in the scintillator, E_{p1} and E_{p2} some two energy values within the flat portion of the pulse distribution and N_{p1} the sum of counts within this portion, then we have:

$$\frac{N_\alpha}{N_{pt}} = \frac{n_C \sigma_C}{n_H \sigma_H} \text{ with } \frac{n_H}{n_C} = 0.8569 \text{ for stilbene}$$

and $\sigma_H = 0.690$ b ($E_n = 14$ MeV).

The proton number is computed from the relation

$$N_{pt} = \frac{14{,}0}{E_{p2} - E_{p1}} N_{p1} . \qquad (2)$$

The value for σ_C found in this manner is (260 ± 20) mb. It was obtained as an average from about 10 spectra including those taken with a $2'' \times 2''$ NE 213 scintillator.

The error of about 8% is mainly systematic. It is dependent on the form of the light curve in the proton energy range between E_{p1} and E_{p2}, because it is implicitely used in Eq. (2), and on the electronic threshold of the PSD-circuit, cutting off the α-spectrum.

The light curves used by the several authors differ mainly at lower and higher energies from one another [1, 3, 25, 26]. The influence of the PSD threshold is evident from Fig. 2: It is slightly above the first minimum in the spectrum, where the carbon recoil pulses mix with the α-pulses. So it is estimated that the value for σ_C rather tends to be somewhat larger than that given above. If one assumes an average cross section of 73 mb for the reaction $^{12}C(n, \alpha_0)^9Be$ (mean value from [11–15]) one obtains $\sigma(n, n')3\alpha = (190 \pm 20)$ mb.

[25] F. X. Haas and J. T. McCarthy, Nucl. Instr. Meth. **50**, 340 [1967].

[26] M. M. Wasson, AERE-Report 4269, Harwell 1963.

Relative Line Intensities in the Lyman Bands of HD and H_2

K. H. Becker and E. H. Fink

Institut für Physikal. Chemie der Universität Bonn, Germany

(Z. Naturforsch. **26 a**, 319—320 [1971]; received 20 January 1971)

Relative intensities of $P(J'+1)$ and $R(J'-1)$ lines have been measured in the $(v'=3, v'')$ progressions of the Lyman bands of HD and H_2. The intensity ratios are in good agreement with previous experimental data and with the results of theoretical calculations which account for the centrifugal distortion.

The influence of vibration-rotation interaction on calculated Franck-Condon factors and transition probabilities of spectral lines of hydrogen molecules has recently been studied by several authors [1–4]. It was found that inclusion of the centrifugal potentials in the calculations is necessary for precise theoretical predictions. The results of such calculations were put to an experimental test by Fink, Akins, and Moore [5] who measured the relative intensities of $P(J'+1)$ and $R(J'-1)$ lines in three $(v'=\text{const}, v'')$ progressions of the Lyman bands of HD, and compared the experimental line intensity ratios with theoretical data obtained from Franck-Condon factor calculations. Later Allison [6] compared the results of Fink et al. with more precise theoretical data obtained from calculations of the total transition probabilities of the corresponding lines. He found that all experimental values were slightly larger than the theoretical data. The present work was performed mainly to decide whether this finding was accidental or a real effect. Due to a more sensitive detection system the accuracy of the measurements could be essentially increased. Therefore, part of the measurements of Fink et al. were repeated, and additional measurements were performed in the $(v'=3, v'')$ Lyman band progression of H_2.

A fluorescence set-up with an argon microwave lamp was used to excite HD and H_2 to the HD $(B\,^1\Sigma_u^+; v'=3; J'=2)$ and $H_2(B\,^1\Sigma_u^+; v'=3; J'=1)$ levels, respectively, through absorption of the 1066 Å argon resonance line [7]. The $(v'=3, v'')$ fluorescence band progressions mainly consist of the $P(3)-R(1)$ and $P(2)-R(0)$ line pairs. The relative intensities of the lines were measured photoelectrically by means of a 1-m scanning monochromator (Hilger α Watts type E 766) and a channeltron photon counter (Bendix type BX 762). For measurements below 1250 Å a sodium salicylate coated EMI 6255 SA photomultiplier was used. Peak heights as well as peak areas were measured to obtain the intensity ratios of the $P(3)$ to $R(1)$ and $P(2)$ to $R(0)$ lines for all bands which were not seriously overlapped by other emissions. In Tables 1 and 2 the results are compared with the previous experimental data and with the theoretical values obtained from calculated total transition probabilities of the HD and H_2 lines [6, 8]. In most of the HD bands the experimental error limits could be reduced. In the HD as well as in the H_2 bands the experimental results are in very good agreement with the theoretical data. In both cases no systematic difference between theoretical and experimental data is observed. Thus the present results prove that the relative line intensities of $P(J'+1)$

[1] M. Halmann and I. Laulicht, J. Quant. Spectry. Radiative Transfer **8**, 935 [1968].

[2] D. Villarejo, R. Stockbauer, and M. Inghram, Chem. Phys. Letters **2**, 11 [1968].

[3] D. Villarejo, R. Stockbauer, and M. Inghram, J. Chem. Phys. **50**, 1754 [1969].

[4] L. Wolniewicz, J. Chem. Phys. **51**, 5002 [1969].

[5] E. H. Fink, D. L. Akins, and C. B. Moore, Chem. Phys. Letters **4**, 283 [1969].

[6] A. C. Allison, J. Chem. Phys. **52**, 4909 [1970].

[7] E. H. Fink, D. L. Akins, and C. B. Moore, J. Chem. Phys. (to be published).

[8] K. H. Becker, E. H. Fink, and A. C. Allison, J. Opt. Soc. Amer. (to be published in April 1971).

Table 1. Intensity ratios $I[P(J'+1)]/I[R(J'-1)]$ for the $(B\,^1\Sigma_u^+;\ v'=3;\ J'=2 \rightarrow X\,^1\Sigma_g^+;\ v'';\ J'\pm 1)$ transition of HD.

v''	Calculated Ref. [6]	Experimental Ref. [5]	Experimental This work
1	1.53	1.58 ± 0.06	1.52 ± 0.05
2	1.42	1.49 ± 0.06	1.45 ± 0.04
3	0.74	0.82 ± 0.08	0.73 ± 0.04
4	1.69	1.74 ± 0.04	1.73 ± 0.04
5	1.44	1.48 ± 0.05	1.43 ± 0.03
6	0.85	0.93 ± 0.06	0.85 ± 0.03
7	1.78	1.85 ± 0.05	1.82 ± 0.05
8	1.44	1.50 ± 0.05	1.46 ± 0.05
9	0.79	0.84 ± 0.05	0.82 ± 0.04
10	1.85	1.88 ± 0.05	1.87 ± 0.04
11	1.52	1.55 ± 0.03	1.53 ± 0.03
12	1.32	1.37 ± 0.04	1.32 ± 0.04
13	0.99	1.07 ± 0.06	0.98 ± 0.04

and $R(J'-1)$ lines in the Lyman bands of HD and H_2 are well represented by calculated transition probabilities if effective potentials

$$V = V_0 + h^2 J(J+1)/(8\pi^2 \mu r^2)$$

Table 2. Intensity ratios $I[P(J'+1)]/I[R(J'-1)]$ for the $(B\,^1\Sigma_u^+;\ v'=3;\ J'=1 \rightarrow X\,^1\Sigma_g^+;\ v'';\ J'\pm 1)$ transition of H_2.

v''	Calculated Ref. [8]	Experimental
1	2.00	1.96 ± 0.06
2	1.82	1.80 ± 0.05
4	2.03	2.06 ± 0.05
5	1.73	1.70 ± 0.05
6	2.58	2.55 ± 0.06
8	1.49	1.52 ± 0.06
9	2.40	2.42 ± 0.08
10	2.01	1.98 ± 0.04
11	1.76	1.74 ± 0.06

are used in these calculations. At least for low rotational quantum numbers, no inclusion of second order correction terms in the effective potential seems to be necessary. Such a correction term was included in calculations of Franck-Condon factors for the NO β-bands by GENEROSA and HARRIS [9].

[9] J. I. GENEROSA and R. A. HARRIS, J. Chem. Phys. **53**, 3147 [1970].

Ein Mikrowellen-Mikrowellen-Doppelresonanzexperiment. Abtrennung der höherfrequenten Pumpe vom Detektor durch Verwendung gekreuzter Felder *

U. ANDRESEN ** und H. D. RUDOLPH

Physikalisches Institut der Universität Freiburg i. Br.

(Z. Naturforsch. **26 a**, 320—322 [1971]; eingeg. am 31. Dezember 1970)

In a microwave double-resonance experiment involving three rotational levels of propylene oxide perpendicular polarization of the pump and signal radiation was employed to prevent the higher-frequency pump radiation (24 GHz) from reaching the signal detector (11 GHz). For this purpose the independent cut-off characteristics of the TE_{10} and TE_{01} waveguide mode were exploited which depend only on the broad or small-face waveguide dimension, respectively.

Wir haben a. a. O. [1] ein Mikrowellen-Mikrowellen-Doppelresonanzexperiment mit modulierter Pumpe [2] innerhalb eines 3-Niveausystems, bestehend aus drei Rotationsenergieniveaus des Moleküls Propylenoxyd, beschrieben, wobei unseres Wissens zum ersten Mal senkrecht zueinander polarisierte Pump- und Signalstrahlung in der Hohlleiterzelle verwendet wurde. Auch die nötige Theorie ist dort gegeben, auf die andersartigen Auswahlregeln wird verwiesen.

Ursprünglich war das Verfahren zu dem Zweck ersonnen worden, ein leidiges Problem der Doppelresonanzspektroskopie auf möglichst einfache Art zu lösen, nämlich die starke Pumpstrahlung vom Detektor der schwachen Signalstrahlung auch in dem Falle wirksam fernzuhalten, in dem die Pumpstrahlung höhere Frequenz als die Signalstrahlung hat und sich daher ungehindert im Hohlleiter, der zum Detektor führt, ausbreiten kann, wenn Pumpe und Signal, wie sonst üblich, parallel zueinander polarisiert sind (beides TE_{10}-Wellen). Bei gekreuzten Feldern jedoch kann man die Tatsache, daß die Grenzwellenlängen der TE_{10}- und TE_{01}-Wellen prinzipiell voneinander unabhängig sind, zum gewünschten Zweck ausnützen. Es gilt für die durchgelassenen (ν) und Grenzfrequenzen (ν_g):

$$\nu(TE_{10}) \geqq \nu_g(TE_{10}) = c/2a\,, \qquad (1)$$

$$\nu(TE_{01}) \geqq \nu_g(TE_{01}) = c/2b\,, \qquad (2)$$

wobei c die Lichtgeschwindigkeit und a bzw. b üblicherweise die Länge der breiten bzw. schmalen Seite des Hohlleiterquerschnitts ist. Ersichtlich kann durch geeignete Abmessungen a, b eines Hohlleiters über (1) und (2) getrennt verfügt werden, wobei schon ein ausreichend langes eingesetztes Hohlleiterstück den Zweck als Sperre erfüllen sollte.

Sonderdruckanforderungen an Prof. Dr. H. D. RUDOLPH, Physikalisches Institut der Universität Freiburg, *78 Freiburg i. Br.*, Hermann-Herder-Str. 3.

* Der wesentliche Inhalt dieser Arbeit wurde auf der FA-Sitzung Molekülphysik der DPG in Bad Nauheim, März 1969, von H. D. R. vorgetragen.

** Jetzige Anschrift: Institut für Physikalische Chemie, Abt. Chemische Physik, *D-23 Kiel*, Olshausenstraße 40—60.

[1] H. D. RUDOLPH, H. DREIZLER u. U. ANDRESEN, Z. Naturforsch. **26 a**, 233 [1971].

[2] R. C. WOODS III, A. M. RONN, E. BRIGHT WILSON JR., Rev. Sci. Instrum. **37**, 927 [1966].