14. COMMISSION DES ETALONS DE LONGUEUR D'ONDE ET DES TABLES DE SPECTRES

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14*a*. SOUS-COMMISSION DES TABLES D'INTENSITÉS

PRÉSIDENT: M. G. J. Minnaert.

MEMBRES: MM. Allen, Bates, Garstang, Green, R. B. King, Layzer, Menzel, J. A. Smit, Zirin.

THE PRIMARY STANDARD

At its second meeting, in September 1957, the Advisory Committee on Redefining the Metre arrived at the unanimous conclusion that the krypton line of approximate wavelength 6056 Å represents the best choice at present available for defining the Metre in accordance with the principles adopted in 1953.* Consequently, on the basis of concordant measurements made at five different laboratories, the Committee issued the recommendation that the Metre be defined as exactly 1 650 763·73 wave-lengths *in vacuo* of the radiation corresponding to the transition $2p_{10}-5d_5$ in krypton of mass-number 86.

The proposed definition is expected to be formally adopted by the General Conference on Weights and Measures in 1960. The primary standard of wave-length will then be identical with that of length, and the angstrom unit exactly 10^{-10} m.

From the wave-number figure given above and the adopted dispersion formula for standard air one obtains to five decimals the following wave-lengths for the proposed primary standard:

$$\lambda_{\text{vacuum}} = 6057{\cdot}80211\ \text{Å},$$

$$\lambda_{\text{stand. air}} = 6056{\cdot}12525\ \text{Å}.$$

The definition refers to the radiation from an atom unperturbed by external influences. There remains, therefore, the practical problem of determining the wave-length shift that will occur in an actual light-source. The krypton lamp developed by Engelhard at P.T.B. (see Report 1955), which was used in the comparisons on which the proposed definition is based, gives a close approach to the ideal wave-length. The difference is of the order of 0·0001 Å, the larger part of which consists of a Doppler shift due to the impact of the exciting electrons, the sign depending on the direction of the current with respect to the direction of observation. Observations at P.T.B. and N.P.L. give for λ6056 a provisional value for this shift of 0·00009 Å. It is to the red when the lamp is viewed from its cathode end. A further shift, always to the red, is proportional to $(pj)^{\frac{1}{2}}$, where p is the krypton pressure and j the current density. It can be calculated [1] and will in general not influence the fourth decimal. The Advisory Committee is expected to issue a statement in due course as to the precise values of these corrections.

Krypton 86 of 99·5 % purity has been produced at the P.T.B. in sufficient quantity to fill 700 lamps.

* Cf. the previous report of Commission 14, *Trans. I.A.U.* **9**, 201, 1957. This reference will henceforth be quoted as 'Report 1955'.

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SECONDARY STANDARDS

In the original programme of this Commission a distinction was made between secondary standards, determined by interferometric comparison with the primary standard, and tertiary standards, interpolated between the secondary standards by means of any large-dispersion spectrograph. This arrangement was intended to reduce the amount of time and labour in obtaining a sufficient number of standards. If a distinction should now be made between different kinds of standards, one would rather classify them according to their purpose. One kind, which we may call class A, would consist of a relatively small number of highly reproducible wave-lengths intended to serve as a substitute for the primary standard to facilitate interferometric measurements in different spectral regions. At present this class comprises lines in natural neon, argon, and krypton, adopted in 1935 and 1955. A number of lines of Hg 198 are being widely used as class A standards without having been formally adopted. It may be expected that the situation with regard to this class of standards will be significantly improved in the near future by direct comparisons with the proposed new primary standard. In the first place it is to be hoped that sufficient material for the adoption of wave-lengths in Hg 198 and Kr 86 at defined and reproducible conditions of excitation will soon become available. Two sets of measurements in Kr 86 are reported below. Further improvements in the standards of natural argon, which is virtually a pure, even isotope, would seem desirable, as well as further measurements in Cd 114 and Ne 20.

Standards of a second type, which may be called class B, are intended for interpolation in grating or prism spectrograms. An accuracy of about $\pm$ 0·001 Å is in general sufficient for this purpose, but there is the additional and essential requirement that lines of not too different intensities should be available at small intervals throughout the spectrum. Class B consists at present of the wave-lengths in the iron arc in air adopted in 1955. Promising improvements by using low-pressure sources and by replacing iron by thorium will be discussed below. Some extensions of rare-gas standards as well as some results in the 1–2μ region included in this report refer also to this category of standards.

Krypton

Preliminary wave-lengths in Kr 86 obtained by direct comparison with λ6057·8021 have been communicated by Barrell from the National Physical Laboratory (N.P.L.) and by Engelhard from the Physikalisch-Technische Bundesanstalt (P.T.B.). The results are quoted in Table 1. The level interval $1s_4$–$1s_5$ occurs in three pairs of lines, giving the individual values 945·0247, 945·0259, 945·0257 cm^{-1}, and the weighted mean 945·0253 cm^{-1}.

Table 1. *Vacuum wave-lengths of* Kr 86

N.P.L.	P.T.B.	N.P.L.	P.T.B.	N.P.L.
6458·0717	·0719	5872·5412	·5416	4455·1669
6422·8004	·8005	5834·4723	—	4426·4319
6238·0758	—	5651·1286	·1286	4401·2015
6084·5441	—	5581·9355	·9353	4377·3504
6057·8021	·8021	5571·8354	·8352	4363·8672
6013·8195	—	5563·7691	·7691	4352·5821
5995·5089	—	4503·6164	—	4275·1716
5881·5289	—	4464·9418	—	

Engelhard has also reported wave-lengths in Kr 84. From the isotopic constitution of natural krypton (see Report 1955) the mean mass-number of even isotopes is found to be 84·01. Consequently, one may expect the wave-lengths of Kr 84 to be practically identical with those of natural krypton, and it is interesting, therefore, to compare Engelhard's results with the krypton standards adopted in 1935. The agreement is satisfactory; the small apparent red-shift of the 1935 standards as shown in Table 2 could be due to the use of a different type of light-source.

Mercury

In Table 3 are collected some recent measurements on the yellow and green lines of Hg 198 as emitted from a Meggers lamp. The values from N.B.S. and N.P.L., which are quoted from Report 1955, have been corrected for pressure effect. The values labelled N.R.C. were obtained by Baird at the National Research Council in Ottawa by using an argon pressure of 0·2 mm Hg at which pressure the correction is negligible. The figures in the last two columns have been reported by Terrien from the International Bureau of Weights and Measures (B.I.P.M.) and Engelhard from P.T.B., in both cases uncorrected for pressure effect.

Table 2. *A comparison of Engelhard's wave-lengths of* Kr 84 *with the 1935 standards of natural krypton*

Kr 84, $\lambda_{vac.}$	Kr 84, λ_{air}	Standards, 1935	Difference
6458·0730	6456·2887	6·291	(+0·002)
6422·8015	6421·0267	1·029	(+0·002)
6057·8031	6056·1262	—	—
5872·5429	5870·9157	0·9158	+0·0001
5651·1296	5649·5616	9·5628	+0·0012
5581·9366	5580·3871	—	—
5571·8362	5570·2894	0·2895	+0·0001
5563·7700	5562·2253	2·2257	+0·0004

Table 3. *Recent measurements on the yellow and green lines of* Hg 198

[*Note added in proof.* The data contained in the Draft Report under this heading are essentially superseded by those given in Table 4 of the Report of the Meeting. They have, therefore, been suppressed in order to avoid a possible confusion.]

Interferometric measurements on some mercury lines in the infra-red, shown in Table 4, have been reported by Humphreys [2] and by Rank *et al.* [3].

Table 4. *Interferometric measurements on infra-red lines of* Hg 198; *wave-lengths in standard air*

Humphreys	Rank *et al.*	Transition
10 139·789	10 139·790	$6p\ ^1P_1$–$7s\ ^1S_0$
11 287·401	—	$7s\ ^3S_1$–$7p\ ^3P_2$
13 570·564	13 570·583	$7s\ ^1S_0$–$7p\ ^1P_1$
13 673·391	—	$7s\ ^3S_1$–$7p\ ^3P_1$
—	15 295·966	$7s\ ^3S_1$–$d^9s^2\ 6p\ ^3P_2$

Neon

Interferometric measurements on twenty-three lines of natural neon in the range 7059–8865 Å have recently been published by Sullivan [4]. Four of the lines belong to the group of adopted standards and show good agreement with the adopted values. All the other lines correspond to transitions $2p$–$2s$ and $2p$–$3d$. There are now available three sets of extensive precision measurements—namely, in addition to Sullivan's, those of Burns, Adams and Longwell [5] and of Meggers and Humphreys [6]—which can be combined to yield accurate values of the $2s$ and $3d$ levels. The procedure is simple because it can be based on the values of the $2p$ levels adopted in 1955. Each line gives directly a value for a high level, and the application of least squares is reduced to assigning appropriate weights to the values obtained from different lines. The final result is condensed in Table 5, where the levels are given in the Paschen notation and their values are referred to $1s_5 = 0$. The estimated uncertainty is in the range from 0·001 to 0·002 cm⁻¹. By combination with the $2p$ levels of Table 3 in Report 1955 a large number of wave-lengths can be calculated, covering the region from 7000 to 15 000 Å. They will provide a useful addition of references for grating measurements in the infra-red, a region which is notoriously poor in standards.

Table 5. *Recommended values of neon levels*

$2s_5$	24 559·271[a]	$3d_6$	27 467·7905[a]	$3s_1''''$	28 366·8131
$2s_4$	24 754·	$3d_5$	27 482·3339	$3s_1'''$	28 368·3336
$2s_3$	25 338·	$3d_4'$	27 548·5062[a]	$3s_1''$	28 378·1418
$2s_2$	25 492·780[a]	$3d_4$	27 550·2800	$3s_1'$	28 393·8380
		$3d_3$	27 565·4209		
		$3d_2$	27 594·7775		
		$3d_1''$	27 657·8213		
		$3d_1'$	27 659·6107		

[a] Derived from one combination only.

Argon

The transitions $2p$–$4d$ and $2p$–$3s$ in argon form a group of lines from 5860 to about 10 000 Å that could become a source of useful standards. Burns and Adams [7] have made extensive interferometer measurements on this group. A few observations of low weight were reported by Meggers and Humphreys [6] and by Meggers [8], and nine lines in the region 5860–6538 Å have been measured also by Littlefield and Turnbull [9]. The latter wave-lengths are systematically smaller by about 0·0015 Å. In this situation it seems better to postpone a possible adoption of values for the $4d$ and $3s$ levels until further observations become available, and to refer to the paper by Burns and Adams for provisional values.

The transitions $2p$–$2s$ and $2p$–$3d$ fall largely beyond the photographic limit in the infra-red. Measurements in this group are being made by C. J. Humphreys by means of a scanning Fabry-Perot interferometer and a PbS-cell. He has kindly communicated his results up to September 1957, for inclusion in this report (Table 6). The accuracy is about 0·001 Å as confirmed by recurring intervals.

Table 6. *Interferometric measurements in argon by C. J. Humphreys; wave-lengths in standard air*

10 673·566	12 487·661	13 313·206	13 622·654
11 668·708	12 802·737	13 367·109	13 678·546
12 112·323	13 228·095	13 504·188	13 718·575
12 343·390	13 272·632	13 599·333	16 940·578
12 439·318			

Iron

The measurements of iron lines as emitted from a hollow-cathode discharge, which were briefly mentioned in Report 1955, have in the meantime been published [10, 11]. More recently Stanley and Meggers [12] have used a microwave-excited electrodeless lamp for interferometric measurements of 103 iron lines in the region 2954–4064 Å. The lamp consisted of a Vycor tube containing a few milligrams of $FeBr_3$ and helium at a pressure of 2 mm Hg. When first lighted the lamp shows the helium spectrum which is soon followed by the bromine spectrum. After a warm-up period of 15–60 sec the iron spectrum becomes very bright, and the helium and bromine spectra virtually disappear. The intensity of the iron spectrum was found comparable to that of the Pfund arc, while the line width is reduced by a factor of two or more.

Stanley has prepared a list of 256 iron wave-lengths by combining the results from the iron-bromide lamp with the hollow-cathode observations. A small correction was applied to the published hollow-cathode value on account of later refinements in the Hg 198 standards. Thirty-five lines that have been measured in both sources indicate no systematic difference. This fact will permit the establishment of one common system of low-pressure iron standards. Stanley's list with the addition of the twenty-seven lines, λ 2851–2457, measured by Blackie and Littlefield is reproduced in Table 7. Further measurements are invited in order to obtain sufficient material for deriving a level system from which a consistent set of standards can be calculated as was done for the iron arc in air (Report 1955).

A comparison between the arc-in-air values and those of Table 7 reveals that for combinations with the low even levels the average wave-number shift is about 0·015 cm^{-1}. The deviations from the average indicate a barely significant correlation with multiplets but no clear-cut dependence on the excitation energy of the upper level. For combinations with the group of high levels (marked 'e' in Report 1955) one finds an average shift of 0·030 cm^{-1} without significant deviations for different multiplets. The present material does not seem to justify a more detailed analysis of the 'pressure effect'. By using the figures given above one would obtain approximate values for low-pressure wave-lengths from those of the arc in air by subtracting $\Delta\lambda = 0{\cdot}015\lambda^2$, where $\Delta\lambda$ is expressed in Å and λ in μ, and twice this amount for lines marked 'e'.

Cadmium

Cadmium 114 is likely to become a useful source for class A standards. Results of interferometric measurements on four lines in the visible have been reported by Batarchoukova, Kartachev and Romanova [13] from the Institute of Metrology in Leningrad (I.M.L.). Burns and Adams [14] have measured a great number of lines over the range 2288–8200 Å. The wave-lengths (in standard air) found for the four visible lines are:

I.M.L. :	6438·4678	5085·8205	4799·9102	4678·1486
B. and A.:	·4691	·8205	·9105	·1493

The difference in the results for the red line is surprisingly large.

Thorium

Meggers has pointed out (see Report 1955) that a thorium-halide lamp, similar in construction to the iron-halide lamp mentioned above, would be an ideal source of standard wave-lengths for large-dispersion spectrographs. The lamp emits a very large number of lines of comparable intensity and uniform distribution throughout the spectrum. Since natural thorium is effectively a pure isotope with mass-number 232, the lines are very sharp and produce good interference patterns with orders up to 400 000, which is nearly ten times better than for the iron arc in air. Stanley and Meggers [15] report that they have determined preliminary seven-figure values for 250 lines in the range from 3263 to 7868 Å. It will be an urgent task to refine these values to eight figures and to extend the measurements in range and number of lines.

WAVE-LENGTH STANDARDS IN THE VACUUM ULTRA-VIOLET

The vacuum ultra-violet (V.U.) may be defined as the region below 2000 Å. Attempts to make interferometric measurements in this region have so far been discouraging. Even if one should eventually succeed, there is little promise that the accuracy of direct measurements will ever surpass or even approach what can be obtained very simply by calculation from atomic energy levels, whose relative values are fixed by well-observed lines in the long-wave region. This possibility of using the combination principle to calculate accurate wave-lengths in the V.U. was pointed out by Paschen [16] already in 1911 and used by Wolff [17] in 1913 in a study of the principal series of Zn, Cd, and Hg.

Table 7. *Provisional wave-lengths (in standard air) of 283 iron lines as emitted by low-pressure sources*

5709·3778	4489·7391	4098·1757	3812·9638	3067·2437
5658·8156	4482·1684	4076·6294	3805·3424	3059·0859
5624·5417	4476·0168	4074·7858	3799·5468	3057·4457
5615·6434	4469·3742	4071·7371	3798·5110	3047·6039
5602·9442	4466·5501	4063·5942	3795·0017	3042·6643
5586·7555	4461·6523	4062·4409	3790·0923	3041·7381
5576·0874	4427·3093	4045·8139	3787·8800	3040·4272
5572·8419	4422·5675	4024·7251	3767·1912	3037·3885
5569·6174	4415·1222	4021·8663	3765·5385	3026·4612
5506·7785	4404·7503	4014·5308	3763·7887	3025·8423
5501·4633	4383·5449	4009·7128	3760·0491	3024·0328
5497·5159	4375·9290	4005·2415	3758·2326	3021·0727
5455·6093	4369·7711	4001·6613	3749·4852	3020·4909
5446·9168	4367·5774	3997·3921	3748·2618	3018·9827
5445·0425	4352·7337	3983·9568	3745·8988	3017·6271
5434·5237	4337·0459	3981·7710	3743·3614	3009·5693
5429·6963	4325·7615	3977·7411	3737·1317	3008·1390
5424·0686	4315·0837	3969·2567	3734·8643	3007·2824
5415·1997	4307·9014	3956·6769	3733·3168	3003·0304
5410·9101	4299·2338	3952·6013	3727·6187	3000·9481
5405·7744	4294·1240	3951·1634	3722·5629	2999·5118
5397·1272	4291·4627	3949·9524	3719·9345	2994·4274
5393·1668	4282·4026	3937·3281	3709·2458	2987·2904
5383·3689	4271·7601	3935·8123	3705·5658	2983·5699
5371·4892	4260·4733	3930·2963	3687·4560	2981·4450
5369·9621	4258·3150	3927·9197	3683·0541	2965·2545
5367·4671	4247·4246	3922·9113	3679·9129	2957·3646
5341·0236	4245·2564	3920·2577	3647·8422	2953·9400
5339·9286	4238·8087	3906·4792	3631·4630	2851·7973
5332·8987	4235·9361	3902·9452	3618·7675	2832·4357
5324·1784	4233·6019	3899·7076	3608·8591	2825·5559
5307·3604	4227·4257	3898·0105	3586·9836	2823·2763
5302·2991	4225·9553	3897·8898	3581·1925	2813·2867
5283·6204	4222·2128	3895·6562	3570·0963	2806·9845
5281·7895	4219·3597	3888·5134	3565·3789	2804·5207
5266·5549	4216·1826	3887·0474	3558·5149	2778·2205
5263·3047	4206·6953	3886·2820	3554·9245	2742·4060
5232·9400	4202·0282	3878·5731	3526·0397	2737·3099
5227·1876	4199·0948	3878·0179	3521·2610	2733·5810
5216·2733	4198·3036	3873·7607	3513·8177	2723·5776
5204·5818	4191·4297	3872·5007	3497·8407	2711·6555
5192·3428	4184·8914	3869·5583	3490·5740	2706·5829
5191·4535	4181·7542	3867·2156	3476·7020	2689·2131
5171·5955	4177·5932	3865·5228	3475·4497	2679·0622
5168·8976	4152·1693	3859·9121	3465·8602	2666·3982
5167·4878	4149·3658	3856·3713	3443·8761	2635·8096
5166·2812	4147·6687	3846·8003	3440·9888	2606·8270
5133·6889	4143·8680	3843·2567	3257·5935	2599·3966
5110·4123	4136·9974	3841·0476	3236·2219	2584·5364
4966·0933	4134·6770	3840·4376	3205·3959	2576·6907
4957·5952	4132·0576	3834·2219	3193·2245	2549·6140
4920·5016	4127·6083	3827·8227	3134·1099	2545·9789
4891·4911	4120·2061	3825·8808	3100·6649	2540·9719
4871·3170	4118·5446	3824·4432	3100·3032	2501·1326
4647·4333	4109·8016	3820·4251	3099·9678	2457·5975
4528·6132	4107·4880	3815·8401	3083·7409	—
4494·5627	4100·7374	3813·0514	3075·7193	—

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The first and second spectra of most elements are potential sources of V.U. standards, which will be automatically obtained as soon as a particular spectrum has been sufficiently well analysed and measured. By this method the V.U. can be covered by standards down to about 1000 Å. A few spectra may give calculable lines with somewhat shorter wave-length, but in order to proceed with calculated standards one will eventually have to base the calculations partly on lines measured by interpolation in the region below 2000 Å. By repeating the process one should be able to push the system of standards to any desired limit. Since the calculations are made in terms of wave-numbers, and $\Delta\lambda/\Delta\sigma$ is proportional to λ^2, the wave-length accuracy need not deteriorate in this process; the error $\Delta\lambda$ will rather tend to decrease in each step.

In accordance with the recommendation at the last meeting of this Commission a brief survey of the present situation regarding V.U. standards will be made in this report.

A special kind of standards is provided by the lines of hydrogen-like spectra, H I, He II, Li III, etc., whose wave-lengths are given by theory to a high degree of precision. Of particular interest are the lines of the Lyman series. They consist of close doublets, $1s\ ^2S_{1/2}\text{–}np\ ^2P_{1/2,3/2}$, the intensities being in the ratio 1:2. The wave-length corresponding to the centre of gravity is given to 0·00001 Å by the formula

$$R\times 10^{-8}\lambda=\frac{1}{Z^2}\frac{n^2}{n^2-1}-\alpha^2\frac{3n^4-8n+9}{12(n^2-1)^2}+\frac{8}{3\pi}\alpha^3(7{\cdot}489-2\ln Z+0{\cdot}0526\,Z)\frac{n^4}{(n^2-1)^2},$$

where R is the Rydberg constant corresponding to the particular atomic mass, Z is the atomic number, and α the Sommerfeld constant (for references, see, e.g. Herzberg [18]). Table 8 gives four-decimal values for the first six lines in the Lyman series of the spectra H I through O VIII. The doublet separation, which is independent of Z, is shown in the last row of the table. The individual components have the wave-lengths $\lambda-\Delta\lambda/3$ and $\lambda+2\Delta\lambda/3$.

Table 8. *Calculated wave-lengths for the first six Lyman lines of the elements from hydrogen through oxygen*

	1s–2p	1s–3p	1s–4p	1s–5p	1s–6p	1s–7p
H	1215·6701	1025·7223	972·5368	949·7431	937·8035	930·7483
D	1215·3394	1025·4433	972·2723	949·4847	937·5484	930·4951
He	303·7822	256·3170	243·0266	237·3308	234·3472	232·5842
Li	134·9977	113·9051	107·9990	105·4679	104·1421	103·3586
Be	75·9277	64·0648	60·7431	59·3196	58·5739	58·1333
B	48·5874	40·9964	38·8709	37·9599	37·4828	37·2008
C	33·7360	28·4656	26·9898	26·3573	26·0260	25·8303
N	24·7810	20·9099	19·8259	19·3613	19·1179	18·9742
O	18·9689	16·0059	15·1762	14·8206	14·6343	14·5243
$\Delta\lambda=$	0·00539	0·00114	0·00043	0·00021	0·00012	0·00007

Of standards calculated on the combination principle the most accurate are those of Hg 198, published by Herzberg [18], and those of the first spectrum of germanium, published by VanVeld and Meissner [19]. They are reproduced in Tables 9 and 10. The germanium wave-lengths refer to a hollow-cathode discharge (the figures in parenthesis give the intensity observed in that light source), while those of Hg 198 refer to a Meggers lamp. The mercury lines of shortest wave-length are high members of the principal series and may, therefore, be rather sensitive to excitation conditions. The accuracy in both sets ranges from one to a few units in the fourth decimal.

A few lines of the principal series in Cd can be calculated from the measurements by Burns and Adams [14]. Mg II [21] and Ca II [22] have also been sufficiently well observed in hollow-cathode sources to yield V.U. standards. They are collected in Table 11 together with the Cd lines.

Other spectra of a similar simple structure, that could be used for the same purpose, are, e.g. Al II, Si I, Zn I, II. Some elements in the first period could also be mentioned, but are less suitable because of too narrow fine-structure, and sensitivity to Doppler and Stark effects.

The second spectra of the transition elements, as for instance the iron group, have large numbers of calculable wave-lengths in the V.U. Many of these spectra are already sufficiently well analysed, but the wave-length measurements need improvement in most cases. Useful standards are at present available in Cu II [23, 24, 25], and Fe II [26, 27, 25]. Until the calculated values have been further improved it may be recommended to use the values given by Wilkinson for 73 Fe II lines from 1964 to 1559 Å, and 158 Cu II lines from 1522 to 862 Å, which he obtained by interpolation on large-dispersion spectrograms by using calculated wave-lengths as references.

Table 9. *Calculated wave-lengths of* Hg 198

1849·4918 (A)	1301·0103 (B)	1235·8371 (C)	1213·9035 (C)
1435·5031 (B)	$1268{\cdot}8246_7$ (A)	1232·2293 (B)	1212 6478 (B)
1402·6190 (B)	1259·2418 (C)	1222·3711 (C)	1208·2242 (C)
1307·7509 (C)	$1250{\cdot}5637_2$ (A)	1220·3672 (B)	1207·3784 (B)

A, calculated entirely from interferometric data of Burns and Adams [20].
B, calculated from more than one combination sum.
C, calculated from one combination sum only.

Table 10. *Calculated wave-lengths of germanium*

1998·8870 (80)	1944·1162 (4)	1865·0525 (8)	1759·2713 (8)
1989·1175 (5)	1938·3003 (15)	1849·6353 (8)	1744·2546 (5)
1988·2669 (40)	1934·0482 (25)	1845·8723 (30)	1742·1952 (20)
1970·8796 (50)	1923·4672 (10)	1841·3274 (50)	1739·1024 (10)
1965·3830 (10)	1917·5924 (20)	1802·6244 (15)	1718·6883 (10)
1963·3728 (7)	1912·4086 (8)	1786·0686 (10)	1702·3873 (1)
1955·1150 (35)	1895·1968 (10)	1765·2843 (9)	1691·6253 (8)
1953·8018 (2)			

Table 11. *Calculated wave-lengths for selected lines of* Mg II, Ca II, *and* Cd I

Mg II	Mg II	Mg II	Ca II	Ca II	Cd
1753·474	1369·4231	1240·3947	1850·691	1673·860	1526·6846
1750·664	1367·7082	1239·9252	1843·088	1651·991	1469·3049
1734·852	1365·5442	1026·1133	1814·495	1649·858	—
1482·8903	1309·4434	1025·9681	1807·337	1644·441	Cd 114
1480·8797	1307·8754	946·7694	1698·183	1643·770	1474·0104
1475·9998	1306·7139	946·7032	1691·779	1342·525	1469·3054
—	—	—	—	1341·889	—

Lines of carbon, nitrogen and oxygen, especially of the first and second spectra of these elements, are of interest because of their frequent appearance in V.U. spectrograms. Unfortunately it is not possible, except for a few of the fainter lines, to calculate their wave-lengths from lines in the long-wave region, so they have to be determined by direct measurements in the V.U. Many such measurements exist, from which weighted means have been derived and proposed as standards [28, 29]. However, since significant improvements are likely to be obtained by exploiting the combination-principle relations between different multiplets in conjunction with some additional experimental data that may soon be available, it seems advisable to postpone a formal adoption of these wave-lengths. In the meantime the wave-lengths determined by Wilkinson may be taken as the best available. When making this recommendation it must be mentioned that some identifications in Table 1 of Wilkinson's paper [29] seem to need revision: e.g. the lines labelled N II, except for four lines at 1085–83, probably have some other origin, and most of the lines attributed to Si I, as well as some carbon lines, will have to be interpreted differently.

TABLES OF SPECTRA

The Solar Spectrum

Mrs Moore-Sitterly reports on the progress of the revision of the Revised Rowland Table:

Minnaert and his staff have completed the measurement of equivalent widths from 4500 to 3800 Å. The revised identifications of atomic lines are fairly definitive over the range of the table, 13 000–2950 Å, but laboratory analyses are seriously inadequate for a complete study of rare-earth lines in the solar spectrum, and more faint lines will undoubtedly be attributed to Fe I as soon as a suitable source has been utilized to reveal the faint lines in the laboratory. Broida and Moore-Sitterly [30] have reported on an attempt to revise molecular identifications in the Sun, and on a revision of solar identifications of CH, OH, and violet CN bands, based on laboratory intensities measured by Broida (CH, CN) and by Dieke and Crosswhite (OH). Of the 2700 lines of these three molecules measured in the laboratory, some 60% have been identified as present or blended in the solar spectrum, while 14% are absent. A similar study of the C_2 identifications is in progress. A monograph similar to that on OH by Dieke and Crosswhite [31] for each of a limited number of diatomic molecules of the more abundant elements would go far toward meeting the present needs of the astrophysicist. The molecular identifications in the current revised solar table are severely limited by lack of accurate laboratory data.

Miss Adam has extended her absolute wave-length measurements to the red [32] and is now nearing the end of additional measurements on strong lines to test further the relation between red-shift and line strength.

Mrs Herzberg [33] has reported the discovery of a multiplet dependence of limb-centre shifts in selected infra-red multiplets of Si I.

McMath and Mohler express the opinion that the excellence of modern diffraction gratings has completely changed the status of the faint lines, particularly of compounds, that are visible in the spectrum of the Sun. In high contrast spectra, such as can be obtained with the vacuum spectrograph of the McMath-Hulbert Observatory in the integrated light, nearly all faint lines previously detected only in spot spectra are present with measurable intensities. Many faint lines, not previously observable, can now be recorded.—The Observatory has prepared for its own use a direct photo-electric tracing of the solar spectrum from 8000 to 3000 Å. It has a dispersion of not less than 0·1 Å/mm and a measured resolving power greater than 500 000. This record of the spectrum of the centre of the disk of the quiet sun can be examined at the Observatory, or copies of parts of it can be supplied to investigators with specific solar problems.

Atomic Energy Levels and Atomic Spectra

Vol. **3** of Moore-Sitterly's *Atomic Energy Levels* (National Bureau of Standards, *Circular* 467) is in print. It contains energy-level data for 124 spectra of the elements 42 Mo through 57 La and 73 Hf through 89 Ac. Vol. **4** will cover the two groups of rare-earth elements and thus complete the periodic system. Section 3 of 'An Ultra-violet Multiplet Table', which parallels vol. **3** of *Atomic Energy Levels*, is in course of preparation.

A list of references to recently published analyses of atomic spectra need not be included here, since they will be found in vol. **3** of *Atomic Energy Levels*.

BENGT EDLÉN

President of the Commission

REFERENCES

[1] Engelhard, E. *Proceedings of Symposium on Recent Developments and Techniques in the Maintenance of Standards, held at the National Physical Laboratory*, May 1951; Stationery Office, London, 1952.

[2] Humphreys, C. J. *Symposium on Molecular Structure and Spectroscopy*, Ohio State University, Columbus, Ohio, 1956.

[3] Rank, D. H., Bennett, J. M. and Bennett, H. E. *J. Opt. Soc. Amer.* **46**, 477, 1956.
[4] Sullivan, S. A. *J. Opt. Soc. Amer.* **45**, 1031, 1955.
[5] Burns, K., Adams, K. B. and Longwell, J. *J. Opt. Soc. Amer.* **40**, 339, 1950.
[6] Meggers, W. F. and Humphreys, C. J. *J. Res. N.B.S.* **13**, 293, 1934.
[7] Burns, K. and Adams, K. B. *J. Opt. Soc. Amer.* **43**, 1020, 1953.
[8] Meggers, W. F. *Sci. Pap. B.S.* **17**, 198, 1921.
[9] Littlefield, T. A. and Turnbull, D. T. *Proc. Roy. Soc.* A, **218**, 577, 1953.
[10] Blackie, J. and Littlefield, T. A. *Proc. Roy. Soc.* A, **234**, 398, 1956.
[11] Stanley, R. W. and Dieke, G. H. *J. Opt. Soc. Amer.* **45**, 280, 1955.
[12] Stanley, R. W. and Meggers, W. F. *J. Res. N.B.S.* **58**, 41, 1957.
[13] Batarchoukova, N. R., Kartachev, A. I. and Romanova, M. F. *Procès-Verbaux Com. Int. Poids Mes.* 2e ser, **24**, 121, 1954.
[14] Burns, K. and Adams, K. B. *J. Opt. Soc. Amer.* **46**, 94, 1956.
[15] Stanley, R. W. and Meggers, W. F. *J. Opt. Soc. Amer.* **47**, 1057, 1957.
[16] Paschen, F. *Ann. der Phys.* **35**, 860, 1911; **42**, 840, 1913.
[17] Wolff, K. *Ann. der Phys.* **42**, 825, 1913.
[18] Herzberg, G. *Proc. Roy. Soc.* A, **234**, 516, 1956.
[19] VanVeld, R. D. and Meissner, K. W. *J. Opt. Soc. Amer.* **46**, 598, 1956.
[20] Burns, K. and Adams, K. B. *J. Opt. Soc. Amer.* **42**, 56, 1952.
[21] Risberg, P. *Arkiv Fysik*, **9**, 483, 1955.
[22] Edlén, B. and Risberg, P. *Arkiv Fysik*, **10**, 553, 1956.
[23] Shenstone, A. G. *Phil. Trans.* A, **235**, 195, 1936.
[24] Shenstone, A. G. *J. Opt. Soc. Amer.* **45**, 868, 1955.
[25] Wilkinson, P. G. *J. Opt. Soc. Amer.* **47**, 182. 1957.
[26] Green, L. C. *Phys. Rev.* **55**, 1209, 1939.
[27] Edlén, B. Unpublished data, quoted by J. C. Boyce, *Carnegie Inst., Washington Year Book*, **41**, 107, 1942.
[28] More, K. R. and Rieke, C. A. *Phys. Rev.* **50**, 1054, 1936.
[29] Wilkinson, P. G. *J. Opt. Soc. Amer.* **45**, 862, 1955.
[30] Broida, H. P. and Moore, Ch. E. *Mém. Soc. Sci., Liège*, **18**, 217 and 252, 1957.
[31] Dieke, G. H. and Crosswhite, H. M. *Bumblebee Report*, no. 87, 1948.
[32] Adam, M. G. *M.N.* **115**, 367, 1955.
[33] Herzberg, L. *Canad. J. Phys.* **35**, 766, 1957.

14*a*. SUB-COMMISSION ON INTENSITY TABLES
REPORT ON DETERMINATIONS OF *f* VALUES

General surveys

Very practical, concise summaries of the theoretical and experimental methods used for the determination of transition probabilities, the notations, the relations between the symbols, etc. are found in:

Unsöld, *Physik der Sternatmosphären*, 2nd ed., chap. 12;
Allen, *Astrophysical Quantities* (1955).

In Flügge's new *Handbuch der Physik* we find an extensive treatment of the basic theory by Bethe and Salpeter (vol. **35**), and a survey of theory and experiments concerning the continuous absorption coefficients by Finkelnburg and Peters (vol. **28**).

Data on transition probabilities for individual spectral lines have been summarized in recent years in bibliographical form, classified according to the atoms or ions:

Unsöld, *Physik der Sternatmosphären*, 2nd ed., pp. 366–70, 1955;
Minnaert, *Trans. I.A.U.* **7**, 388, 1950; **9**, 214, 1955;
Garstang, *Vistas in Astronomy*, **1**, 268, 1955.

None of these lists is exhaustive, and they complement each other.

Similar lists are kept up to date by Biermann (Göttingen), Unsöld (Kiel), E. Müller (Ann Arbor), Hubenet (Utrecht).

A catalogue of transition probabilities for 300 lines of astrophysical interest is found in Allen's *Astrophysical Quantities* (p. 63).

Added note. The following excellent monograph with an extensive bibliography has now been published:

V. N. Kolesnikov and L. V. Leskov, *Uspekhi Fisicheskikh Nauk*, **65**, 3, 1958.

Experimental determinations

(*a*) *In absorption, from atomic beams.* This excellent, fundamental method has been applied by Bell, Davis, King and Routly to the resonance lines of several atoms. From the equivalent widths, absolute f-values are deduced. The results for Cu I and Fe I at first showed discrepancies of a factor 2 and 3 with previous measurements with an absorption tube; these last ones, however, can be corrected by means of the latest vapour pressure data and the results are now in reasonably good agreement. It is a great progress, that reliable values for these lines are now available, to which many others may be tied.

Cu I, $\lambda 3247$ and $\lambda 3274$: $f=0{\cdot}31$ and 0·16 (King *et al.*, atomic beam); 0·42 and 0·22 (Stockbarger, *Ap. J.* **91**, 488, 1949, furnace, corrected).

Fe I, $\lambda 3720$: $f=0{\cdot}032$ (King *et al.* 1957, atomic beam); 0·043 (Kopfermann and Wessel, *Z. Phys.* **130**, 100, 1951, atomic beam); 0·046 (Ziock, *Z. Phys.* **147**, 99, 1957); 0·030 (King, *Ap. J.* **95**, 78, 1942; furnace, corrected).

Cr I, $\lambda 4254$, 4275, 4290: $f=0{\cdot}055$, 0·043, 0·032.

Mn I, $\lambda 4030$, 4033, 4034: $f=0{\cdot}062$, 0·046, 0·031.

Results for Co I 3526 and Pb I are not yet final.

(*b*) *In absorption, using the graphite furnace.* King and his collaborators measured relative values for 107 lines of Ca I between 3000 and 6700 Å, for a considerable number of Fe I lines in the region 2500 to 3000 Å and for the Pb I lines of the solar spectrum in the region 3500–4000 Å.

(*c*) *In emission, in the electric arc and the flame.* A great number of elements have been investigated by Allen and Asaad (*M.N.* **117**, 36, 1957), using copper electrodes with which minute quantities of other elements are mixed. The f-values are determined with respect to lines for which absolute measurements are available. The astonishing results, communicated already at the Dublin meeting (1955) and published in *M.N.* **115**, 571, 1955, have now been partly explained: atomic states of the type $d^n s^2 - d^n sp$ are weaker than normal. Empirical rules for estimating oscillator strengths are given.

Eberhagen, combining the optical measurements with an electrical measurement of the arc current, determined directly absolute values. He applied the method especially to Sr (*Z. Phys.* **143**, 392, 1955).

Beautiful results have been obtained by using arcs, stabilized by a vortex of air and water (Motschmann, *Z. Phys.* **143**, 77 1955). By means of absolute intensity measurements, absolute f-values could be obtained.

Lochte-Holtgreven and his collaborators at Kiel have made an important series of measurements for C I and C II, O II, N II, Si II. At first the measurements for C I were found to be consistent with the theory of Bates and Damgaard; in other sources of light, however, discrepancies appeared which have not yet been cleared up.

The measurements of Bouigue, confirmed by quantum-mechanical calculations, show that the spectra of flames may be used with profit for lines which appear at low temperatures, as, for example, the bands of CN; a vibration temperature may be safely defined.

(*d*) *From lifetime determinations.* New techniques have been applied here. In the 'method of delayed coincidences', a gas is excited by extremely short bursts of electrons; with a multiplier the number of photons emitted by spontaneous de-excitation a time Δt after the excitation is measured (Heron *et al.*, *Nature*, **174**, 564, 1954; *Proc. Roy. Soc.* A. **234**, 565, 1956, applied to different He levels; Ziock, *Z. Phys.* **147**, 99, 1957). By a somewhat related method, a steady source of light is observed with two photo-multipliers with interference filters, sensitive one to the frequency ν_1, the other to ν_2; these correspond to the two frequencies of a cascade transition. Each of the photons ν_1 and ν_2 gives a pulse; the pulses ν_1 are delayed by an amount of time Δt, and coincidences with pulses ν_2 are observed. (Brannen *et al. Nature*, **175**, 810, 1955; applied to Hg λ4358.)

(*e*) Physicists in U.S.S.R. have applied the excellent method of anomalous dispersion to many atoms not yet studied in this way.

Theoretical determinations

A very clear survey of the situation in this field has been given by Garstang (1955, *loc. cit.*).

The classical paper of Bates and Damgaard has proved of the greatest use. Comparisons between their results, and those obtained by more perfect methods, show an agreement which for most astrophysical purposes is satisfactory (see, for example, McCarroll and Wakely, *Air Glow and Aurorae*, p. 337; Tawde and Rajeswary, *J. Sci. Industr. Res.* **14** B, 302, 1955; Institut f. Experimentalphysik, Kiel).

Progress in methods has been especially made: (1) by modifying the central field approximation by a suitable polarization potential, in order to take into account the correlation between the electrons (see, for example, Douglas, *Proc. Camb. Phil. Soc.* **52**, 687, 1956); (2) by carefully treating the deviations from the Russell-Saunders coupling, especially (in intermediate coupling) the spin-orbit interaction and further the configuration interaction. Trefftz, Schlüter *et al.* (*Z. Ap.* **44**, 1, 1957) extended the Hartree-Fock method by considering the case of non-orthogonal wave functions.

For forbidden lines, these effects are especially important. It was known that in some cases the spin-other orbit and the spin-spin interactions have to be taken into account. Garstang (*Proc. Camb. Phil. Soc.* **52**, 107, 1956) now showed that in some cases configuration interaction has also a substantial effect. However, if we use formulae neglecting this interaction, with *observed* energy levels, the major part of the effect is automatically taken into account. The new powerful methods, introduced by Racah, were applied to electric quadrupole radiation by Garstang (*Proc. Camb. Phil. Soc.* **53**, 214, 1957). He computed very useful tables of relative line strengths for all multiplets of electric quadrupole radiation; these are published in mimeographed form. Naqvi and Talwar (*M.N.* **117**, 463, 1957) have emphasized the effect of magnetic interactions, especially on atoms having p^3 as their ground configuration.

More and more the necessary calculations are being made by means of electronic machines (see, for example, Vainstein, *Optika i Spektroskopia*, **3**, 313, 1957).

Though it is not possible to publish catalogues of wave-functions, attention is called to the general review by D. R. Hartree in *Reports on Progress in Physics*, **11**, 1948, and the article by R. S. Knox, to be published in Seitz and Turnbull, *Solid State physics*, vol. **4**. Hartree's book, *The Calculation of Atomic Structures* (1957), contains a complete account of the method of calculating wave-functions and a supplementary list of such functions published since his article of 1948.

Literature on special transition probabilities since 1955*

Ag I Allen and Asaad, *M.N.* **117**, 36, 1957; Terpstra, Diss. Utrecht, 1956.

Al I Allen and Asaad, *M. N.* **117**, 36, 1957. Nikonova and Prokofiev, *Optika i Spektroskopia*, **1**, 290, 1956; Ostrovskiy, *Optika i Spektroskopia*, **2**, 673, 1957; Parchevskiy and Penkin, *J. Exp. theor. Phys.* **28**, 379, 1955.

As II Yanagawa, *J. Phys. Soc. Japan*, **10**, 1029, 1955.

Ba II Nikonova and Prokofiev, *Optika i Spektroskopia*, **1**, 290, 1956.

Bi I Allen and Asaad, *M.N.* **117**, 36, 1957.

C I Yilmaz, *Phys. Rev.* **100**, 1148, 1955; Bolstin, Levinson, Levin, *J. exp. theor. Phys.* **29**, 449, 1955; Richter, *Z. Phys.*, 1958.

* A few earlier papers have been added which up to now were overlooked.

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C I and C II Institut f. Experimentalphysik, Kiel.

Ca I Olsen, *Ap. J.* **62**, 28, 1957. Olsen, 1958; Allen, *M.N.* **117**, 622, 1957.

Ca II Nikitin and Gordienko, *Proc. Acad. Sci. Armen.* S.S.R. **20**, 165, 1955; Nikonova and Prokofiev, *Optika i Spektroskopia*, **1**, 290, 1956.

Cd I van Hengstum, dissertation, Utrecht, 1955; van Hengstum and Smit, *Physica*, **22**, 86, 1956.

Co I Allen and Asaad, *M.N.* **115**, 571, 1955; **117**, 36, 1957; Bell, Davis, King, Routly, 1958.

Cr I See Co I; Nikonova and Prokofiev, *Optika i Spektroskopia*, **1**, 290, 1956; Ostrovskiy and Penkin, *Optika i Spektroskopia*, **3**, 193, 1957.

Cu I See Co I; Bell, *Astr. J.* **62**, 7, 1957; Ostrovskiy and Penkin, *Optika i Spektroskopia*, **3**, 193, 1957; Parchevskiy and Penkin, *J. Exp. theor. Phys.* **28**, 379, 1955.

F IV See C I.

Fe I See Co I; Bell, *Astr. J.* **62**, 7, 1957; King, *Astr. J.* **62**, 20, 1957; Bakker, Aarts, Harting, *Physica*, **20**, 1250, 1954; Crosswhite, *Spectrochim. Acta*, **4**, 122, 1950; Parchevskiy and Penkin, *Vestn. Univ. Leningrad*, no. 11, 1954; Volosov, *J. exp. Theor. Phys.* 1953; Ziock, *Z. Phys.* **147**, 99, 1957; Osberghaus, 1958.

Ga I Allen and Asaad, *M.N.* **117**, 36, 1957; Osberghaus and Ottinger, 1958.

Ge I Yanagawa, *J. Phys. Soc. Japan*, **10**, 1029, 1955.

H Green, *Ap. J. Supp.* no. 26, **3**, 37, 1957.

He I Trefftz, Schlüter, Dettmar, Jörgens, *Z. Ap.* **44**, 1, 1957; Heron, Mc Whirter, Rhoderick, *Nature* **174**, 564, 1954; *Proc. Roy. Soc.* A, **234**, 565, 1956; Veselov, *J. Exp. Theor. Phys.* **19**, 959, 1949.

Hg I Brannen, Hunt, Adlington, Nicholls, *Nature*, **175**, 810, 1955.

Li I Veselov, *J. Exp. theor. Phys.* **19**, 959, 1949.

Mg I Allen, *M.N.* **117**, 622, 1957.

Mn I Allen and Asaad, *M.N.* **115**, 571, 1955; **117**, 36, 1957; Bell, Davis, King, Routly, 1958; Nikonova and Prokofiev, *Optika i Spektroskopia*, **1**, 290, 1956; Ostrovskiy and Penkin, *Optika i Spektroskopia*, **3**, 193, 1957.

Mo I Nikonova and Prokofiev, *Optika i Spektroskopia*, **1**, 290, 1956.

N I Motschmann, *Z. Phys.* **143**, 77, 1955.

N II See C I; McCarroll and Wakely, *Airglow and Aurorae*, p. 337 (London, 1956); Mastrup and Wiese, *Zs. f. Astroph.* 1958.

Ne V Bolotin, Levinson, Levin, *J. Exp. Theor. Phys.* **29**, 449, 1955.

Ni I Allen and Asaad, *M.N.* **115**, 571, 1955; **117**, 36, 1957; Parchevskiy and Penkin, *Vestn. Univ. Leningrad*, no. 11, 1954.

O I Jürgens, *Z. Phys.* **138**, 613, 1954; Kingsbury, *Phys. Rev.* **99**, 1846, 1955; Omholt, *J. Atmosph. Terr. Phys* **9**, 28, 1956.

O II Mastrup and Wiese, *Zs. f. Astroph.* 1958.

O III See C I.

Pb I Allen and Asaad, *M. N.* **117**, 36, 1957; Engler, *Z. Phys.* **144**, 143, 1956; Bell, Davis, King, Routly, 1958.

Sc I Ostrovskiy and Penkin, *Optika i Spektroskopia*, **3**, 391, 1957.

Si I Allen and Asaad, *M.N.* **117**, 36, 1957.

Si II Institut f. Experimentalphysik, Kiel.

Sn I Allen and Asaad, *M.N.* **117**, 36, 1957.

Sr I Eberhagen, *Z. Phys.* **143**, 393, 1955. Mannkopf, *Experim. Tech. d. Phys.*, Sonderheft Spektrosk., 1955.

Sr II Nikonova and Prokofiev, *Optika i Spektroskopia*, **1**, 290, 1956.

Te I Yanagawa, *J. Phys. Soc. Japan*, **10**, 1029, 1955.

Ti I Allen and Asaad, *M.N.* **115**, 571, 1955; Mitrofanova, *Pulkovo Bull.* **19**, no. 153, 1955. Ostrovskiy, Parchevskiy, Penkin, *Optika i Spektroskopia*, **1**, 1956.

Ti II Mitrofanova, *Pulkovo Bull.* no. 153, 1955; Institut f. Experimentalphysik, Kiel.

Tl I Nikonova and Prokofiev, *Optika i Spektroskopia*, **1**, 290, 1956.

The sum of the oscillator strengths for the alkali-like ions Ca^{+} and Al^{++} was calculated by Bersuker, *Dokl. Acad. Nauk*, **113**, 1017, 1957; *Optika i Spektroskopia*, **3**, 97, 1957.

Forbidden lines

General paper: Naqvi, *Astr. J.* **56**, **45**, 1951.

[A III] and [A XI] Osterbrock, *Ap. J.* **114**, 469, 1951.
[A IV] Naqvi and Talwar, *M.N.* **117**, 463, 1957.
[Ca II] Nikitin, *C.R. Acad. Sci. U.S.S.R.*, **98**, 31, 1954.
[Ca II] and [Ca VII] Osterbrock, *Ap. J.* **114**, 469, 1951.
[Ca XV] Garstang, *Proc. Camb. Phil. Soc.* **52**, 107, 1956.
[Cl II] Osterbrock, *Ap. J.* **114**, 469, 1951.
[Fe II] Garstang, not published.
[Fe III] and [Fe V] Garstang, *M.N.* **117**, 393, 1957.
[Fe XIV] Froese, *M.N.* **117**, 615, 1957.
[Fe XV] Osterbrock, *Ap. J.* **114**, 469, 1951; Blaha, *Bull. astr. Insts. Czech.* **8**, 34, 1957.
[H I] Wild, *Ap. J.* **115**, 206, 1952.
[K III], [K IV] and [K VI] Osterbrock, *Ap. J.* **114**, 469, 1951.
[N I] Garstang, *Ap. J.* **115**, 506, 1952; *Airglow and Aurorae*, p. 324; Petrie, *J. Geophys. Res.* **55**, 143, 1950.
[N II] Mc Carroll and Wakely, *Airglow and Aurorae*, p. 337.
[Ni II], [Ni III] Garstang, *M.N.* **118**, 234, 1958.
[O I] Petrie, *J. Geoph. Res.* **55**, 143, 1950.
[O II] See [N I]; Naqvi and Talwar, *M.N.* **117**, 463, 1957; Seaton and Osterbrock, *Ap. J.* **125**, 66, 1957; Garstang, *Ap. J.* **115**, 507, 1952.
[S I] Osterbrock, *Ap. J.* **114**, 469, 1951.
[S II] Garstang, *Ap. J.* **115**, 506, 1952; Naqvi and Talwar, *M.N.* **117**, 463, 1957.
[Xe XIII] Osterbrock, *Ap. J.* **114**, 469, 1951.

Continuous absorption

Ca I Seaton, *Ann. Astrophys.* **18**, 206, 1955. Jutsum, *Proc. Phys. Soc.* A, **67**, 190, 1954.
In Marr, *Proc. Phys. Soc.* A, **67**, 196, 1954.
Tl Marr, *Proc. Roy. Soc.* A, **224**, 83, 1954.

General paper: Marr, *Proc. Phys. Soc.* A, **68**, 544, 1955.

Molecules

N_2, N_2^+, NO, O_2^+ Jarmain, Fraser, Nicholls, *Ap. J.* **118**, 228, 1953.
N_2^+, CN, C_2, O_2, TiO Jarmain, Fraser, Nicholls, *Ap. J.* **119**, 286, 1954.
N_2, NO, O_2, O_2^+, OH, CO, CO^+ Jarmain, Fraser, Nicholls, *Ap. J.* **122**, 55, 1955.
CH_4, CO, NO Vincent-Gneisse, *Ann. Phys.* **10**, 693, 1955.
CN (and other molec.) Fraser, *Proc. Phys. Soc.* A, **67**, pt. 10, 939, 1954.
CN Bouigue, *Ann. Astrophys.* **17**, 35, 1955.
C_2 Tawde and Rajeswary, *J. Sci. Industr. Res.* **14**B, 302, 1955; Bouigue, *Ann. Astrophys.* **71**, 35, 1955; Phillips, *Ap. J.* **125**, 153, 1957; Wyller, *Ap. J.* **125**, 177, 1957; *Mém. Soc. Liège*, **13**, 97, 1953.
CO Penner and Aroeste, *J. Chem. Phys.* **23**, 2244, 1955; Barrow, Gratzer, Malherbe, *Proc. Phys. Soc.* **69**, 574, 1956.
OH Penner and Aroeste, *J. Chem. Phys.* **23**, 2244, 1955; Rahman, *Physica* **21**, 663, 1955.
O_2 de Jager, *B.A.N.* **13**, 9, 1956.
H_2O Plyler and Benedict, quoted in *Ap. J.* **126**, 583, 1957; Ditchburn and Heddle, *Proc. Roy. Soc.* A, **226**, 509, 1954.
ICl, BCl Brooks and Crawford, *J. Chem. Phys.* **23**, 363, 1955.

Hyperfine structure and isotope shift

These effects are conspicuous in many Fraunhofer lines and should be taken into account in the precise analysis of profiles. Data on the separation of the components and their relative intensities are scattered all through the physical literature. Those on hyperfine structure proper have been collected by H. Kopfermann, *Kernmomente* (Frankfurt, 1956); those on the isotope shifts are found in Striganov and Dontsov, *Uspekhi Fisicheskikh Nauk*, **55**, 315, 1955.

From the nuclear moment and the known isotopic abundances, the astrophysicist may reconstruct the pattern of the spectral line as it is found in nature. However he would be happier if he had the directly observed splitting, with the intensities of the components. Some recent papers may be mentioned, in so far as they refer to atoms of astrophysical interest.

Ag Woodgat and Hellwarth, *Nature*, **176**, 395, 1955.
Ba Jackson, *Phys. Rev.* **106**, 948, 1957.
Ca Kelly, Kuhn, Pery, *Proc. Phys. Soc.* A, **67**, 181 and 450, 1954.
Cd Kuhn and Ramsden, *Proc. Roy. Soc.* A, **237**, 485, 1956.
Cu Ting and Lew, *Phys. Rev.* **105**, 581, 1957; Kaliteyevskiy and Chaika, *Optika i Spektroskopia*, **1**, 606, 1956.
Eu Krebs and Winkler, *Ann. Phys.* **20**, 60, 1957.
Gd Kopfermann, Krüger, Steudel, *Ann. Phys.* **20**, 258, 1957; Speck, *Phys. Rev.* **101**, 1725, 1956.
He Stone, *Proc. Phys. Soc.* **68**, 1152, 1955; Kireev, *Optika i Spektroskopia*, **1**, 833, 1956.
He+ Series, *Proc. Roy. Soc.* A, **226**, 377, 1954.
In Jackson, *Phys. Rev.* **101**, 1425, 1956.
La Lührs, *Z. Phys.* **141**, 486, 1955.
Mn Woodgate and Martin, *Proc. Phys. Soc.* **70**, 485, 1957; Nöldeke und Rottmann, 1957, Phys. Institute Heidelberg.
Mo, Zr, I, Sb Murukawa, *Phys. Rev.* **100**, 1369, 1955.
Nd Nöldeke, *Z. Phys.* **143**, 274, 1955.
Pb Zhiglinskiy, *Optika i Spektroskopia*, **3**, 9, 1957.
Ru Murakawa, *J. Phys. Soc. Japan*, **10**, 919, 1955.
Sm Nöldeke, *Z. Phys.* **143**, 274, 1955.
Sn Hindmarsh and Kuhn, *Proc. Phys. Soc.* A, **68**, 433, 1955.
Y v. Ehrenstein, Fricke, Kopfermann, Penselin, *Naturwissenschaften*, 1957.
Zn Böckmann, Krüger, Recknagel, *Naturwissenschaften*, **44**, 7, 1957.

Stark effect

The profiles of the hydrogen lines in celestial objects are not yet completely understood. Basic for research in this field is a precise knowledge of the Stark splitting, which, unfortunately, is very complicated for the higher spectral lines. Miss Underhill has started the computation for the series $n = 1$ to 5, $n = 2$ to 18, using zero order theory.

The Stark quadratic effect also contributes to the damping of many other Fraunhofer lines. An excellent survey up to 1950 is found in *Landolt-Börnstein*, 1, 1, 246, by Joos and Saur. It would be useful if in future the new data could be collected in these reports.

It is a pleasure to acknowledge the kind help of the President of Commission 14, the members of Sub-commission 14*a* and other scientists in the preparation of this report.

M. G. J. MINNAERT
President of the Sub-Commission

COMMISSION 14

Report of Meeting. 15 August 1958

PRESIDENT: B. Edlén.

SECRETARY: Mrs C. Moore-Sitterly.

Silent tribute was paid to the memory of two members lost by death since the 1955 meeting, A. S. King and K. Burns. Both had contributed actively to fundamental work in spectroscopy over a long period of time.

The *Draft Report* was discussed item by item.

THE PRIMARY STANDARD

The President pointed out that although the Primary Standard is no longer a question for Commission 14 to decide, yet this Commission is vitally interested. Barrell discussed the considerations taken into account by the Advisory Committee on Redefining the Metre [1] in recommending the line λ6056 (transition $2p_{10}$–$5d_5$) in krypton of mass-number 86 as the primary standard. The choice lay among three lines: the red line of Cd 114, the green line of Hg 198, and the Kr 86 line. Comparisons had been made in a wide selection of laboratories, and the krypton orange line was selected as the most reproducible line when observed under proper conditions. Barrell presented a slide illustrating the comparison of the Fabry-Perot pattern at 40 cm path difference of Kr 86 and of Hg 198 as observed under the best practical conditions for each line.

Meggers suggested that the comparison of the Kr 86 line with that of Hg 198 was not fair, since Hg was observed at 273° K and Kr at 63° K. He felt that with an atomic-beam source all objections to the Hg 198 line would be overcome, and that for practical operation it was preferable. Barrell pointed out that the immediate availability of the Kr 86 standard would meet an urgent need to provide metrology with a definition of the metre some fifty times as precise as the present one.

Another objection to the krypton line is that some difficulty may arise in separating the proposed primary standard from neighbouring lines of similar intensity in the krypton spectrum. Engelhard pointed out that this difficulty could be met by using an interference polarizing filter designed to separate the standard, and that the neighbouring lines provide useful sub-standards.

A recommendation had been drafted by Barrell, Engelhard and Terrien, of practical conditions for reproduction of the Kr 86 standard. It was presented at the meeting by Barrell, as follows:

(1) Conditions of excitation: (*a*) the purity of the Kr 86 shall not be less than 99%; (*b*) the temperature of the coldest point in the interior of the lamp shall not be higher than the triple point of nitrogen, that is approximately 63° K. The krypton pressure will then be about 0·03 mm Hg or less; (*c*) the current density shall not exceed 4 mA/mm^2; (*d*) in the case of an Engelhard hot-cathode lamp operated with direct current, it is recommended that the lamp be used with the anode toward the observing equipment.

(2) Wave-length correction. Under the conditions stated above, the shift of wave-length of the orange line of Kr 86 is less than $\pm$0·0001 Å with respect to the radiation from an undisturbed atom as implied in the definition proposed by the Advisory Committee.

The Commission provisionally adopted these recommendations, pending the detailed specifications to be given by the Advisory Committee.

Krypton

Barrell submitted new data on measurements of krypton lines based on the orange line of Kr 86 as reference, and evaluated from measurements made at the N.P.L. with Fabry-Perot étalons at 125 and 400 mm path differences. These results, which are reproduced in Tables 1, 2 and 3, supersede those of the N.P.L. in Table 1 of the *Draft Report*.

Table 1. *Provisional vacuum wave-lengths and wave-numbers of* Kr 86 *determined at* 125 mm *path difference*

Term desig.	$\lambda_{vac.}$ Å	Wave-number	Term desig.	$\lambda_{vac.}$ Å	Wave-number
$2p_9$–$5d_4'$	6458·0718	15 484·4981	$1s_5$–$2p_2$	5563·7690	17 973·4276
$2p_8$–$5d_4$	6422·8005	15 569·5324	$2p_9$–$7d_4'$	5522·0431	18 109·2393
$2p_8$–$5d_1''$	6375·3508	15 685·4113	$2p_{10}$–$6d_5$	5502·2375	18 174·4245
$2p_9$–$4s_5$	6238·0758	16 030·5842	$2p_{10}$–$6d_3$	5492·4608	18 206·7753
$2p_8$–$4s_4$	6224·4539	16 065·6665	$2p_{10}$–$7d_5$	5229·6319	19 121·8048
$2p_6$–$6d_3$	6153·1080	16 251·9494	$1s_4$–$3p_8$	4503·6163	22 204·3784
$2p_{10}$–$5d_6$	6084·5441	16 435·0850	$1s_4$–$3p_7$	4464·9417	22 396·7089
$2p_{10}$–$5d_5$	(6057·8021)	(16 507·6373)	$1s_4$–$3p_6$	4455·1668	22 445·8488
$2p_7$–$6d_1''$	6037·5041	16 563·1359	$1s_2$–$3p_4$	4426·4318	22 591·5599
$2p_{10}$–$5d_3$	6013·8195	16 628·3674	$1s_2$–$3p_3$	4411·6061	22 667·4817
$1s_4$–$2p_4$	5995·5089	16 679·1513	$1s_2$–$3p_2$	4401·2014	22 721·0689
$1s_4$–$2p_3$	5881·5289	17 002·3818	$1s_4$–$3p_5$	4377·3503	22 844·8703
$1s_4$–$2p_2$	5872·5412	17 028·4033	$1s_5$–$3p_{10}$	4363·8671	22 915·4551
$2p_9$–$6d_4'$	5834·4723	17 139·5107	$1s_2$–$3p_1$	4352·5820	22 974·8686
$1s_2$–$3p_6$	5709·0942	17 515·9135	$1s_3$–$3p_4$	4301·6956	23 246·6473
$1s_5$–$2p_4$	5674·0238	17 624·1770	$1s_3$–$3p_3$	4287·6922	23·322·5697
$1s_3$–$3p_{10}$	5651·1286	17 695·5803	$1s_5$–$3p_7$	4284·1718	23 341·7341
$1s_2$–$3p_5$	5581·9355	17 914·9330	$1s_5$–$3p_6$	4275·1715	23 390·8743
$1s_5$–$2p_3$	5571·8354	17 947·4075	$1s_2$–$5p_5$	4264·4849	23 449·4908

Table 2. *Values of recurring level intervals in* Kr 86 *from measurements at* 125 mm *path difference*

Pair of lines λ (Å)	$1s_4$–$1s_5$ cm⁻¹	Pair of lines λ (Å)	$1s_2$–$1s_3$ cm⁻¹
5881, 5571	945·0257	4426, 4301	655·0874
5872, 5563	945·0243[a]	4411, 4287	655·0880
5995, 5674	945·0257	—	—
4464, 4284	945·0252	—	—
4455, 4275	945·0255	—	—

[a] Measurement of λ 5872 disturbed by overlapping patterns.

Table 3. *Provisional vacuum wave-lengths and wave-numbers of* Kr 86 *and* Kr 84 *determined at* 400 mm *path difference, with preliminary values of isotope shift*

Term desig.	Kr 86 $\lambda_{vac.}$ Å	Kr 84 $\lambda_{vac.}$ Å	Kr 86 Wave-number	Kr 84 Wave-number	Diff. 86–84 in mK
$2p_9$–$5d_4'$	6458·0721	6458·0733	15 484·4973	15 484·4944	+2·9[a]
$2p_8$–$5d_4$	6422·8004	6422·8015	15 569·5326	15 569·5299	+2·7
$2p_9$–$4s_5$	6238·0759	6238·0768	16 030·5840	16 030·5817	+2·3
$2p_{10}$–$5d_6$	6084·5441	6084·5452	16 435·0851	16 435·0821	+3·0
$2p_{10}$–$5d_5$	(6057·8021)	6057·8032	(16 507·6373)	16 507·6342	+3·1
$2p_{10}$–$5d_3$	6013·8196	6013·8206	16 628·3672	16 628·3644	+2·8
$1s_4$–$2p_4$	5995·5091	5995·5103	16 679·1507	16 679·1474	+3·3
$2p_9$–$6d_4'$	5834·4725	5834·4734	17 139·5100	17 139·5072	+2·8
$1s_3$–$3p_{10}$	5651·1287	5651·1296	17 695·5800	17 695·5772	+2·8
$1s_2$–$3p_5$	5581·9354	5581·9367	17 914·9331	17 914·9290	+4·1
$1s_5$–$2p_3$	5571·8356	5571·8364	17 947·4068	17 947·4042	+2·6
$1s_5$–$2p_2$	5563·7690	5563·7698	17 973·4277	17 973·4250	+2·7

[a] Measured only from the cathode side of the Engelhard lamp.

Terrien [2] reported the determination at the B.I.P.M. of the vacuum wave-length 5651·12863 for Kr 86, which is in complete agreement with the N.P.L. and P.T.B. results given in Table 1 of the *Draft Report*.

Baird (letter, March 1958) reported that Kr 86 is being produced also at the National Research Council in Ottawa. He pointed out further that if Jackson's values for natural krypton are corrected according to Engelhard's formula for the pressure shift, the agreement with present values for Kr 84, as given in Table 2 of the *Draft Report*, is excellent.

Mercury

In consequence of a recent note by Terrien [2] and private information by Terrien and Barrell, the discussion in the *Draft Report* of the visible lines of Hg 198 had to be revised, and Table 3 of that report should be replaced by the following data (Table 4) quoted from Terrien's note:

Table 4. *Observed vacuum wave-lengths of* Hg 198

B.I.P.M.	N.P.L.	P.T.B.
5792·26851	5792·2685	5792·2685
5771·19857	5771·1985	5771·1985
5462·27077	5462·2707	5462·2707
4359·5625	4359·5625	—

These values are referred to the proposed Kr 86 standard and reduced to zero pressure of carrier gas [3] with the exception of the P.T.B. values, for which a pressure correction could not be specified. It appeared likely that the four-decimal mean values of the B.I.P.M. and the N.P.L. results should be correct to one unit in the last decimal. In view of the urgent need for authorized values of these wave-lengths, the Commission decided to make a provisional recommendation of the following wave-lengths of Hg 198 (Table 5):

Table 5. *Recommended wave-lengths of* Hg 198 (see also page 232)

λ_{vacuum}	$\lambda_{standard\ air}$
5792·2685	5790·6628
5771·1985	5769·5984
5462·2707	5460·7532
4359·5625	4358·3375

Edlén called attention to recent measurements of infra-red lines of Hg 198 to supplement Table 4 of the *Draft Report* (wave-lengths in air): Peck [4] 10 139·794 Å, 11 287·408Å; Terrien (letter, Jan. 1958) 10 139·79$1_5$ Å.

Neon

The Commission adopted the values of neon levels presented in Table 5 of the *Draft Report*, for calculating infra-red wave-length standards. In Table 6 are collected the wave-lengths thus calculated for all of the 106 combinations $2p$–$3d$ and $2p$–$2s$ permitted by the J-selection rule. For completeness the combinations with $2s_4$ and $2s_3$ have been included. They are given with two decimals and are based on the provisional level values $2s_4$= 24 754·150 and $2s_3$=25 338·134.

Argon

The wave-lengths for infra-red argon lines given in Table 6 of the *Draft Report* have in the meantime been published by Humphreys and Paul [5]. Humphreys (letter, July 1958) submitted the results of additional measurements from which he had derived the following level values (Table 7).

The Commission recommended the provisional adoption of these levels for calculating infra-red standards. The corresponding wave-lengths are collected in Table 8.

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Table 6. *Neon, calculated wave-lengths, in standard air, of transitions 2p–3d and 2p–2s*

7051·2923	8300·3263	8767·5360	9313·973	11536·345
7059·1074	8301·5597	8771·6563	9326·507	11601·536
7064·7587	8365·7486	8778·7329	9373·308	11614·11
7437·3919	8376·3614	8780·6210	9377·227	11688·002
7472·4386	8377·6065	8782·0012	9425·379	11766·792
7488·8712	8417·1591	8783·7533	9433·008	11789·05
7535·7741	8418·4274	8792·5050	9459·210	11789·895
7544·0443	8463·3575	8830·9072	9486·68	11984·94
7833·0303	8484·4435	8853·8669	9534·163	12066·340
7839·0546	8495·3598	8865·3060	9547·405	12459·39
7839·9893	8544·6959	8865·7552	9665·424	12595·01
7927·1177	8571·3524	8919·5007	10295·417	12689·21
7936·9961	8582·9029	8988·57	10562·408	12769·532
7943·1814	8591·2587	9148·672	10620·664	12887·16
7944·1412	8634·6470	9201·759	10798·07	12912·021
8118·5492	8635·3175	9220·058	10844·477	13219·248
8128·9108	8647·0411	9221·580	11143·02	15230·713
8136·4057	8654·3831	9226·690	11177·533	17161·94
8248·6824	8655·5224	9275·520	11390·439	—
8259·3790	8679·4925	9297·990	11409·134	—
8266·0772	8681·9211	9300·853	11522·745	—
8267·1166	8704·1116	9310·584	11525·02	—

Table 7. *Argon levels, relative to* $1s_5 = 0{\cdot}0000$, *based on interferometric measurements*

$2s_5$	20 324·715	$3d_6$	18 524·007[a]	$3d_4$	19 876·596	$3s_1''''$	21 497·234
$2s_4$	20 499·501	$3d_5$	18 674·269[a]	$3d_1''$	20 282·206	$3s_1''$	21 661·376
$2s_3$	21 717·879[a]	$3d_3$	18 995·166	$3d_1'$	20 572·796	$3s_1'''$	21 678·181
$2s_2$	21 831·261	$3d_4'$	19 606·394[a]	$3d_2$	21 003·973	$3s_1'$	22 223·107

[a] Determined from one combination only.

Table 8. *Argon, calculated wave-lengths, in standard air, of transitions 2p–3d and 2p–2s*

8874·799	11467·544	12933·190	13992·804	16860·083
9194·636	11645·865	12956·657	14093·638	16940·579
9291·528	11668·707	13008·260	14249·191	17444·900
9340·580	11687·601	13028·423	14577·456	17445·245
9486·059	11719·485	13213·990	14739·136	17914·626
9951·845	11896·630	13228·102	14974·564	17914·722
10254·024	12026·646	13230·895	15030·510	18427·762
10478·033	12112·322	13272·632	15046·501	19965·722
10673·564	12139·735	13302·310	15172·689	20317·007
10681·769	12343·390	13313·206	15329·340	20616·221
10683·402	12377·192	13367·109	15353·126	20986·107
10700·983	12402·826	13367·823	15555·458	21332·881
10722·226	12439·318	13499·404	15734·906	21534·198
10773·367	12456·113	13504·188	15776·609	22039·557
10861·074	12487·660	13544·201	15883·158	22077·176
10880·940	12554·321	13573·611	15989·486	23133·199
10892·358	12621·616	13599·329	16122·653	23966·512
10950·725	12638·478	13622·655	16180·018	32297·09
11078·865	12702·278	13678·547	16264·067	—
11248·347	12733·415	13718·575	16292·105	—
11393·698	12746·229	13825·713	16519·862	—
11441·829	12802·734	13907·472	16740·073	—

Iron

Table 9 has been compiled from measurements communicated to the Commission by Hands and Littlefield in July 1958. The differences Δλ shown in the table, between these wave-lengths and those of Table 7 of the *Draft Report*, reveal a good over-all agreement. Edlén stressed the need for further measurements of iron lines in low-pressure light sources.

H. D. Babcock (letter, July 1958) suggested that the iron lines λλ 11 973, 11 593, 11 439, 11 374, and 9118 in the list of iron standards adopted in 1955, should be used with caution until it has been shown that they are not influenced by nearby water-vapour absorption lines.

Table 9. *Low-pressure iron wave-lengths (in standard air) measured by Hands and Littlefield*

λ	Δλ	λ	Δλ	λ	Δλ
5615·6431	−0·0003	5167·4880	+0·0002	4299·2339	+0·0001
5586·7552	−0·0003	5166·2804	−0·0008	4282·4024	−0·0002
5572·8403	−0·0016	5139·4616	—	4271·7596	−0·0005
5455·6096	+0·0003	5110·4126	+0·0003	4271·1625	—
5434·5235	−0·0002	5041·7557	—	4260·4733	0·0000
5429·6962	−0·0001	4957·5962	+0·0010	4250·7860	—
5405·7750	+0·0006	4920·5020	+0·0004	4216·1830	+0·0004
5397·1279	+0·0007	4891·4917	+0·0006	4202·0284	+0·0002
5371·4890	−0·0002	4528·6133	+0·0001	4199·0942	−0·0006
5341·0228	−0·0008	4482·1695	+0·0011	4187·7954	—
5328·5288	—	4466·5496	−0·0005	4187·0371	—
5328·0383	—	4461·6519	−0·0004	4181·7525	−0·0017
5324·1776	−0·0008	4427·3092	−0·0001	4143·8672	−0·0008
5270·3560	—	4415·1219	−0·0003	4143·4141	—
5269·5376	—	4404·7496	−0·0007	4132·0568	−0·0008
5232·9395	−0·0005	4383·5443	−0·0006	4071·7369	−0·0002
5227·1892	+0·0016	4375·9288	−0·0002	4063·5931	−0·0011
5216·2735	+0·0002	4325·7612	−0·0003	4045·8112	−0·0027
5194·9417	—	4315·0838	+0·0001	—	—
5171·5956	+0·0001	4307·9014	0·0000	—	—

Cadmium

The discrepancy between the measurements of the red Cd 114 line given in the *Draft Report* were discussed. Terrien reported that recent observations by him and by Baird tend toward the higher value. Mme Volkova felt that the Leningrad result might possibly have been affected by the use of Cd 114 that was not sufficiently pure.

Germanium

The Commission voted provisional recommendation of a list of calculated wave-lengths of vacuum ultra-violet germanium lines, submitted to the Commission by Meissner in July 1958 and reproduced here in Table 10. This list, which replaces Table 10 of the *Draft Report*, was derived by combining the results given by Van Veld and Meissner [6] and by Andrew and Meissner [7]. It represents a selection of lines that have been checked in actual experiment to be suitable as standards. Meissner pointed out that the list is still to be regarded as provisional, pending further interferometric measurements in the infra-red part of the germanium spectrum [7a].

In response to a suggestion by H. D. Babcock, the Commission agreed to publish abstracts of its recommendations concerning wave-length standards and light sources in a number of suitable journals, since the *Trans. I.A.U.* are too little known among physicists. The journals suggested by the Commission were: *Journal of the Optical Society of America*, *Optica Acta*, *Revue d'Optique*, and *Optika i Spektroskopija*.

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Table 10. *Calculated germanium standards*

λ	Int.	λ	Int.	λ	Int.	λ	Int.
1998·8870	(80)	1876·0102	(5)	1748·8570	(7)	1691·0899	(15)
1997·8062	(8)	1865·0525	(8)	1744·2545	(8)	1690·9024	(4)
1989·1173	(5)	1861·095	(4)	1744·0533	(8)	1690·034	(8)
1988·2669	(40)	1860·085	(12)	1742·1950	(20)	1681·342	(8)
1987·8488	(9)	1849·6353	(8)	1739·1024	(10)	1675·560	(8)
1970·8796	(50)	1845·8723	(30)	1738·479	(15)	1674·270	(15)
1965·3830	(10)	1844·410	(10)	1738·1183	(8)	1673·850	(1)
1963·3728	(7)	1841·3274	(30)	1724·3080	(9)	1671·010	(5)
1962·0129	(30)	1810·100	(4)	1720·7463	(5)	1667·8013	(8)
1955·1150	(35)	1802·6244	(15)	1718·6882	(10)	1665·2748	(6)
1944·1162	(4)	1793·0709	(8)	1718·4928	(4)	1658·375	(4)
1938·3003	(15)	1786·0684	(10)	1716·7844	(20)	1651·954	(8)
1934·0482	(25)	1785·0457	(30)	1715·8358	(9)	1651·5282	(6)
1929·8260	(40)	1766·0646	(9)	1713·081	(10)	1650·292	(8)
1923·4672	(10)	1765·2843	(9)	1702·3872	(1)	1647·531	(4)
1917·5924	(20)	1764·1848	(10)	1695·8595	(6)	1643·193	(8)
1908·4340	(7)	1759·2711	(8)	1694·3423	(3)	1635·257	(8)
1903·5620	(2)	1758·2788	(15)	1691·8655	(7)	1630·173	(8)
1895·1968	(10)	1750·0430	(20)	1691·6252	(8)	—	

TABLES OF SPECTRA

Mrs Moore-Sitterly presented a sample page of the current revision of Rowland's *Table of Solar Spectrum Wave-Lengths*, now in progress. She submitted, also, a sample page of data on CH containing the laboratory and solar data used for the revision of CH identifications in the solar spectrum. This page was designed by her and Broida as a model to illustrate to laboratory spectroscopists the needs of the astrophysicist regarding molecular spectra of astrophysical interest. It was taken from a paper that will be published as a *Circular* of the U.S. National Bureau of Standards.

The Commission was informed that Schröter is working at the Potsdam Observatory on absolute solar wave-lengths determined interferometrically for twenty Fraunhofer lines in the red. The red shift and centre-limb effect are being investigated.

Mrs Moore-Sitterly announced that vol. 3 of *Atomic Energy Levels* (National Bureau of Standards, *Circular* 467) had now been printed.

After the discussion of the *Draft Report*, two papers were presented. Meggers discussed the results obtained by himself and Stanley on Thorium Standards [8]. The present system of international secondary standards is based on interferometric determinations of wave-lengths emitted at atmospheric pressure by an electric arc between iron electrodes. Because of the poor quality and uneven distribution of these iron standards they are not suitable for accurate measurement of wave-lengths in the spectra of heavier elements, most of which are more complex and consist of much sharper lines than the standards. Quartz-tube lamps containing a small quantity of a thorium halide, when excited by microwaves, emit thousands of uniformly sharp and evenly distributed lines whose wave-lengths can be determined with about one-tenth the error of locating iron-arc lines. Preliminary values of 222 vacuum wave-lengths emitted by a thorium-iodide lamp have been measured relative to 5462·2705 and 4047·7144 Å emitted by a similar lamp containing Hg 198. Fabry-Perot interferometers with plate separations of 25, 40 or 50 mm were used with a stigmatic grating spectrograph in making these measurements. The thorium wave-lengths range from 3288 to 6990 Å. The accuracy in relative value of twenty-seven classified thorium lines is tested by means of the combination principle, which indicates that the average error is less than 1 part in 20 million. In conclusion, Meggers stressed the need for extending these standards to wave-lengths shorter than 3300 Å.

The second paper was by Herzberg who presented a report on Vacuum Ultra-violet Standards [9]. In the course of work on Lamb shifts in hydrogen and helium, new wave-

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length standards in the vacuum ultra-violet have been developed which are believed to have a precision better than 0·001 Å. Like the early vacuum ultra-violet standards of Fe II and Cu II, the new ones are based on the combination principle. Such standards of Hg 198, Ge, Mg II and Ca II have already been given in the President's report. Standards of C II in the region 1040 to 560 Å have been obtained by measuring some longer wave-length lines against the Mg II lines and then applying the combination principle to C II. Standards of neutral nitrogen in the region 970 to 900 Å have been obtained by a precise measurement of the resonance lines at 1200 Å against the Hg 198 standards and the re-measurement of a number of infra-red multiplets of N I. Finally, these nitrogen standards have been used to measure the resonance doublet of Ar II at 932 and 920 Å, and these, together with longer wave-length lines, have been used to derive Ar II standards in the region 730 to 520 Å. With the help of the C II and Ar II standards the helium lines at 584, 537 and 591 Å have been measured in the tenth or eleventh order of a 3-metre vacuum spectrograph, with an accuracy of ±0·0005 Å, and these in turn may now be used as standards. There are now precise standards available over the whole region from 2000 to 500 Å with the exception of some minor gaps. Efforts should be made to close these gaps and to extend the system to the region below 500 Å.

Swings brought to the attention of Commission 14 the desirability of forming a Sub-Commission 14*b* to replace Sub-Commission 29*b* in handling questions regarding molecular spectra of astrophysical interest. It was felt that molecular as well as atomic spectra fitted naturally into the scope of Commission 14. A recommendation was passed providing for a Sub-Commission 14*b* on 'Molecular Spectra of Astronomical Interest'.

The meeting then adjourned.

REFERENCES

[1] *Procès-Verbaux du Comité International des Poids et Mesures* [2] 26B, 1958, in press; (*Procès-Verbaux du Comité Consultatif pour La Définition du Mètre*, pp. M 54, M 62, M 80, 2e Session, 1957).
[2] Terrien, J. *C.R.* **246**, 2362, 1958.
[3] Baird, K. M. and Smith, D. S. *Canad. J. Phys.* **35**, 455, 1957.
[4] Peck, E. R. *J. de Phys.* **19**, 399, 1958.
[5] Humphreys, C. J. and Paul, E. *J. de Phys.* **19**, 424, 1958.
[6] Ref. 19 of the *Draft Report*.
[7] Andrew, K. L. and Meissner, K. W. *J. Opt. Soc. Amer.* **48**, 31, 1958.
[7*a*] Meissner, K. W., VanVeld, R. D. and Wilkinson, P. G. *J. Opt. Soc. Amer.* **48**, 1001, 1958.
[8] Meggers, W. F. and Stanley, R. W. *J. Res. Nat. Bur. Stand.* **61**, 95, RP 2891, 1958.
[9] Herzberg, G. *Proc. Roy. Soc.* A **248**, 309, 1958.

Note added in proof: According to private communications (June, 1959) the most recent values for the wave-length of the green Hg 198 line, obtained as results of extensive measurements at the B.I.P.M., the N.P.L., and the N.R.C., are, respectively, 5462·270 63, 5462·2706, and 5462·2705 Å. These new results indicate that the uncertainty of the values in Table 5 (above on page 228) is somewhat larger than was assumed by the Commission. In this situation it appears advisable to leave the question open until the next meeting and to regard the above recommendation as withdrawn.

Report of Meeting of Sub-Commission 14a. 16 August 1958

PRESIDENT: M. G. J. Minnaert.

SECRETARY: C. W. Allen.

No essential corrections to the *Draft Report* were required.

The President announced that a very comprehensive list of *f*-values was in preparation in Leningrad by Y. I. Ostrovski and collaborators. It should appear in 1959.

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C. W. Allen reviewed the problem brought up at the 1955 meeting relating to the increase of f-values with excitation potential. It is now thought that the effect is due almost entirely to the fact that the low level lines of the Fe group atoms are of the type $d^n s^2 - d^n sp$. Such transitions have systematically low f-values and thus give rise to an apparent excitation potential effect. G. Traving suggests that there may be a selection effect whereby lines with a high E.P. can be measured only if they have abnormally high f-values.

D. Layzer described a new general method for computing the factor σ^2 which leads to f-values. It depends on an expansion of σ in the form

$$\sigma = \sigma_0 + \sigma_1/(z-s) + \ldots,$$

where z is the atomic number and s a screening constant. The method has been found very effective for light atoms and promises to give reasonable and independent results for atoms of the iron group.

Miss E. A. Müller and L. H. Aller referred to the work on solar abundances which uses f-values. Values from many sources had been considered and compared in order to reach a decision on the f-values of Li, Be, C, N, O, Na, Mg, Al, Si, P, S, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, Ga, Ge, Rb, Sr, Pd, Ag, Cd, In, Sn, Sb, Ba, Yt and Pb. Several difficulties were mentioned, for example, the fact that absolute measurements are usually made on ultimate lines which are not suitable for abundance purposes. There is a need for f-values of the heavy elements Ag, Pb, Sb and Sn which are of importance in atom building.

For the future it was agreed that the work of the Sub-Commission should be expanded by the fuller inclusion of (i) data on Stark effect and damping and (ii) data on cross-sections for electron and ion collisions.