$$\nu_0^{-1} = 2\pi\gamma_2^{-1}[m/kT)]^{1/2} ;$$

γ_2 is a constant, k is Boltzmann's constant, m is the reduced mass of a colliding pair, and T is the absolute temperature. We have analyzed the observed spectra using Eq. (1). Figure 1(a) is a graph of $\log_{10}(I/\sqrt{\nu})$ versus ν for liquid Xe. The experimental points fall on a straight line over most of the frequency range of the wing, in good agreement with the theory for gases. The slope of the graph gives a value of $\nu_0 = 10.5 \pm 0.5$ cm^{-1} for liquid Xe. A similar plot gives straight lines for the depolarized Rayleigh wings of the spherical-top molecules, as shown in Fig. 1(b). The slopes of these lines[7] were found to be roughly proportional to $[m/(kT)]^{1/2}$; the constant of proportionality γ_2^{-1}, which is a measure of the distance between two colliding molecules for maximum induced anisotropy, was determined to be 0.6 Å for the molecular liquids.

It is concluded that the theory of collision-induced light scattering in gases appears to explain the existence and shape of the depolarized Rayleigh wing for liquids composed of isotropic molecules. Preliminary observations in this laboratory indicate that scattering due to induced anisotropy may be of more general importance since a similar dependence [Eq. (1)] over a limited frequency range has been found for liquids composed of anisotropic molecules such as CS_2, C_6H_6, C_6D_6, C_6F_6, and $C_6H_5NO_2$.

We are grateful to Professor C. J. L. Lock of McMaster University for purifying the more reactive liquids investigated.

Note added in proof. A similar depolarized spectrum with exponential line shape has been observed in liquid argon (P. A. Fleury and J. P. McTague, Opt. Commun. 1, 164, 1969; J. P. McTague, P. A. Fleury, and D. B. Du Pré, Phys. Rev. 188, 303, 1969).

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Electron *g* Factors of Low-Lying Levels of Ce I [†]

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Electron *g* factors have been measured for 33 low-lying states of Ce I with the atomic-beam magnetic-resonance technique.

INTRODUCTION

The measurement of electron *g* factors to high precision provides quantitative evidence with which to judge the validity of theoretical atomic wave functions. Such measurements thus yield information that can be useful in guiding theoretical investigations of atomic states and their interactions.

The case of Ce I is very attractive experimentally. Forty-five odd-parity levels and two even-parity levels below 7000-cm^{-1} excitation energy, and with $J > 0$, have been identified in optical spec-

TABLE I. Compilation of measured values of g_J. The data in columns 1, 2, 3, and 5 are from Ref. 2.

Configuration	State	Energy level (cm^{-1})	Expected relative intensity of state	Value of g_J	
				Optical	Atomic beam
$4f5d6s^2$	$^1G_4$	0	0.167	0.9462	0.945 43 (3)
$4f5d6s^2$	$^3F_2$	228	0.144	0.7661	0.765 15 (3)
$4f5d6s^2$	$^3H_4$	1279	0.074	0.8889	0.889 79 (3)
$4f5d6s^2$	$^3G_3$	1388	0.069	0.7360	0.734 94 (3)
$4f5d6s^2$	$^3F_3$	1663	0.058	1.077	1.077 36 (3)
$4f5d6s^2$	$^3H_5$	2208	0.041	1.033	1.032 12 (4)
$4f5d^26s$	$^5H_3$	2369	0.037	0.5975	0.599 78 (2)
$4f5d6s^2$	$^1D_2$	2378	0.037	0.937	0.936 54 (3)
$4f5d^26s$	$^5H_4$	2437	0.036	0.9854	0.985 92 (3)
$4f5d6s^2$	$^3G_4$	3100	0.024	1.081	1.077 03 (4)
	$J=4$	3196	0.022	0.6668	0.666 12 (3)
$4f5d^26s$	$^5H_5$	3210	0.022	1.160	1.162 77 (3)
$4f5d6s^2$	$^3F_4$	3312	0.021	1.083	1.085 82 (4)
$4f5d6s^2$	$^3D_1$	3710	0.016	0.616	0.615 49 (2)
$4f5d^26s$	$^5I_5$	3764	0.016	0.906	0.906 91 (3)
	$J=0$	3974	0.014	•••	•••
$4f5d6s^2$	$^3H_6$	3976		1.157	1.160 32 (4)
	$J=1$	4020	0.013	1.489	1.494 04 (4)
	$J=3$	4160	0.012	0.730	0.729 33 (3)
$4f5d^26s$	$J=4$	4173	0.012	1.029	1.029 48 (4)
	$J=5$	4199	0.012	1.150	1.150 21 (3)
	$J=5$	4417	0.010	1.179	1.177 90 (3)
	$J=6$	4455	0.010	1.118	1.117 14 (4)
	$J=2$	4746	0.008	1.165	1.165 93 (5)
$4f^26s^2$	$^3H_4$	4762	0.008	0.806	0.805 08 (8)
	$J=2$	4766	0.008	1.153	1.149 45 (10)
	$J=3$	5006	0.007	1.253	1.236 74 (4)
	$J=1$	5097	0.007	1.886	1.882 57 (6)
	$J=2$	5210	0.006	1.225	1.226 94 (5)
	$J=7$	5315	0.006	1.215	1.216 25 (7)
	$J=2$	5409	0.006	0.773	
	$J=3$	5519	0.005	1.244	1.245 30 (5)
	$J=0$	5571			
	$J=4$	5572	0.005	1.315	1.316 58 (3)
	$J=1$	5637	0.005	1.389	•••
	$J=1$	5674	0.005	0.140	•••
	$J=7$	5802	0.004	1.237	•••
	$J=2$	5904	0.004	0.905	•••
	$J=3$	6234	0.003	1.042	1.049 65 (6)
	$J=2$	6303	0.003	1.419	•••
	$J=3$	6337	0.003	1.232	•••
	$J=4$	6475	0.003	0.897	•••
	$J=3$	6621	0.003	1.147	•••
	$J=5$	6663	0.003	0.953	•••
	$J=8$	6809	0.002	1.250	•••
	$J=2$	6836	0.002	0.683	0.680 78 (3)

troscopic investigations by Martin.[1,2] Martin has assigned angular momentum, excitation energy, and g_J values to all of those levels; to some of them he has been able to give the electronic configuration and L-S-state descriptions (Table I).

Three low-lying states (for which we measured $g_J = 0.94543$, 0.76515, and 1.07736) have been observed previously with the atomic-beam magnetic-resonance technique by Smith and Spalding.[3] Their values are in agreement with those of the present work.

EXPERIMENTAL DETAILS

The atomic-beam apparatus used for the experiment is a conventional two-pole flop-in machine with a mass-spectrometer detector. This machine and its associated electronic data-handling system have been described in detail previously.[4,5] For this experiment the mass-spectrometer detector was adjusted to observe the intensity of the 88% abundant Ce^{140} in the beam.

The source oven was a tantalum cylinder, closed except for a 0.25 × 0.01-in. vertical slit and fitted with a sharp-lipped tantalum inner crucible which contained Ce metal. The oven was heated by electron bombardment to a nominal temperature of 2200 °K (vapor pressure ≈ 0.1 mm).[6]

The intensity of the homogeneous magnetic field in which the rf transitions were induced was set and held constant by observing the rf resonance $(F, m_F) \leftrightarrow (F', m_F') = (2, -1) \leftrightarrow (2, -2)$ of a beam of K^{39} from an independent source oven. The intensity of this beam was measured with a surface-ionization detector.

EXPERIMENT

For atoms such as Ce^{140}, which have nuclear spin $I = 0$, one resonance can be observed for each atomic state ($J \neq 0$) provided that (i) the lifetime of the state is long enough for the atom to traverse the apparatus (ii) the relative population of the state is sufficient to allow the achievement of an adequate signal-to-noise ratio, and (iii) the atomic magnetic moment be large enough so that the deflection achieved by the inhomogeneous magnetic fields is adequate to allow observation of the resonance.

For a given state, the resonance observed is ordinarily a double-quantum transition between magnetic substates $m_J = 1$ and $m_J = -1$. Multiple-quantum transitions of higher order may also be observable if they take place between states with $m_J = -m_J'$ and if the rf power is adequate. The relative intensity of the transition should be given by the Boltzmann factors calculated for the temperature of the oven.

For magnetic fields that are not too strong, the frequency of the multiple-quantum transition (for any multiplicity) at a given magnetic field H is $\nu = g_J \mu_0 H/h$, where μ_0 is the Bohr magneton and h is Planck's constant. Since H is set with high precision by means of the K^{39} resonance, a measurement of ν yields the value of g_J directly.

Because of the large density of low-lying states in the Ce I level scheme (26 states below 5000 cm^{-1}), the population of most of the observable states, and consequently the signal-to-background ratio, will be small. Although, in principle, the data-handling system used allows one to work with arbitrarily small signal-to-background ratios, practical considerations such as time and, ultimately, the limiting very long-term performance of the system demands that some reasonable integration time be chosen for any resonance search.

In the present experiment the integration time was chosen so that all states below 5000 cm^{-1}

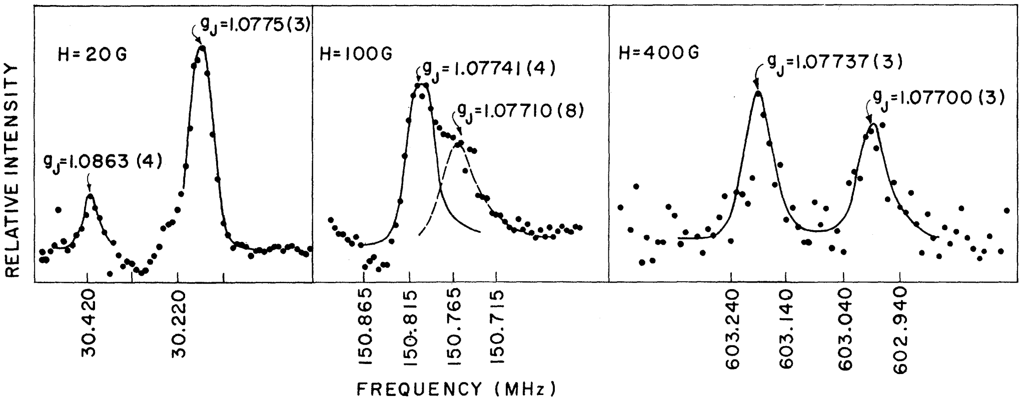

FIG. 1. Resonances for states with g_J near 1.077 at fields of 20, 100, and 400 G.

should have been observable. No claims are made, however, that some weak states could not have been missed in the region searched. Fortuitously, good behavior of the apparatus did allow the observation of a few states of higher excitation.

An initial search for resonances was made with the uniform magnetic field set at 10 G. This search covered the rf region 6.85–28.33 MHz, which corresponds to g_J in the range 0.49–2.02.

The resonances thus found were looked at again at higher values of the magnetic field (20, 100, 200, and 400 G) in order to improve precision and resolution (Fig. 1). For example, the resonance for which the average over measurements at all fields yields $g_J = 1.07703$ was not even barely resolved from the one with $g_J = 1.07737$ in the observations with a uniform field below 100 G.

The measurement of g_J, of course, provides no direct information about J or the energy level of the state in which the resonance occurs. In order to make such identifications, the final values of g_J were compared with Martin's[2] optical spectroscopic measurements of Landé g factors. In cases where such a comparison was not definitive, relative intensities of the resonances were compared with the expected Boltzmann factors calculated from Martin's energy levels. Table I summarizes the present measurements and their assignments to Martin's level scheme. The expected relative intensities (column 4) are calculated from the Boltzmann factors

$$p_i = e^{-E_i/kT} \Big/ \sum_j e^{-E_j/kT}$$

The even-parity $4f^2 6s^2\ ^3H_4$ state at 4762 cm^{-1} is of special interest. It might be expected that atoms in this state would decay to one of the low-lying odd-parity states, and indeed a strong infrared line at 21 000 Å has been reported by Champeau and Verges.[7] In the present atomic-beam investigations, the relative intensities of the resonances for this state were consistent (within the limitations of the experimental technique) with the normalized Boltzmann factor for the energy level of the state and the nominal oven temperature of 2200 °K. The half-life of the state for a free atom, then, must be at least the average transit time (1.5 msec) of atoms through the atomic-beam apparatus.

This long half-life does not necessarily imply a discrepancy with the optical-spectroscopic observations. In the atomic-beam apparatus an atom is quite free from perturbations, while in the discharge source used in optical spectroscopy the atoms are subject to electromagnetic fields and collisions with other atoms and electrons — all of which may induce transitions that otherwise might be forbidden.

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