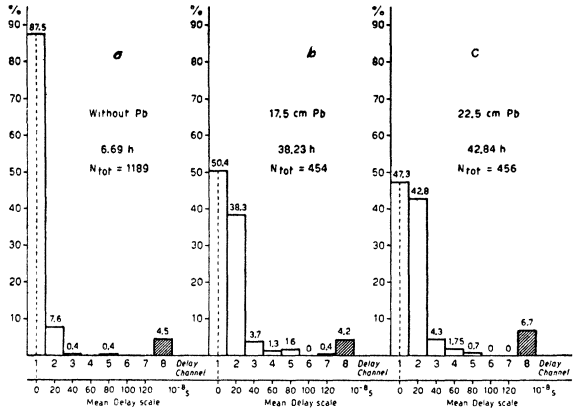

FIG. 2. Experimental results. The true scale for the abscissa is a "mean" scale, which takes into account the spreading due to the counter fluctuations.

One can calculate readily that under our experimental conditions the time origin is given, in more than 98 percent of the cases, by the arrival of an electron. Thus, the histograms (b) and (c) can be assumed to give the actual distributions of penetrating events relative to the electrons. They are in fairly good agreement with the results of McCusker and his co-workers,[2] who rule out the existence of delays greater than about 1.5 μsec. As it is reasonable to assume that the electron-photon component travels with the velocity of light throughout the whole development of the shower, the most plausible interpretation of the delays found is that they are due to the velocities of the penetrating particles produced in the development of the shower, these velocities being, on the average, smaller than those of the electron-component.

For a rough comparison, we have calculated the delay distribution to be expected on the hypothesis that all of the pairs produced in atmospheric showers are mesons which are created, together with the electron-photon component, at a definite height vertically above the apparatus (corresponding to a pressure of 100 g/cm^2) with a generation spectrum of the type $E^{-3}dE$, and are absorbed in the atmosphere by ionization loss and natural decay. The calculated distribution is cut off at $\tau=0.45$ μsec, owing to the lead shield; this is obviously independent of the generation spectrum and practically independent of the height of formation chosen, at least for heights greater than that chosen. The cut-off time is thus an upper limit for the delays due to a penetrating particle, always in the form of a meson or particle of lighter mass, which can be traced back from the apparatus to the origin of the shower. The counting rates of the delay channels 4 to 7 (about 2 to 3 percent of the total number of penetrating events) must therefore be due to pairs which have traveled for a noticeable fraction of their paths from the origin of the shower, as particles with a mass much larger than that of the meson. The experimental results are in rough agreement with the calculated distribution for $\tau \leqslant 0.45$ μsec, but no great significance can be attached to this agreement as an indication of the accuracy of the hypothesis made.

[1] A detailed description of the electronics employed, as well as a discussion of the effect of the fluctuations in the times of discharge of the counters will appear shortly in *Nuovo Cimento*. For the method used in the calibration of the time axis see *Energia Elettrica*, November, 1950.
[2] McCusker, Ritson, and Nevin, Nature **166**, 400 (1950).

Microwave Spectra of Deutero-Ammonias

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December 1, 1950

APPROXIMATELY 125 lines of ND_3, ND_2H, and NDH_2 have been found[1] in the region from 2000 to 17,000 Mc. This work is part of a program to provide precise reference standards for frequency and intensity to lower frequencies than previously available as an adjunct to compilation of microwave spectra tables.[2]

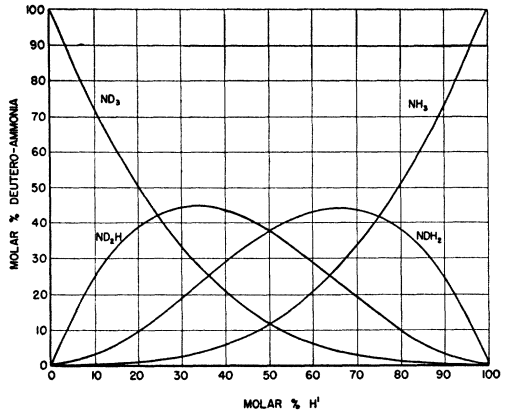

FIG. 1. Deutero-ammonia equilibrium ratios *vs* H[1] contamination.

All measurements were made using a 5-kc, zero-based, square-wave-modulated Stark spectrograph employing a synchronous detector.[3] A new design of mica and metal *S*-band absorption cell allowed high temperature outgassing.[4] Hyperfine spacings were found to be somewhat different from NH_3; hyperfine lines are not included in Table I.

The source of the deutero-ammonias for this work was a high pressure bomb of ND_3 containing up to 5 or 10 percent H[1]. In the presence of other H[1] containing molecules, the partially deuterated ammonias are known to be formed rapidly[5] in the ratios indicated in Fig. 1. This effect was utilized to generate the partially deuterated ammonias and to provide a means of isotopic assignment of the lines on the basis of intensity growth. Excluding the NH_3 lines, measurements showed that there were three qualitatively distinct types of lines. Within one-half hour after insertion of a fresh sample of ND_3, type (0) lines decreased perhaps 10 percent or more of their initial strong values; type (1) lines increased by 10 to 100 percent above the initial strong intensity; and type (2) lines increased from essentially zero to an intensity many times the initial value. A reference to Fig. 1 indicates that, in a system where the hydrogen contamination drives the equilibrium from

TABLE I. Deutero-ammonia microwave spectrum.[a]

Freq. (Mc)	Rel. int.	Freq. (Mc)	Rel. int.	Freq. (Mc)	Rel. int.	Freq. (Mc)	Rel. int.	Freq. (Mc)	Rel. int.
2094[0]	43	4161	8	5236	3	7104	10	12620	40
2186[0]	75	4199	12	5364	99	7238[1,b]	3	12778	1290
2290[0]	15	4216	8	5368	5	7388[1]	90	13065	169
3261		4219	9	5392	120	7562[2]	350	13119	523
2403[0]	5	4241	7	5415	200	7803	185	13175	23
2408		4282	2	5495	210	8278		13210	1200
2431		4407	105	5508[1]	84	8283	470	13316	400
2480		4410	30	5549	2	8778	60	13488	234
2533[0]	5	4511	25	5574	3	8903	54	13626	580
2599		4721	36	5582[1]	320	8922		13657	106
2614	4	4850	72	5632[1]	55	9014	220	13923	586
2652	7	4859	141	5635[1]	114	9521	600	14067	620
2668		4907	90	5689	1	9636		14102	700
2699		4915	23	5726	2	9829		14566	530
2746		4938	14	5786[1,b]	110	9967		15004	18
2786		4948	96	5787[1,b]	120	10091		15132	384
2800	4	4956	37	5964[1,b]	126	10660	50	15524	35
2900	3	5025	27	6105[1,b]	132	10844	1750	15634	9
2939	3	5030	7	6164[1,b]	120	11400	100	15772	280
2978	3	5122	3	6390[1,b]	45	11975	250	15935	20
3010	3	5124	6	6463	153	11983	250	16320	134
3187	17	5192	42	6598	46	12147	500	16455	210
3470[1]	29	5199[1]	290	6641[1,b]	27	12150	1833	16493	153
3865[1]	290	5213	2	6922[1,b]	13	12392	700	16497	34
4086[1]	13	5230	5	6975	1	12444	75		

[a] Superscripts 0, 1, 2 denote, respectively, line types 0, 1, 2.
[b] Assignments subject to further tests.

the most deuterated condition toward a more nearly equal concentration of H^1 and H^2, the intensity changes of type (0), (1), and (2) lines are to be associated respectively with 0, 1, and 2, hydrogen replacements per molecule of ND_3. From a measure of the type and amount of intensity drift observed for a given type line, a quantitative estimate was made as to the instantaneous location on the ratio curves. From this position a prediction could be made as to the intensity change to be expected by driving the assumed equilibrium slightly toward NH_3 or ND_3 by addition of a small amount of the appropriate gas. In every instance both the initial change and the rate of the line intensity confirmed the indicated correlation between line type and deutero-hydrogen assignment. The complete assignment of all observed lines by these techniques awaits further work.

Table I lists the lines so far measured. Rough frequency measurements for this preliminary survey were made by means of cavity frequency meters with precision measurements to be made later directly against the NBS frequency standards. Relative intensities expressed, as recorder line-heights, are shown in Table I when intensity measurements were made and are uncorrected for the unknown isotopic abundance. Line intensities in restricted frequency regions were reproducible for a given type line. However, variations of equipment sensitivity with line-height and frequency correspondingly limit the ranges within which these values have significance.

Helpful discussions with C. H. Townes during the course of this work are gratefully acknowledged.

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[1] Harold Lyons, Phys. Rev. **76**, 161 (1949); J. Appl. Phys. **21**, 59 (1950). Lyons, Kessler, Rueger, and Nuckolls, Phys. Rev. **81**, 297 (1951).

[2] P. Kisliuk and C. H. Townes, J. Research Nat. Bur. Stand. **44**, 611 (1950).

[3] Strandberg, Wentink, and Kyhl, Phys. Rev. **75**, 270 (1949); McAfee, Hughes, and Wilson, Jr., Rev. Sci. Instr. **20**, 821 (1949); A. H. Sharbaugh, Rev. Sci. Instr. **21**, 120 (1950).

[4] A description of this cell is to be submitted soon to the Rev. Sci. Instr.

[5] See also an account of similar difficulties with the deutero-ammonias in the infrared by J. S. Burgess, Phys. Rev. **76**, 1267 (1949).

The Enhanced Photoelectric Emission Effect in Barium Oxide*

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November 29, 1950

THE activation effect of ultraviolet radiation on the photoelectric emission from BaO recently reported by Dickey and Taft[1] has been studied in this laboratory. Since the reported effect was found for thin films of the oxide, whereas our observations have been made on thermionically active oxide cathode coatings, and since the pronounced wavelength dependence of this effect was not described, it seems desirable to report at this time the results of our study.

Figure 1 (A) shows the spectral distribution of photoelectric emission from a normal sample of pure[2] BaO. This cathode was activated for thermionic emission by drawing current to a movable tantalum anode. A Richardson plot gave thermionic constants of $\varphi = 1.44$ ev and $A = 0.026$ amp/cm^2 °K^2. Maxima in the photoelectric response curve between $h\nu = 3.6$ and 4.0 ev have been found for all samples, although the exact shape in this region differs. These maxima for BaO were previously reported by Apker[3] and are not unlike the maxima found[4] for KI and attributed to exciton production. Curve B was obtained after allowing 3700A radiation ($h\nu = 3.37$ ev) to fall on the sample for 30 minutes. In the region of the photoelectric threshold, below 1.5 ev, the photoemission was doubled, whereas in the region of the exciting wavelength the increase was only about 30 percent.

Measurement of the photo-current in the ultraviolet region from unactivated samples could not be carried out without the radiation used in this measurement changing the state of photoelectric activation, particularly for photo-emission near the threshold. An attempt was made to determine the wavelength range over which photoelectric activation could be produced. All ultraviolet wavelengths down to and including 2537A produced the effect as did wavelengths in the visible. A sample in a low state of activity for enhanced photo-emission could be activated by 7000A radiation, whereas a partially activated sample, e.g., that of Fig. 1, could not be activated further by 4000A. Although the relative efficiencies for these activating wavelengths have not yet been investigated thoroughly, it is clear that the efficiency increases with higher energies but that irradia-

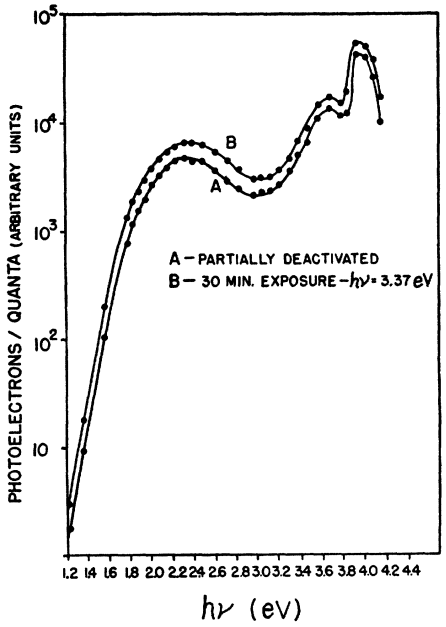

FIG. 1. (A) Spectral distribution of photo-emission from BaO sample. (B) Spectral distribution resulting following 30-minute irradiation at $h\nu = 3.37$ ev.

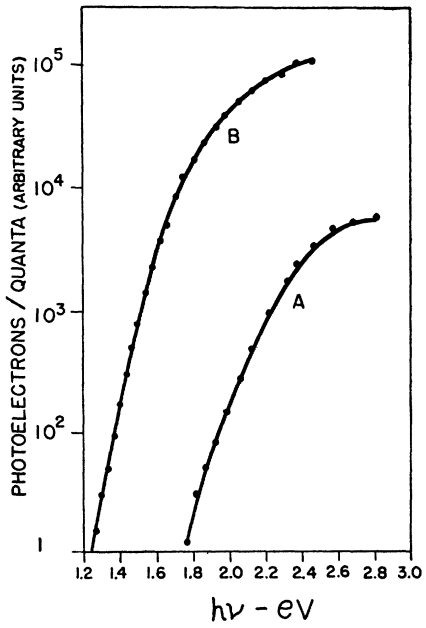

FIG. 2. Spectral distribution of photo-emission from BaO near the threshold, (A) initial unactivated state, (B) after 30 minutes irradiation at $h\nu = 3.37$ ev.