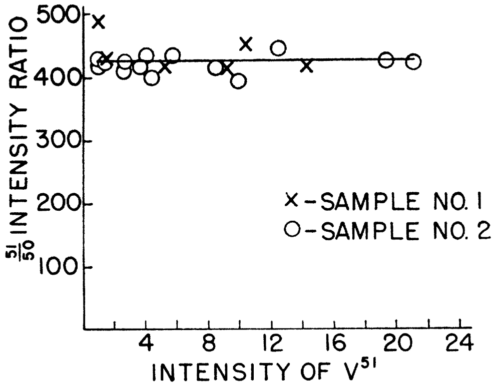

FIG. 1. The ratio of the V^{51} peak to the mass 50 peak is shown to be independent of the V^{51} intensity which in effect demonstrates the one to one correspondence of the mass 50 peak to the vapor pressure of vanadium.

The existence of the odd-odd V^{50} with an abundance of 0.23 percent is unexpected. Aston[2] examined vanadium with his mass spectrograph in 1924 and reported it to be 100 percent V^{51}. His apparatus at that time, however, was not very sensitive, and the failure to detect V^{50} not surprising. In checking the literature, conflicting reports are found in regards to radioactive vanadium isotopes, and in the latest table of isotopes by Seaborg and Perlman[3] V^{50} is not listed. A recent article by Cork, Keller, and Stoddard[4] reports a 635-day activity produced in vanadium irradiated in a pile. This activity may be due to V^{49} previously reported as having a half-life of 600 days[5] and produced in their experiment by a $(n,2n)$ reaction on V^{50}. It would be interesting to examine chromium produced by a (d,n) reaction on vanadium since V^{50} would go into the 26.6-day Cr^{51} while V^{51} would end up as stable Cr^{52}.

Although the relatively high abundance of V^{50} speaks against it, one might expect that as in the case of K^{40} and other odd-odd nuclei heavier than N^{14},** V^{50} would be unstable. A check with a thin-walled beta-counter, however, failed to reveal any activity. A subsequent experiment wherein vanadium was placed on photographic plates for a period of 8 days also failed to reveal any ionizing events in excess of the cosmic-ray background.

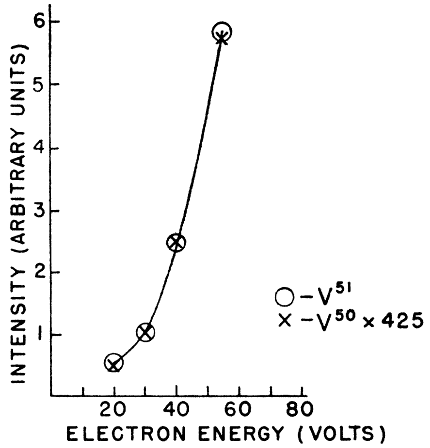

FIG. 2. The ionization efficiency curve for the mass 50 peak is shown to have the same shape as that of vanadium by the congruence of the two curves, the one for V^{51} and the other for the mass 50 peak times 425.

It is interesting to note in connection with the stability of V^{50} that on calculating the mass of Cr^{50}, V^{50}, and Ti^{50} using Wigner's[6] semi-empirical formula, one finds Cr^{50} and Ti^{50} to have practically identical mass with V^{50} about one-milli mass unit heavier. The presence of spin dependent forces not taken into account may, however, decrease the mass of V^{50}. It is possible that we are dealing with a situation wherein all three isobars, Cr^{50}, V^{50}, and Ti^{50}, have very nearly equal masses and, consequently, are stable or at least undetectably radioactive. A cloud chamber has been set up in which all three elements have been placed, and it is hoped that this will enable a critical examination as to their radioactivity.

I wish to thank Professor A. O. Nier for his constant interest and encouragement. Thanks are due also to Dr. W. D. Armstrong for the beta-counter work, to Phyllis Freier for the photographic plate work, and to Professor C. Critchfield for many helpful suggestions. The instrument used in this work was built with a grant from the Graduate School. The research was supported by the Joint Program of the ONR and the AEC. Assistance was also given by the University of Minnesota Technical Research Fund.

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** A possible exception to this rule is La^{138} reported by Inghram, Hayden, and Hess, Jr., Phys. Rev. **72**, 967 (1947).

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Nuclear and Molecular Information from the Microwave Spectrum of FCl*

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The rotational transitions for $J=0\rightarrow1$ in FCl^{35} and FCl^{37} have been observed near 30,000 mc for both the ground vibrational state and the first excited vibrational state. A specially constructed Stark absorption cell resistant to fluorine corrosion was used. The hyperfine structure due to the electric quadrupole moment of the chlorine nuclei splits the $J=1$ levels so that the observed lines are triplets. The frequencies of the twelve resulting lines are given in Table I.

The hyperfine structure spacings do not agree with the theoretically predicted pattern for nuclear quadrupole splitting, even including second-order corrections. To explain this we assume an extra term in the Hamiltonian of the form $cI\cdot J$. Such a term has been found necessary to explain the spectrum of the alkali halides observed by Nierenberg and Ramsey,[1] and has also been introduced to explain small deviations from predicted frequencies in the NH_3 inversion spectrum.[2–4] The value of c for FCl^{35} is 0.036 ±0.009 mc and 0.019±0.009 mc for FCl^{37}. The magnetic field required at the Cl nucleus to produce interactions of this magnitude is unexpectedly large—about 70 gauss. It seems difficult to account for so large a field from molecular rotation alone, and the hypothesis of Van Vleck[1] that the field is due to coupling with higher electronic states is perhaps more plausible. The ratio $c^{35}/c^{37}=1.9\pm0.97$ is in agreement, within the rather large experimental error, with the ratio of the magnetic moments 1.2055 ±0.003 taken from Goldsmith and Inglis.[5] Assuming the effective magnetic field is the same in both isotopic species these two ratios should be the same.

Table I. Observed transitions and frequencies.

Molecule	v	$J=0\rightarrow1$ F	Frequency, mc
FCl^{35}	0	$3/2\rightarrow1/2$	30,873.004 ±0.042
		3/2 5/2	30,843.948 ±0.042
		3/2 3/2	30,807.413 ±0.042
	1	$3/2\rightarrow1/2$	30,611.761 0.069
		3/2 5/2	30,582.614 0.069
		3/2 3/2	30,545.994 0.069
FCl^{37}	0	$3/2\rightarrow1/2$	30,280.107 ±0.042
		3/2 5/2	30,257.159 0.042
		3/2 3/2	30,228.359 0.042
	1	$3/2\rightarrow1/2$	30,026.195 0.069
		3/2 5/2	30,003.218 0.069
		3/2 3/2	29,974.470 0.069

Table II. Molecular constants of FCl.

	FCl^{35}	FCl^{37}
B_e	15,483.688 ±0.026 mc	15,189.221 ±0.026 mc
I_e	54.1822×10^{-40} g cm²	55.2326
D_e	0.0263 mc[a]	0.0253
α	130.666 ±0.029 mc	126.957 ±0.029
r_e	1.62811×10^{-8} cm	
μ	0.881 ±0.02 debye	
c	0.036 ±0.009 mc	0.019 ±0.009
eq$Q$	−145.94 ±0.26 mc	−114.92 ±0.26

[a] Calculated from the vibrational frequency given by A. L. Wahrhaftig, J. Chem. Phys. **10**, 248 (1942); also P. A. Griswold, thesis, State University of Iowa, 1949.

The values of the quadrupole coupling energy are $eqQ^{35}=-145.99\pm0.26$ mc and $eqQ^{37}=-114.92\pm0.26$ mc. The ratio $eqQ^{35}/eqQ^{37}=1.2704\pm0.004$ is only in fair agreement with the ratio of the quadrupole moments obtained by Davis and Zabel[6] from the spectrum of atomic chlorine, $Q^{35}/Q^{37}=1.2795\pm0.0026$. The existence of coupling with higher order electronic states also introduces a "pseudo-quadrupole" coupling[1,3] of unknown magnitude, indistinguishable from the nuclear coupling. Such a contribution to eq$Q$, being the same in both isotopic molecules, would tend to alter the observed ratios.

The ratio $Be^{37}/Be^{35}=0.9809821\pm0.0000024$ gives for the mass ratio $Cl^{35}/Cl^{37}=0.9459775\pm0.000004$. This agrees quite well with the value obtained by Townes *et al.*[7] from the microwave spectrum of ICl, 0.9459801±0.000005. Both microwave determinations disgree with the best value from mass spectroscopy,[8] 0.9459445 ±0.000007. We conclude that the latter is probably in error.

Stark effect measurements were made on the line $F=3/2\rightarrow3/2$, $M_F=3/2\rightarrow3/2$. The analysis of these data requires the solution of the secular equation for the case of intermediate field strength[9] $\mu^2E^2/B\sim eqQ$. The value of the molecular electric dipole moment appears in Table II along with other derived and measured molecular constants.

The bond in FCl is estimated at 80 percent covalent, 20 percent ionic, the latter figure being an average of the value obtained from electro-negativity difference and that obtained from the observed dipole moment. The large observed quadrupole coupling is in qualitative agreement with the value calculated on this basis, but somewhat larger than that obtained by assuming the covalent bond to be an $s-p$ hybrid[10] and neglecting other contributions to q.

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