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

PRÉSIDENT: Dr G. Herzberg, Director, Division of Pure Physics, National Research Council, Sussex Drive, Ottawa, Ontario, Canada.

MEMBRES: Mlle Adam, Barrell, Dieke, Edlén, Engelhard, Harrison, Kiess, Layzer, Littlefield, McMath, Meggers, Migeotte, Minnaert, Mohler, Racah, Mme Moore-Sitterly, Terrien.

La Commission a deux Sous-Commissions: 14*a*, 14*b*.

THE PRIMARY STANDARD

Following the recommendation of the Advisory Committee on Redefining the Metre (see the previous reports of Commission 14 (**20**) (**21**)), the 11th General Conference of Weights and Measures (Onzième Conférence Générale des Poids et Mesures) on 14 October 1960 has unanimously adopted the following two resolutions.

'1. La Onzième Conférence Générale des Poids et Mesures, considérant

que le Prototype International ne définit pas le Mètre avec une précision suffisante pour les besoins actuels de la métrologie,

qu'il est d'autre part désirable d'adopter un étalon naturel et indestructible,

décide:

(i) Le Mètre est la longueur égale à 1 650 763·73 longueurs d'onde dans le vide de la radiation correspondant à la transition entre les niveaux $2p_{10}$ et $5d_5$ de l'atome de krypton 86.

(ii) La Définition du Mètre en vigueur depuis 1889, fondée sur le Protoptype International en platine iridié, est abrogée.

(iii) Le Prototype International du Mètre sanctionné par la Première Conférence Générale des Poids et Mesures de 1889 sera conservé au Bureau International des Poids et Mesures dans les mêmes conditions que celles qui ont été fixées en 1889.

'2. La Onzième Conférence Générale des Poids et Mesures invite le Comité International

(i) à établir des instructions pour la mise en pratique de la nouvelle Définition du Mètre,

(ii) à choisir des étalons secondaires de longueur d'onde pour la mesure interférentielle des longueurs et à établir des instructions pour leur emploi,

(iii) à poursuivre les études entreprises en vue d'améliorer les étalons de longueur.'

Thus the labour of a large number of physicists over many years has at last come to fruition: the wave-length in vacuum of a spectral line (the orange line of Kr^{86}) is now (even legally) the international standard of length and replaces the meter bar at Sèvres.

At the same time the krypton line has become the primary standard of wave-length. This wave-length is (in vacuum)

$$\lambda_{vac} = 6057{\cdot}80210_5\ \text{Å}$$

where now the angström unit is exactly 10^{-10}m. If Edlén's dispersion formula for air is adopted (as recommended by the Joint Commission for Spectroscopy in 1952) the wave-length of the krypton line in standard air is

$$\lambda_{air} = 6056{\cdot}125253\ \text{Å}$$

Any future change in the dispersion of air affects only this latter value, and not the fundamental standard which is the vacuum value.

The definition of the primary standard refers to the radiation from atoms unperturbed by

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external influences. Detailed investigations at the BIPM, the PTB (Germany), at NPL (United Kingdom), NRC (Canada) and NSL (Australia) of the various factors which influence the precise wave-length and the width of the line have led to the following recommendation of the International Committee for Weights and Measures for the most favourable conditions for the reproduction of the krypton line:

'Conformément au paragraphe 1 de la Resolution II adoptée par la Onzième Conférence Générale des Poids et Mesures (octobre 1960), le Comité International des Poids et Mesures recommande que la radiation du krypton 86 adoptée comme étalon fondamental de longueur soit réalisée au moyen d'une lampe à décharge à cathode chaude contenant du krypton 86 d'une pureté non inférieure à 99 pour cent, en quantité suffisante pour assurer la présence de krypton solide à la température de 64 °K, cette lampe étant munie d'un capillaire ayant les caractéristiques suivantes: diamètre intérieur 2 à 4 millimètres, épaisseur des parois 1 millimètre environ.

'On estime que la longueur d'onde de la radiation émise par la colonne positive est égale, à 1 cent-millionième (10^{-8}) près, à la longueur d'onde correspondant à la transition entre les niveaux non perturbés, lorsque les conditions suivantes sont satisfaites:

1. le capillaire est observé en bout de façon que les rayons lumineux utilisés cheminent du côté cathodique vers le côté anodique;

2. la partie inférieure de la lampe, y compris le capillaire, est immergée dans un bain refrigérant maintenu à la température du point triple de l'azote, à 1 degré près;

3. la densité du courant dans le capillaire est $0{\cdot}3 \pm 0{\cdot}1$ ampère par centimètre carré.'

Engelhard and Terrien (**23**) have published in some detail their investigations on the shifts of the Kr^{86} line as a function of pressure (p), current density (j) and temperature (T). Engelhard (**22a**) gives the following empirical formula for the Stark shifts (for $p < 1$ mm Hg, $T < 75°K$, $j < 3$ A/cm^2)

$$\Delta\nu\ (\text{cm}^{-1}) = -0{\cdot}074 \left[\frac{p}{T(1 + aj^b)}\right]^{2/3} j^{1/2}$$

Here $a \approx 1/3$, $b \approx 3/2$ for glass capillaries of 2 to 4 mm internal diameter and a wall thickness of less than 1 mm. To the above expression must be added the Doppler shift due to impact of the exciting electrons which is $+0{\cdot}00019$ cm^{-1} when $T = 63$ °K and the anode is nearest the observer.

Rowley (**73**) at NPL finds that within the limited range of measurement ($0{\cdot}07 < j < 1{\cdot}1$ A/cm^2, $0{\cdot}005 < p < 0{\cdot}6$ mmHg, $59 < T < 73$ °K) the variations of wave-number from a Kr^{86} lamp may be expressed by $\Delta\nu\ (\text{cm}^{-1}) = -0{\cdot}08\ (pj/T)^{2/3} + 0{\cdot}000026\ T - 0{\cdot}0018$ (cathode nearest the observer) and $\Delta\nu = -0{\cdot}08\ (pj/T)^{2/3} - 0{\cdot}000026\ T + 0{\cdot}0018$ (anode nearest the observer). Further work on these shifts is in progress at NRC, NSL and NPL and it is hoped will lead to considerable improvements in the accuracy to which the primary standard can be reproduced.

According to Baird (**7**) the work at NRC has confirmed that the practical lamp recommended by the Advisory Committee on the Metre *does* reproduce the unperturbed wave-length at least to an accuracy of 1 in 10^8 or the wave-number to $0{\cdot}00016$ cm^{-1}. On the other hand there is evidence to suggest that a slight asymmetry in the line emitted by the lamp makes the effective wave-length depend to a certain extent on the means of viewing, for example on whether a Fabry-Perot étalon or a Michelson interferometer is used. This effect, which may be as much as ± 0·00005 cm^{-1}, together with the present uncertainty in the Doppler shift due to electron impact (about ± 0·00005 cm^{-1}), makes it unreliable at present to assume an accuracy much better than 1 in 10^8, or to attempt corrections (to such accuracy) according to published formulae for conditions of excitation much different from the recommended method of operation of the lamp.

CLASS A SECONDARY STANDARDS

According to Edlén (**21**), class A secondary standards are highly reproducible standards which have been directly compared with the primary standard in several laboratories with an accuracy comparable to that of the primary standard and which may serve as substitutes for the primary standard to facilitate interferometric measurements in different spectral regions.

A number of Kr^{86} lines other than the primary standard have been measured at NPL (see previous report (**21**), Table I), at NRC (**8**), at NSL (**14**) and at NBS (**46**) and are being measured at BIPM (**82**). The results for seven of the lines are compared in Table 1. Terrien (**81**) has so far given only the wave-length of the green line (see Table 1) but is studying the variations of this wave-length with current density, pressure and direction of current. Once that is done, by measuring several other Kr^{86} lines, he expects to verify the combination principle in the Kr^{86} spectrum with an accuracy of 2×10^{-9} or better.

Table 1. Observed vacuum wave-lengths of Kr^{86} lines

λ_{vac} (Å)	NPL(**21**)	NRC(**8**)	NSL*(**14**)	BIPM(**82**)	NBS*(**46**)	PTB(**22a**)	IML(**9a**)
6458	·0721	·0719	·07240			·0719	·0723
6013	·8196				·8195		
5651	·1287	·1285	·12851	·12863	·1286	·12861	·1286
4503	·6163	·6159	·61553				·6165
4464	·9417	·9414					
4455	·1668	·1664					
4377	·3503	·3500					

* uncorrected for pressure effects.

Table 2. Observed vacuum wave-lengths of Hg^{198} lines

λ_{vac} (Å)	BIPM(**20**)(**82**)	NPL(**20**)	PTB*(**20**)	NRC(**8**)	NSL*(**14**)	NBS**(**45**)	IML(**9a**)
5792	·26851	·2685	·2685	·2683	·2680$_4$	·2683$_4$	·2680
5771	·19857	·1985	·1985	·1982	·1981$_6$	·1982$_9$	·1981
5462	·27065	·2707	·2707	·2705	·2705$_2$	·2704$_6$	·2705
4359	·5625	·5625		·5621	·5619$_6$	·5622$_5$	
4047				·7144		·7145$_5$	

* without pressure corrections.
** argon pressure at $\frac{1}{4}$ mm Hg.

For Hg^{198} a set of provisional wave-length values was recommended at the last meeting but this recommendation was later withdrawn. Since then Baird and Smith (**8**) and Bruce and Hill (**14**) have published their measurements of the four or five principal lines and Terrien (**82**) has remeasured the green line. The new values together with the older values already included in the last report are collected together in Table 2. In addition Barger and Kessler (**46**) have recently measured by means of an atomic beam (emission) the two ultra-violet mercury lines 2537 and 3132 Å relative to the primary standard obtaining the vacuum wave-lengths

$$2537{\cdot}26873 \pm 0{\cdot}00003 \text{ Å}$$
$$3132{\cdot}74985 \pm 0{\cdot}00004 \text{ Å}$$

The relative values of these two lines have been measured with even higher accuracy.

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In the previous report four lines of Cd^{114} were listed which would be useful as class A standards. These lines have now also been measured at NSL by Bruce and Hill (**14**). In Table 3 the three available sets of measurements are compared.

Table 3. Observed vacuum wave-lengths of Cd^{114} lines

λ_{vac} (Å)	I.M.L.*	B.A.**	NSL(**14**)	NRC(**7**)
6440	·2480	·2486	·24659	·2489
5087	·2385	·2381	·23849	·2385
4801	·2520	·2522	·25358	·2522
4679	·4583	·4587	·45526	·4580

* Institute of Metrology, Leningrad: Batarchoukova, Kartachev and Efremov (**9a**)
** Burns and Adams (**15**)

CLASS B SECONDARY STANDARDS

For routine measurements of spectral lines with a precision of better than 0·01 Å it is necessary to have a large number of secondary standards whose wave-lengths are known with an accuracy of 0·001 Å or better but which need not be of the high accuracy of the class A standards. Until 1955 the lines of the iron arc in air were commonly used for this purpose. Commission 14 has been mainly responsible for establishing these standards and a final table was prepared by Edlén for the Dublin meeting (**20**). However it is now generally recognized that the lines of the open Fe arc are rather broad and liable to displacements by pole and pressure effects so that even for moderately precise measurements better standards are desirable. Fe lines emitted in hollow cathode discharges or in high-frequency discharges through Fe halide vapours, using Ne, Ar or He as carrier gases have been found to be greatly superior to Fe lines as emitted in open arcs. There are appreciable differences in the wave-lengths of the two types of sources, and new measurements of low pressure Fe lines had to be made. In the preceding report by Edlén (**21**) a list embodying the results of the work of Stanley and Dieke (**78**) (slightly corrected), Stanley and Meggers (**79**) and Blackie and Littlefield (**12**) was presented. More recently Crosswhite (**18**) and Hands and Littlefield (**31**) have remeasured some of the lines and added others. Since it is necessary for the formal adoption of secondary standards that at least two but preferably three different laboratories arrive at concordant results, we present in Table 4 both the values listed by Edlén but referred to vacuum and the more recent values of Crosswhite and Hands and Littlefield. In most cases the differences are much less than 0·001 Å. Those lines for which this difference is 0·0005 Å or less might be considered for adoption as standards.

Table 4. Observed vacuum wave-lengths of Fe lines at low pressures

λ_{vac} (Å)	IAU*	Cross-white (**18**)	Hands & Littlefield (**31**)	λ_{vac} (Å)	IAU*	Cross-white (**18**)	Hands & Littlefield (**31**)
5710	·9618			5599		·8516	
5660	·3861			5596		·2119	
5626	·1030			5588	·3067		·3064
5617	·2023		·2020	5577	·6358		
5604	·4997			5574	·3894		·3878

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λ_{vac} (Å)	IAU*	Cross-white (18)	Hands & Littlefield (31)
5571	·1640		
5567		·2495	
5565		·1442	
5556		·4373	
5545		·4750	
5544		·7293	
5536		·9554	
5508	·3083		
5507		·3986	
5502	·9917		
5499	·0433		
5495		·9891	
5489		·2681	
5478		·0851	
5475		·4212	
5467		·9152	
5464		·7932	
5464		·4782	
5457	·1255		·1258
5448	·4306		
5446	·5558		
5436	·0342		·0340
5434		·4560	
5431	·2055		·2055
5425	·5764		
5416	·7051		
5412	·4143		
5407	·2773		·2779
5405		·6535	
5405		·6208	
5405		·3300	
5399		·1036	
5398	·6278		·6285
5394	·6663		
5384	·8658		
5390		·9768	
5381		·0702	
5375		·2029	
5372	·9829		·9827
5371	·4554		
5368	·9598		
5366		·8911†	·8858†
5366		·3638	
5342	·5092		·5084
5341	·4139		

λ_{vac} (Å)	IAU*	Cross-white (18)	Hands & Littlefield (31)
5334	·3821		
5331		·4709	
5330		·0131	·0111
5329		·5208	·5204
5325	·6595		·6587
5323		·5219	
5308	·8370		
5303	·7744		
5289		·9988	
5285	·0907	·0906	
5283	·2593	·2594	
5274		·6312	
5271		·8226	·8228
5271		·0028	·0041
5268	·0206	·0205	
5264	·7696	·7688	
5254		·9450	
5248		·5099	
5243		·9496	
5236		·8433	
5234	·3968		·3963
5231		·3034	
5228	·6428		·6445
5226		·9800	
5218		·8414	
5217	·7257	·7261	·7258
5216		·6319	
5210		·0436	
5206	·0310	·0314	
5203		·7584	
5197		·5490	
5196		·9199	
5196		·3877	·3884
5193	·7888	·7897	
5192	·8992	·9001	
5173	·0359		·0361
5170	·3373	·3371	
5168	·9272		·9274
5167	·7202	·7204	·7194
5163		·7090	
5140		·8935	·8935
5140		·6821	
5135	·1193	·1188	
5111	·8365	·8363	·8368
5109		·0642	

λ_{vac} (Å)	IAU*	Cross-white (18)	Hands & Littlefield (31)
5070		·1780	
5053		·0424	
5051		·2267	
5043		·1603	·1616
5016		·3400	
5013		·4652	
5007		·5136	
5007		·1080	
5003		·2569	
4995		·5216	
4986		·9369	
4986		·6426	
4985		·2422	
4983		·8878	
4967	·4791†	·4729†	
4958	·9787		·9797
4958		·6822	
4940		·1908	
4921	·8753		·8757
4920		·3655	
4904		·6776	
4892	·8571	·8575	·8577
4892		·1199	
4879		·5718	
4873		·4977	
4872	·6776	·6779	
4861		·0973	
4790		·9888	
4738		·0966	
4711		·6004	
4708		·5898	
4692		·7230	
4680		·1536	
4669		·4392	
4668		·7585	
4655		·9316	
4648	·7346	·7340	
4626		·3393	
4620		·5804	
4612		·5685	
4604		·2283	
4529	·8831		·8832
4495	·8236		
4490	·9987		
4483	·4260		·4271
4477	·2728		
4470	·6285		
4467	·8036		·8031
4462	·9045		·9041
4428	·5525		·5524
4423	·8094		
4416	·3621		·3619
4405	·9875		·9868
4384	·7765		·7759
4377	·1586		·1584
4370	·9991		
4368	·8048		
4353	·9572		
4338	·2653		
4326	·9779		·9776
4316	·2973		·2974
4309	·1131		·1131
4300	·4432		·4433
4295	·3321		
4292	·6701		
4283	·6076		·6074
4272	·9623		·9618
4272			·3546
4261	·6726		·6726
4259	·5137		
4251			·9827
4248	·6204		
4246	·4516		
4240	·0023		
4237	·1289		
4234	·7941		
4230			·9362
4228	·6163		
4227	·1455		
4223	·4020		
4220	·5482		
4217	·3702		·3706
4207	·8804		
4203	·2121		·2123
4200	·2779		·2773
4199	·4866		·4857
4192	·6108		
4186	·0708		
4182	·9328		·9311
4178	·7707		

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λ_{vac} (Å)	IAU*	Cross-white (18)	Hands & Littlefield (31)
4153	·3401		
4150	·5359		
4148	·8383		
4145	·0366		·0358
4144			·5826
4138	·1642		
4135	·8432		
4133	·2232		·2224
4128	·7727		
4121	·3685		
4119	·7066		
4110	·9613		
4108	·6471		
4101	·8947		
4099	·3324		
4077	·7804		
4075	·9364		
4072	·8868		·8867
4064	·7418		·7407
4063	·5882		
4046	·9569		·9542
4025	·8625		
4023	·0030		
4015	·6656		
4010	·8463		
4006	·3739		·3736
4002	·7927		
3998	·5224		
3985	·0836		
3982	·8972		
3978	·8663		
3970	·3797		·3791
3957	·7966		·7965
3953	·7199		
3952	·2816		
3951	·0703		
3938	·4427		
3936	·9265		
3931	·4091		·4084
3929	·0319		·0310
3924	·0222		·0215
3921	·3679		·3669
3907	·5858		·5851
3904	·0509		·0504
3900	·8124		·8111
3899	·1149		
3898	·9941		
3896	·7600		·7590
3889	·6153		·6144
3888	·1489		
3887	·3833		·3827
3879	·6724		
3879	·1171		
3874	·8588		
3873	·5984		·5980
3870	·6553		
3868	·3120		
3866	·6187		
3861	·0066		·0050
3857	·4649		·4639
3847	·8913		
3844	·3468		
3842	·1371		·1365
3841	·5270		·5256
3835	·3097		·3090
3828	·9088		·9077
3826	·9664		·9656
3825	·5284		·5278
3821	·5093		·5083
3816	·9231		·9220
3814	·1337		
3814	·0460		·0456
3806	·4227		
3800	·6256		
3799	·5895		
3796	·0793		·0789
3791	·1686		·1678
3788	·9557		·9549
3768	·2616		·2609
3766	·6084		
3764	·8582		·8574
3761	·1176		
3759	·3006		·3000
3750	·5510		·5497
3749	·3273		·3264
3746	·9636		
3746			·6244
3744	·4256		·4261
3738	·1943		·1931
3735	·9263		·9246

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λ_{vac} (Å)	IAU*	Cross-white (18)	Hands & Littlefield (31)
3734	·3784		·3781
3728	·6788		·6777
3723	·6217		·6206
3720	·9926		·9916
3710	·3011		
3706	·6202		·6192
3688	·5057		·5055
3684	·1027		
3680	·9606		·9600
3648	·8816		·8808
3632	·4982		·4972
3619	·7995		·7984
3611			·1880
3609	·8885		·8874
3588	·0074		
3582	·2148		·2141
3571	·1157		·1161
3566	·3971		·3959
3559	·5313		·5306
3555	·9400		·9389
3543			·0865
3542			·0939
3527	·0478		
3522	·2678		·2670
3514	·8226		·8216
3501			·8634
3498	·8415		·8404
3491	·5729		·5718
3477	·6974		·6959
3476	·4448		·4439
3466	·8528		·8518
3448			·2612
3444	·8631		
3441	·9750		
3441			·5906
3287			·6984
3258	·5329		
3237	·1559		
3222			·9964
3206	·3221		
3194	·1476		
3192			·5806
3185			·8144
3135	·0181		
3101	·5647		

λ_{vac} (Å)	IAU*	Cross-white (18)	Hands & Littlefield (31)
3101	·2029		
3100	·8674		
3084	·6365		
3076	·6129		
3068	·1351		
3059	·9753		
3058	·3347		
3048	·4904		
3043	·5496		
3042	·6231		
3041	·3119		
3038	·2725		
3027	·3424		
3026	·7234		
3024	·9134		
3021	·9526		
3021	·3706		
3019	·8621		
3018	·5061		
3010	·4463		
3009	·0156		
3008	·1588		
3003	·9058		
3001	·8229		
3000	·3863		
2995	·3006		
2988	·1619		
2984	·4405		
2982	·3150		
2966	·1205		
2958	·2286		
2954	·8032		
2852	·6352		
2833	·2689		
2826	·3874		
2824	·1073		
2814	·1152		
2807	·8115		
2805	·3471		
2779	·0404		
2743	·2172		
2738	·1199		
2734	·3901		
2724	·3843		
2712	·4593		

λ_{vac} (Å)	IAU*	Cross-white (18)	Hands & Littlefield (31)	λ_{vac} (Å)	IAU*	Cross-white (18)	Hands & Littlefield (31)
2707	·3855			2546	·7432		
2690	·0115			2541	·7350		
2679	·8582			2501	·8864		
2667	·1911			2458	·3413		
2636	·5952						
2607	·6057						
2600	·1735						
2585	·3098						
2577	·4623						
2550	·3792						

*as given by Edlén (**21**) but converted to vacuum, based on the data of Stanley and Dieke (**79**), Stanley and Meggers (**80**), and Blackie and Littlefield (**12**).

† The large discrepancy between wave-lengths marked by a dagger clearly indicates that one or the other of the two values must be erroneous.

Even Fe lines produced by low-pressure sources have a comparatively large Doppler width since the atomic weight is not very high, and in addition they are not very uniformly and densely distributed over the whole visible and ultra-violet spectral region. It was for these reasons that Meggers (**59**) first suggested the use of the spectrum of thorium as a source of standards since for it the atomic weight is high and therefore the Doppler width small and in addition the density of the lines is much greater than in the case of Fe at least in the region above 2700 Å (below this wave-length the Th spectrum is much weaker). Meggers and Stanley (**61**) were the first to present a list of interferometrically measured Th lines. This list has recently been extended by Davison, Stanley and Giacchetti (**19**) at Purdue University, and independently Littlefield and Wood (**52**) have measured 360 Th lines in the region 2560 – 9050 Å which include most of the lines measured by Meggers, Davison, Stanley and Giacchetti. In Table 5 we present a combined list of these wave-lengths. Again for most lines the agreement is within less than 0·001 Å and quite often within less than 0·0005 Å. Lines for which this is the case may be recommended as standards. A very complete list of Th lines based on grating measurements in the region 2000 to 11 560 Å has been published by Zalubas (**90**).

Table 5. Observed vacuum wave-lengths of Th lines

λ_{vac} (Å)	M.S. D.S.G.*	L.W.**	λ_{vac} (Å)	M.S. D.S.G.*	L.W.**	λ_{vac} (Å)	M.S. D.S.G.*	L.W.**
9050		·7361	8332		·7414	7981		1713
8970		·1446	8323		·1447	7902		·5333
8760		·6500	8254		·6630	7849		·7019
8750		·4354	8189		·1644	7819		·9220
8711		·6275	8172		·0357	7800		·5056
8667		·8683	8161		·9723	7791		·0803
8575		·4779	8159		·7467	7744		·6391
8512		·8602	8140		·7148	7649		·4852
8480		·6879	8095		·8171	7587		·6231
8423		·5413	8034		·6424	7569		·9286

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λ_{vac} (Å)	M.S. D.S.G.*	L.W.**
7432		·3012
7430		·9893
7420		·4404
7387		·5381
7343		·1749
7286		·9118
7220		·0449
7209		·9944
7170		·8724
7152		·2559
7126		·5264
7086		·1241
7020		·5050
7002		·7366
6991	·5839	·5848
6945	·5265	·5275
6913	·1336	·1346
6836	·8110	·8122
6830	·9200†	·9264†
6782		·2860
6781		·9972
6758	·3178	·3202
6729	·3157	·3175
6680	·5516	
6676		·5410
6664	·1090	·1095
6660	·5161	
6595	·7610	·7608
6593	·3055	·3051
6590	·3596	·3590
6585	·7251	·7240
6555	·9711	·9703
6533	·1467	·1457
6492	·5313	·5311
6459	·0677	·0678
6415	·3880	·3860
6413	·6719	·6710
6378	·6939	·6919
6344	·6138	·6132
6329	·0284	·0276
6263	·1496	·1498
6259	·1546	·1552
6226	·2495	·2488
6208	·9379	·9377
6193	·6187	·6189

λ_{vac} (Å)	M.S. D.S.G.*	L.W.**
6184	·3327	·3327
6153	·6958	·6954
6104	·2839	·2845
6089	·7160	·7172
6087	·0592†	·0413†
6050	·7259	·7256
6039	·3697	·3687
6022	·7040	·7025
6008	·7362	·7361
5976	·7207	·7207
5975	·3199	·3199
5940	·4709	·4703
5887	·3329	·3328
5854	·3040	·3038
5805	·7508	·7507
5791	·2494	·2517
5762	·1487	·1478
5726	·9770	·9768
5708	·6867	·6870
5659	·4960	
5641	·3115	·3117
5616	·8790	·8791
5588	·5778	·5779
5580	·9077	·9077
5574	·9014	·9033
5559	·8862	·8845
5549	·7170	·7166
5540	·8000	·8004
5511	·5244	·5230
5500	·7830	·7834
5453	·7341	
5432	·6212	
5427	·1863	
5418	·9916	·9918
5409	·1569	·1572
5388	·1087	·1084
5345	·0676	·0673
5328	·4574	·4575
5278	·9689	
5259	·8245	·8241
5232	·6159	·6161
5178	·4025	·4030
5160	·0411	·0419
5155	·6787	·6794
5116	·4697	·4702

λ_{vac} (Å)	M.S. D.S.G.*	L.W.**
5069	·3868	·3860
5051	·2039	·2048
5030	·0588	·0580
5018	·6539	
5003	·4922	·4925
4941	·0205	·0207
4921	·1890	·1894
4896	·3215	·3220
4880	·096	·0960
4866	·8360	·8357
4864	·5307	·5309
4842	·1951	·1955
4809	·4773	·4775
4790	·7256	·7249
4767	·9330	
4753	·7430	
4705	·3060	·3063
4687	·5060	·5064
4674	·9690	·9696
4669	·4788	·4792
4664	·5076	·5079
4633	·0583†	·0548†
4596	·7074	·7077
4589	·7123	·7108
4572	·2526	·2537
4557	·090	·0888
4536	·526	·5261
4511	·7908	
4494	·5941	·5944
4483	·4270	·4267
4466	·5938	·5930
4459	·2531	·2526
4446	·5561†	·5789†
4434	·2075	·2060
4410	·1211	·1205
4404	·1637	·1637
4402	·8181	·8170
4392	·3440	·3441
4383	·0916	·0913
4379	·4070	·4079
4375	·3536	·3529
4367	·1573	·1568
4343	·4763	·4747
4332	·0619	·0614
4319	·6305	·6300

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λ_{vac} (Å)	M.S. D.S.G.*	L.W.**	λ_{vac} (Å)	M.S. D.S.G.*	L.W.**	λ_{vac} (Å)	M.S. D.S.G.*	L.W.**
4316	·4681	·4687	3804	·1547	·1547	3397	·7022	·7018
4308	·3878	·3881	3786	·6749	·6755	3394	·9671	
4301	·0489	·0469	3782	·0402	·0400	3393	·0085	·0085
4293	·0177	·0178	3772	·4418	·4418	3391	·8224	
4278	·5179	·5166	3764	·0032	·0022	3386	·5033	·5030
4274	·5600	·5594	3753	·6351	·6344	3381	·8303	·8303
4258	·6944	·6945	3743	·9872	·9870	3379	·5438	
4236	·6562	·6560	3728	·9624	·9635	3375	·9439	·9437
4231	·6182†	·6270†	3720	·4925	·4930	3367	·4846	
4216	·0156	·0155	3712	·3596		3359	·5671	·5669
4210	·0764	·0755	3702	·0312	·0310	3352	·1916	·1912
4194	·1980	·1975	3693	·6171	·6163	3351	·3147	
4179	·2374	·2372	3683	·5345	·5343	3338	·8302	·8302
4166	·9403	·9400	3671	·0139	·0126	3333	·4377	
4159	·7076	·7063	3669	·1843	·1851	3331	·4345	·4348
4151	·1568	·1562	3657	·7353	·7344	3327	·4222	
4133	·9191	·9196	3643	·2867	·2869	3326	·0772	·0768
4128	·5760	·5756	3633	·8655	·8655	3325	·7090	·7086
4116	·9200	·9194	3623	·8281	·8279	3319	·3451	
4109	·5789	·5790	3616	·1634	·1638	3310	·3176	·3184
4101	·4984	·4982	3613	·4574	·4571	3309	·0107	
4095	·9028	·9024	3599	·1462	·1465	3305	·1894	·1898
4087	·6741	·6734	3593	·8041	·8044	3303	·1432	
4068	·5993		3585	·1983	·1979	3294	·8969	
4060	·3990	·3984	3577	·5784	·5774	3293	·4692	·4681
4044	·5368	·5362	3568	·2822	·2819	3288	·7360	·7358
4037	·1879	·1878	3560	·4657		3284	·6168	
4020	·2649	·2640	3552	·4159	·4160	3279	·6774	
4013	·6293	·6288	3545	·0303	·0301	3278	·6464	
4009	·3435	·3429	3540	·5982	·5992	3271	·0424	
3995	·6786	·6784	3519	·4094	·4096	3263		·6101
3981	·2150	·2138	3512	·1612	·1609	3258		·3057
3968	·5144	·5142	3504	·7875		3257		·2128
3950	·0813		3499	·6216	·6238	3252		·8541
3934	·0243	·0237	3494	·5174		3250	·2817	
3924	·9104	·9096	3480	·1683		3245		·3844
3906	·2924	·2929	3469	·2125	·2113	3239		·0503
3870	·7605	·7589	3463	·8418		3237	·5072	
3864	·5009	·5001	3452	·6909	·6912	3231	·7837	
3855	·6036	·6027	3443	·5651	·5644	3229		·9412
3843	·0498	·0492	3434	·9829	·9829	3222		·2210
3840	·7833	·7845	3422	·1909	·1908	3221	·2807	
3829	·4708	·4708	3413	·9918	·9915	3211	·7062	
3819	·7692	·7693	3406	·5347	·5351	3211		·2360
3814	·1497	·1501	3403	·6721		3209	·4538	

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λ_{vac} (Å)	M.S. D.S.G.*	L.W.**	λ_{vac} (Å)	M.S. D.S.G.*	L.W.**	λ_{vac} (Å)	M.S. D.S.G.*	L.W.**
3201	·4110		3009		·3731	2774		·7712
3196		·2443	3005	·1238		2772		·8287
3196	·0930		3003		·2759	2771		·6330
3189		·1558	2989		·1032	2769		·6588
3185		·8697	2986	·1138		2765		·9399
3185	·1982		‡2974		·8794	2765		·4526
3181		·1135	‡2969		·5528	2764		·4215
3179		·9671	2960	·7181		2761	·2064	·2055
3176	·6446	·6456	2958		·4444	2752		·9798
3170	·2453	·2451	2949	·9299	·9292	2750		·3437
3167		·0146	2944	·5896		2747		·9679
3155		·6888	2943		·7199	2743		·8744
3155	·2142	·2144	2929		·1101	2739	·1343	
3151		·3673	2925		·9066	2733		·6171
3146		·9544	2920	·6956	·6952	2730		·1343
3146		·5480	2919	·7768		2723		·1851
3140		·2154	2918		·2651	2722		·4973
‡3137		·1244	2912	·8617		2708		·9784
‡3131		·9762	2903	·5642		2704		·7588
3126		·6507	2900		·5695	2698	·3463	
3126		·4131	2892		·0958	2696		·3518
3126		·1146	2888	·6647	·6640	2693		·2153
3125		·2926	2885		·8943	2691	·7988	
3123		·8678	2885		·1342	2688		·4503
3120		·4304	2879	·5016		2687	·9305†	·9353†
3116	·4413		2871		·2480	2685		·0856
3109		·1983	2855	·1810		2680	·6797	
3107	·9274		2852		·0981	2659	·4547	
3103		·5637	2850	·1635		2651	·3722	·3713
3090	·9908		2843		·6477	2642		·2749
3089		·3658	2838		·1289	2626		·5199
3081		·1116	2835	·3111		2624		·2308
3079		·7227	2833		·1475	2619		·7891
3077	·3040		2831		·2740	2601		·6597
3073	·0080		2827		·6868	2597		·8229
3068	·6213	·6206	2822		·8559	2589		·8332
3062		·5896	2821		·1650	2577		·4595
3049		·9789	2820		·1521	2567		·3570
3047	·8379		2816		·8994	2566		·3615
3042	·8257		2815		·1477	‡ Added values		
3035		·9925	2808		·6543	3133	·0109	
3034	·9487	·9480	2798		·5609	3021	·9360	
3028	·1103		2795		·0787	2971	·4332	
‡3027		·4556	2787		·9526			
‡3011	·6130		2781	·5368†	·5150†			

* Meggers and Stanley (**61**), Davison, Stanley and Giacchetti (**19**).

** Littlefield and Wood (**52**). The wave-lengths above 7000Å are considered by them to be provisional.

† The large discrepancy between wave-lengths marked by a dagger clearly indicates that one or the other of the two values must be erroneous.

Good standards in the infra-red are still rather scarce. Littlefield and Rowley (**50**) have measured thirteen intense Ar lines in the region 1·2 to 1·7μ. The spectrum was excited in a liquid nitrogen cooled Geissler tube and also in an electrodeless high frequency discharge tube. The measurements were made relative to the orange line of Kr^{86} using a reflecting echelon having 40 plates each of thickness 7 mm, a lead sulphide cell being used for detection of the infra-red radiation. These lines as well as several others have also been measured by Humphreys and Paul (**38**) (**39a**) with the aid of a Fabry-Perot interferometer and by Peck (**69a**) by direct fringe count. The three sets of measurements are compared in Table 6.

Littlefield and Rowley have also recalculated by the combination principle the infra-red wave-lengths given in Table 8 of the previous report (**21**) which was based on older measurements of Humphreys and Paul. Using Humphreys and Paul's revised values of Table 6, a very satisfactory agreement is obtained with the Ritz standards of Littlefield and Rowley except for the lines involving the level $3d_1''$. This discrepancy seems to be related to the comparatively large discrepancy in the lines 12806 and 13626 Å as measured by the two groups of investigators according to Table 6.

Table 6. Observed vacuum wave-lengths of ArI lines in the infra-red

λ_{vac} (Å)	Humphreys and Paul (**39a**)	Littlefield and Rowley (**50**)	Peck (**69a**)
8266			·794$_5$
9125			·471$_4$
9227			·0302
10472			·922
10676	·489		·4907
10684	·698		
11081	·901		
11671	·903		
12115	·639		
12346	·770		
12406	·220	·218	
12442	·724		
12459	·523		
12491	·079	·079	
12705	·755		
12806	·241	·247	·2401
12960	·203	·203	·2004
13011	·822	·821	
13217	·606		
13231	·727		
13276	·266	·266	
13316	·850	·855	
13370	·766	·768	
13507	·883	·882	·884
13626	·383	·391	·387
13682	·290	·292	
13722	·327	·329	·3271
14097			·4914
16945	·210	·213	·209

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In Table 4 of the previous report (**21**) a number of infra-red lines of Hg^{198} were given. Slight revisions have been made by Humphreys and Paul (**39a**) in their values and Peck (**69a**) has made new measurements. In Table 7 these new measurements are compared with the older ones of Rank, Bennett and Bennett (**69b**). Table 8 gives similar measurements by Littlefield, Rowley and Sharp (**51**) and Batarchoukova, Kartachev and Efremov (**9a**) on several strong infra-red lines of Kr^{86} in an Engelhard lamp.

Table 7. Observed vacuum wave-lengths of Hg^{198} lines in the infra-red

λ_{vac} (Å)	Humphreys and Paul (**39a**)	Rank *et al.* (**69b**)	Peck (**69a**)
10142	·572*	·5698	·573$_3$
11290	·496$_3$		·497$_4$
13074	·906$_6$		
13574	·282$_2$	·2933	
13677	·135$_1$		·134$_2$
15300	·154$_3$	·1456	·153$_9$

* Assumed as standard.

Table 8. Observed vacuum wave-lengths of Kr^{86} lines in the infra-red (Batarchoukova, Kartachev and Efremov (9a); Littlefield, Rowley and Sharp (51))

7603·6337 Å	8776·1579 Å	13626·141 Å	15339·154 Å
7854·9810	8931·1428	14430·735	15376·233
8511·2073	9754·4317	15243·781	16789·722

Rank and his collaborators (**70**) (**70a**) have suggested the use of molecular absorption lines as standards in the infra-red. In particular they have given an extensive table of wave-numbers and wave-lengths of the 001-000, 002-000, 101-000 and 010-000 bands of HCN and of the 1-0 and 2-0 bands of CO. These bands cover (with some gaps) the region $1{\cdot}82\mu - 16{\cdot}0\mu$. Some lines have been measured interferometrically, others by a large grating using overlapping orders, and still others are calculated from well-known molecular formulae using molecular constants determined from the directly measured lines.

A considerable number of Ritz standards for the vacuum ultra-violet have been obtained by Herzberg (**33**). These standards are based on the measurement, in a high grating order, of certain secondary standards against other Ritz standards (of Hg^{198}, Mg II, N I and Ge I; see Edlén's previous report (**21**)). Edlén (**22**) and Minnhagen (**63**) have somewhat extended and very slightly corrected this list. The new list is presented in Table 9.

Table 9. Vacuum ultra-violet standards based on the combination principle

Spectrum	λ_{vac} (Å)	Spectrum	λ_{vac} (Å)	Spectrum	λ_{vac} (Å)	Spectrum	λ_{vac} (Å)
A II	1973·4837*	C I	1329·6005	O I	1306·0286*	C II	1139·3317
A II	1961·3610*	C I	1329·5775	O I	1304·8575*	C II	1138·9358
A II	1941·0724*	C I	1329·1230	O I	1302·1686*	C II	1066·1332
A II	1909·5689*	C I	1329·1001	N I	1200·7113*	C II	1065·9199
C II	1760·8191*	C I	1329·0863	N I	1200·2238*	C II	1065·8913
C II	1760·4735	C I	1328·8332*	N I	1199·5490*	C II	1037·0182
C II	1760·3954*	C II	1323·9955	C II	1141·7445	C II	1036·3367
C II	1335·7077*	C II	1323·9513	C II	1141·6574	N I	965·0415
C II	1335·6627	C II	1323·9059	C II	1141·6246	N I	964·6258
C II	1334·5323*	C II	1323·8617	C II	1139·4730	N I	963·9904

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Spectrum	λ_{vac} (Å)	Spectrum	λ_{vac} (Å)	Spectrum	λ_{vac} (Å)	Spectrum	λ_{vac} (Å)
N I	955·4376	A II	697·4893	A II	573·3622	A II	528·6508
N I	955·2647	A II	693·3015	A II	572·0139	A II	526·4971
N I	952·5231	A II	691·0377	C II	560·4386	A II	524·6805
N I	952·4151	C II	687·3521	C II	560·4367	A II	522·7921
N I	952·3037	C II	687·3453	C II	560·2394	A II	519·3271
A II	932·0528*	C II	687·0526	A II	560·2229	A II	518·9090
A II	919·7815*	A II	686·4888	A II	556·8172	A II	514·3097
N I	910·6456	A II	679·4001	A II	555·7662	A II	510·5566
N I	910·2785	A II	679·2187	A II	553·1260	A II	510·5511
N I	909·6976	A II	677·9521	A II	550·9042	A II	505·0119
C II	904·4801	A II	676·2428	A II	550·4807	A II	503·6501
C II	904·1416	A II	672·8565	C II	549·5700	A II	502·1632
C II	903·9616	A II	671·8516	C II	549·5110	A II	501·1899
C II	903·6235	A II	670·9450	C II	549·3785	A II	500·8019
C II	858·5590	A II	666·0112	C II	549·3195	A II	496·6594
C II	858·0918	A II	664·5626	A II	548·7810	A II	496·6438
A II	762·1995	A II	661·8692	A II	547·9958	A II	494·6678
A II	754·8243	C II	636·2511	A II	547·4602	A II	492·4080
A II	748·1977	C II	635·9945	A II	547·1647	A II	490·7010
A II	745·3217	A II	612·3719	A II	546·1770	A II	489·1955
A II	744·9252	A II	602·8581	A II	543·7307	A II	488·9616
A II	740·2695	A II	597·7003	A II	543·2035	A II	488·7928
A II	737·4541	C II	595·0245	A II	542·9125	A II	487·2274
A II	730·9293	C II	595·0219	A II	541·3017		
A II	725·5481	C II	594·8000	A II	540·8063		
A II	723·3611	A II	583·4368	A II	537·4195		
A II	718·0903	A II	580·2634	A II	537·1398		
A II	704·5233	A II	578·6046	A II	535·0713		
A II	698·7748	A II	578·1068	A II	533·0796		
A II	697·9414	A II	576·7361	A II	530·4951		

* Measured by Herzberg (**33**) against other Ritz standards.

Reader, Meissner and Andrew (**72**) have measured by means of Fabry-Perot interferometers Cu II lines in the region 2885 – 1979 Å while independently Littlefield and Wood (**52**) have measured, by means of a reflection echelon with 25 plates of 7 mm thickness, Cu II lines in the regions 8513 – 7399 and 2885 – 2190 Å. Where they overlap the two sets agree quite well with some exceptions probably due to unresolved hyperfine structure. Both groups of authors have calculated vacuum ultra-violet standards from their data using the combination principle. In Table 10 the two sets of wave-lengths are given. They will be very useful for work in the vacuum ultra-violet.

Kiess and Corliss (**47**) and Martin and Corliss (**54**) have made a detailed study of the first and second spectra of iodine in the visible and ultra-violet regions. From this work they have derived by the combination principle about 100 lines of I I and 300 lines of I II in the region below 2000 Å which may serve as standards of intermediate accuracy particularly when Fe or thorium iodide lamps are used.

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Table 10.

Vacuum ultra-violet standards of Cu II based on the combination principle

λ_{vac} (Å)	R.M.A.(72)	L.W.(52)	λ_{vac} (Å)	R.M.A.(72)	L.W.(52)	λ_{vac} (Å)	R.M.A.(72)	L.W.(52)
1989		·8541	1535	·0024	·0033	1020	·1075	·1073
1979		·9550	1531	·8557	·8555	1019	·6545	·6542
1970		·4927	1519	·8370	·8370	1018	·7075	·7052
1944		·5866	1519	·4917	·4917	1018	·0643	
1663	·0017	·0022	1517	·6312		1017	·9983	·9973
1660	·0009	·0026	1496	·6860	·6874	1013	·4002	·3994
1656	·3216	·3218	1488	·6373	·6380	1012	·6834	·6827
1649	·4573	·4573	1485	·6777	·6772	1012	·5972	·5951
1621	·4256	·4270	1485	·6104		1011	·4362	·4360
1617	·9151	·9151	1473	·9788		1010	·6395	
1611	·1180	·1190	1444	·1305	·1305	1008	·7284	·7280
1610	·2964	·2979	1442	·1389		1008	·5692	·5674
1608	·6396		1065	·7822	·7824	1006	·9843	·9834
1606	·8338	·8341	1059	·0960	·0962	1004	·0557	·0526
1604	·8474	·8482	1056	·9545	·9544	1001	·0130	·0124
1602	·3882		1054	·6903	·6911	999	·7944	·7948
1598	·4024	·4034	1049	·7556	·7548	998	·3063	·3058
1593	·5557	·5546	1044	·7434	·7431	992	·9533	·9525
1590	·1646	·1649	1036	·4695	·4690	989	·2368	·2340
1569	·2123	·2135	1035	·1631	·1630	983	·9804	·9773
1566	·4151		1033	·5679	·5675			
1565	·9240	·9240	1031	·7661	·7659			
1558	·3446	·3453	1028	·3281	·3282			
1541	·7031	·7017	1027	·8312	·8305			
1540	·3889		1022	·1021	·1022			

NEW WORK ON SPECTRA OF INDIVIDUAL ATOMS

A large number of investigations of individual atomic spectra have been published during the last three years or are in the process of publication. The following is a partial list of work that has come to the writer's attention:

He I: Herzberg (**33**), Martin (**53a**) — Li I: Johansson (**41**)
Li II: Herzberg and Moore (**34**), Freytag (**26**) — Li III: Freytag (**26**)
C I: Herzberg (**33**), Minnhagen (**64**) — C II: Herzberg (**33**)
N I: Eriksson (**25**), Herzberg (**33**) — N II: Eriksson (**24**)
O I: Herzberg (**33**) — Ne I: Hepner (**32**)
Si II: Shenstone (**75**) — Si III: Toresson (**85**) — Si IV: Toresson (**84**)
P I and P II: Martin (**53**) — S I: Toresson (**85**)
Cl I: Humphreys and Paul (**39**), Minnhagen (**65a**)
Ar I: Paul and Humphreys (**69**) — Ar II: Minnhagen (**63**), Herzberg (**33**)
Ca I: Kaiser (**43**) — V III: Iglesias and Velasco (**40b**)
Ti I: Kiess and Thekaekara (**47a**), Wilson and Thekaekara (**88a**)
Mn II: García-Riquelme, Iglesias and Velasco (**28**) — Mn III: Catalán (**16**)
Fe I: Kiess, Rubin and Moore (**48**) — Co III: Shenstone (**76**)
Ni III: García-Riquelme (**27**)
Ge I: Andrew and Meissner (**4**), (**5**), Meissner, VanVeld and Wilkinson (**62**)
Ge II: Andrew and Meissner (**6**), Meissner, VanVeld and Wilkinson (**62**)
Br II: Rao (**71**), Martin and Tech (**55a**)
Kr I: Thekaekara and Dieke (**83**), Paul and Humphreys (**69**)
Zr I: Howe (**37**) — Nb II: Iglesias (**40**)

Ru I:	Kessler (**44**), McNally and Kessler (**57**), Trees (**86**)		
Ru II:	Shenstone and Meggers (**77**)		
Te II:	Handrup (**30a**)		
I I:	Kiess and Corliss (**47**), Murakawa (**67**)	I II:	Martin and Corliss (**55**)
Xe I:	Thekaekara and Dieke (**83**)	Ba I:	Garton and Codling (**29**)
Pr I and II:	Belyanin (**10**)	Ho I:	Belyanin (**11**)
Er I and II:	McNally and Vander Sluis (**58**), Vander Sluis (**88**)		
Hf III and IV:	Klinkenberg, Van Kleef and Noorman (**48c**)	Ta II:	Kiess (**46a**)
Re I:	Trees (**87**)	Re II:	Meggers, Catalán and Sales (**60**)
Os I and II:	Van Kleef (**48a**), Van Kleef and Klinkenberg (**48b**)	Au III:	Iglesias (**40a**)
Th I:	Zalubas (**89**) (**90**)		
Pu I:	Bovey (**13**), Gerstenkorn (**30**), Bovey and Gerstenkorn (**13a**)		
Pu II:	McNally and Griffin (**56**)	Pm II:	Johnson (**42**)

A general discussion of the present state of work on the rare earth spectra has been given by Moore (**66**).

SOLAR SPECTROSCOPY

The subject of solar spectroscopy in general is of course the domain of Commission 12. However a number of studies have been reported and suggestions been made by members of Commission 14 which refer to work for which both Commissions may be jointly responsible.

Miss Adam and her collaborators (**1**), (**3**), (**68**) have continued the measurements of absolute wave-lengths for solar and vacuum arc lines. A few measurements have also been made using integrated light from the solar disk (Higgs (**36**)). In view of the local velocity fields which are known to exist on the Sun such wave-lengths may well be more reliable than centre of disk values for a moderate number of observations, though allowance must be made for the centre to limb change in wave-length. A new determination of this 'limb-effect' has been made for medium strength iron lines in the 6300 Å region (Adam (**2**)). This indicates a red shift at the extreme limb greater than the relativity value. The work has been continued by Higgs (**36**) who finds that the increasing red shift towards the limb is accompanied by line asymmetry. Similar measurements have been made in the 8500 and 8900 Å regions for lines of Fe I, Si I and Ca II by Mrs. Herzberg (**35**). She finds that for the Ca II lines near 8500 Å the wave-lengths near the limb are significantly larger than those predicted by relativity theory while for the Fe lines they are in good agreement. See also Schröter (**74**).

With a view to identifying some of the fainter solar lines Kiess, Rubin and Moore (**48**) have measured about 1800 new faint iron lines, in an arc in air, of which 700 have been newly classified. Nearly 400 of the faint lines are found in the Sun's spectrum, of which 75% are unblended lines and 25% are blended with lines to which other chemical origins have been assigned.

At the McMath-Hulbert Observatory three investigations concerned with the determination of the wave-lengths of solar lines are under way with the vacuum spectrograph:

(1) The first of these deals with the complete identification of the faint lines present in sunspot spectra in the region including Hα. The identification and measurement of these lines is essential for a definitive study of the possibility of detecting deuterium in the solar spectrum.

(2) W. E. Mitchell of the Ohio State University is measuring the wave-lengths of about 100 lines in the ultra-violet part of the solar spectrum between 3000 and 3600 Å. Direct intensity photo-electric tracings constitute the fundamental observational data for Mitchell's investigation. He also hopes to provide from his tracings an improved calibration of this portion of the Sun's ultra-violet spectrum.

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(3) An observational programme carried out with the vacuum spectrograph is directed toward the accumulation of a large sample of sunspot spectra. There still remain several thousand unmeasured and unidentified lines in the spectra of sunspots. It is hoped that most of these unidentified and unmeasured features can be assigned preliminary wave-lengths and intensities.

The problem of identifications of weak solar lines due to molecular lines is dealt with in the report of Sub-Commission 14b.

TABLES AND OTHER AIDS FOR WORK IN SPECTROSCOPY

The National Bureau of Standards has published in two large volumes a *Table of Wave-numbers* prepared by Coleman, Bozman and Meggers (**17**). This Table gives, on the basis of the Edlén formula for the dispersion of air, the vacuum wave-numbers corresponding to wave-lengths in air from 2000 Å to 1000μ (from 2000 – 10000 Å in steps of 0·01 Å). The vacuum corrections are also given.

The revision of the 1928 edition of Rowland's Solar Spectrum Table by Mrs Moore-Sitterly of NBS and M. Minnaert and J. Hougast of the Utrecht Observatory is nearly completed. A prepublication of the photometric data may be found in *Rech. Astron. Obs. Utrecht* **15**, 1960, giving equivalent widths and reduced widths for the region λ 3164—λ 8770 Å. A definitive edition which in addition contains improved wave-lengths, identifications, excitation potentials and multiplet numbers is being prepared as an NBS Monograph.

Mrs Moore-Sitterly is in the process of completing Section 3 of 'An Ultra-violet Multiplet Table' covering the elements 42 Mo through 57 La and 72 Hf through 89 Ac. It is planned to conclude this work with a Finding List for all three sections. The 1945 Multiplet Table (*Princeton Observatory Contribution* No. 20) has been reprinted as *Technical Note* No. 36 of NBS. A new multiplet table extending from the X-ray region to the micro-wave region has been started in order to take account of the much increased range of astrophysical observations.

A new Photometric Solar Atlas covering the spectral region 7500 – 12000 Å is being prepared by L. Delbouille of the Institut d'Astrophysique de l'Université de Liège. It is based on recordings made at the Jungfraujoch with an Ebert-Fastie type spectrometer of 7·3m focal length. The same recordings are being used by Delbouille, Roland, Swensson and Mohler for the preparation of wave-length tables with identifications of solar and terrestrial lines.

A similar table for the region 2·9 to 3·7μ is being prepared by Mohler and collaborators at McMath-Hulbert Observatory with the large vacuum spectrograph. In this connection it is pointed out by McMath that the comparatively low degree of precision (1 in 500 000) for solar lines in the infra-red from 1 to 3μ is due to the great width of the solar lines and to the irregular and variable wave-lengths of these features. McMath recommends that all tables of wave-lengths for solar lines specify completely and with great detail the circumstances under which the observations have been made. The pertinent data are: area of the Sun's surface observed, position of the observed area, the duration of the observation, and the proximity of disturbed regions of the solar surface.

J. Junkes and his collaborators at the Vatican Observatory have started the preparation of an atlas of thorium lines. Such an atlas will be extremely important if the thorium standards are to be more widely used. Junkes and Milazzo are in addition planning an atlas of spectra in the vacuum ultra-violet.

The preparation of a revised and extended version of Grotrian's *Graphische Darstellung der Spektren von Atomen und Ionen mit ein, zwei und drei Valenzelektronen* to include most other atoms has been suggested by Lochte-Holtgreven. He and Unsöld have also suggested the preparation of an atlas of standard stellar spectra.

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Harrison at MIT is continuing efforts to rule gratings larger than 10 inches in ruled width. He is also developing new automatic devices for reducing wave-lengths from echellegrams. Rank, Saksena and McCubbin, Jr. (**70b**) and Svensson (**80**) have measured the dispersion of air in the regions 3651 to 15300 Å and 2302 – 6907 Å respectively and have found excellent agreement with Edlén's formula.

G. HERZBERG
President of the Commission

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

PRÉSIDENT: Professor M. G. J. Minnaert, Director of the Astronomical Observatory, Zonnenburg 2, Utrecht, the Netherlands.

MEMBRES: Allen, Bates, Garstang, Green, R. B. King, Layzer, Lochte-Holtgreven, Smit, Zirin.

REPORT ON TRANSITION PROBABILITIES

Note. General references will be found in the Bibliography, in the same order in which they are quoted in the text. References to special transition probabilities, however, are collected into a separate section.

Since the last meeting of the IAU, the interest in fundamental data on transition probabilities has considerably increased. On one hand it became clear that the determination of cosmical abundances, for which they are needed, is of the greatest importance for a study of stellar evolution. On the other hand the investigation of the atomic processes in the chromosphere, in nebulae, in interstellar space, where thermodynamic equilibrium does not exist, requires a detailed knowledge of the atomic interactions with radiation and with particles. This increased interest has not only stimulated to new experimental and theoretical research, but also to special symposia, survey papers and general projects.

At the end of our 1958 report, we mentioned already the excellent monograph by Kolesnikov and Leskov, with an extensive bibliography, in which a serious attempt was made to compile a general table of *f* values for atoms and diatomic molecules. Shortly afterwards, in March 1959, a conference on Measurement and Calculation of Oscillator Strengths was held at the Physics Research Institute of the Leningrad State University (Report published in the same year). A bibliographic survey on transition probabilities up to 1958 is found in Varsavsky's thesis.

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