It is possible — the white illumination being 40 Lux — to observe differences in brightness for red, green and blue of 1 %.

In our opinion it is possible to characterise lamps comparing them in three colours with the normal lamp; in this way the distribution of energy is sufficiently determined for all technical purposes.

If an absolutely standardised lamp is chosen for the known lamp as a comparison-standard, it is possible to measure absolutely the spectral composition, of a lightsource with the photometer bench.

It is also possible to measure with our method the absolute spectral composition for any lightsource.

It is our opinion that the double monochromator used in the way described can be an important help in heterochromatic photometry.

Physics. — *The spectrum of the solar corona* [1]). By T. L. DE BRUIN. (Communicated by Prof. P. ZEEMAN.)

(Communicated at the meeting of April 2, 1932.)

1. *Historical note.*

References to the phenomenon of the solar corona at the time of a total eclips of the sun can be traced through the whole history of mankind [2]). The spectroscopic study of the solar corona started in the same year 1868 that the helium in the sun was discovered. The next year 1869 brought the discovery of the mysterious "coronium".

At the total eclips of August 18, 1868 POGSON, RZIHA and TENNANT observed the continuous spectrum of the corona, but no absorption or emission lines. At the total eclips of August 7, 1869, HARKNESS and YOUNG independently observed the green coronal line and YOUNG proved that it has a truly coronal origin. YOUNG's measures of the line placed it at 1474 K (KIRCHOFF scale) or in the modern scale at λ 5317. Many additional observations later continued to place it at or near 5317 *A*. At the eclips of 1893 FOWLER photographed nine coronal rings with a slitless spectrograph, all of which agree in position with selected lines reported as of coronal origin in the 1886 eclips. At the eclips of 1898 FOWLER, SHACKLETON and W. J. LOCKYER made the interesting discovery that the famous green coronal bright line is not at 5317 but at 5303.

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[1]) Preliminary note: Nature. March 26, 1932.

[2]) A very extensive report over: "Eclipses of the Sun" by S. A. MITCHELL. Chap. 3. Handbuch der Astrophysik. Bd. IV, p. 231.

Data before 1918 see: LICK. Obs. Bull. X. Nr. 318 343, p. 8. 1918 1923 by W. W. CAMPBELL a. J. H. MOORE. A short and popular note over: Kosmische spectra, see: T. L. DE BRUIN, Hemel en Dampkring. April. Mei. 1931.

Since 1893 also more coronal lines farther to the violet have been detected at several expeditions in the years 1896, 1898, 1900, 1901, 1905, 1908. On August 21, 1914 CARRASCO and independently BOSLER and BLOCK discovered a new bright line in the red at λ 6374. More accurate determinations of wavelengths have been made at the eclipses in 1918, 1922, 1926, 1929 and 1930.

Since 1869 the time spent in photographing the coronal spectrum has amounted to a grand total of about one hour, an average of one minute per year. At the eclips of May 9, 1929 GROTRIAN [1]) detected a new line at 6704 and at the October eclips 1930 MITCHELL [2]) discovered a new line still farther to the red at 6776. Up to the present the total lines ascribed to coronal origin may be fifteen although a few lines may still be suspicious. The most characteristic wavelengths are at:

8.	6776	6.	4086
4.	6704	8.	3987
15.	6374	15.	3601
20.	5303	6.	3454
6.	4231	20.	3388

2. *Attempts to explain the corona and its spectrum.*

The spectrum of the corona has three separate characteristics: first the bright line spectrum of "coronium" existing only in the inner corona and extending on the average to about 200.000 km. from the sun's edge; second, the continuous spectrum of the middle corona and third the FRAUNHOFER lines showing feebly in the outer corona. The corona has been observed to the enormous distance of ten million miles of the sun. Numerous authors have tried to explain these characteristics.

From the very extensive literature concerning this subject we mention the papers and ideas of NEWCOMB (1887) [3]), Sir NORMAN LOCKYER [4]) 1887 (chemical dissociation theory), HUGGINS [5]) 1885 (electrical theory), BIGELOW [6]) 1889 (magnetic theory), EBERT [7]) 1893 (electro-magnetic theory), SCHAEBERLE [8]) (mechanical theory), SVANTE ARRHENIUS [9]) 1908 (radiation pressure theory), SCHWARZSCHILD [10]) 1906 (electron gas theory).

From the attempts to explain especially the bright line spectrum of

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[1]) GROTRIAN, Zs f. Astr. **2**. 106. 1931. **3**. 199. **1931**.
[2]) MITCHELL, Astr. Journ. **75**. 1. 1932.
[3]) NEWCOMB, Pop. Astr. 6th. ed. 1887.
[4]) LOCKYER, Chemistry of the Sun. 1887.
[5]) HUGGINS, Proc. R. S. London. **39**. 108. 1885.
[6]) BIGELOW, Solar Corona discussed by spherical harmonix. 1889.
[7]) EBERT, Astronomy a. Astrophysics. **12**. 804. 1893.
[8]) SCHAEBERLE, Contr. Lick. Obs. N⁰. 4.
[9]) ARRHENIUS, Worlds in the Making. 1908.
[10]) SCHWARZSCHILD, Astr. Mit. Sternwarte. Göttingen. **13**. 63. **1906**.

"coronium" we mention the papers of NICHOLSON [1]) (1911). NICHOLSON tried to explain the coronium lines as emission lines of the hypothetical elements "proto-fluorine" and "coronium", atomconfigurations with nuclei having a charge of 5^e and 7^e. PANNEKOEK [2]) (1922) has assumed that the coronal lines may be due to *Ca* III. More recently FREEMAN [3]) (1928) tried to explain the spectrum as emission of neutral argon. MECKE and WILDT [4]) (1930) incline to believe that the lines may be "Raman-lines". ROSENTHAL [5]) (1930) tried to explain the line spectrum as emission of the helium atom in special stages. Scientific criticism however has shown that none of these theories can be hold upright and now 63 years after its discovery "coronium" is still a mystery. Ideas however have been changed the last five years, after BOWEN's famous explanation (1928) of the mysterious "nebulium" [6]). Forbidden lines in the ionised atoms of oxygen and nitrogen have been recognised in the strong nebular lines. This idea also brought forward the explanation of the famous green Auroral line 5577 (MC. LENNAN, 1928) [7]) as due to a forbidden combination in neutral oxygen. An investigation by BOWEN and MENZEL [8]) to explain the coronium lines in the same way did not have success. EDDINGTON [9]) has shown that on account of the great energy of the sun "coronium" cannot find its explanation from atoms in the corona in metastable states. However the present writer assumed that the source of the coronium lines would be found among the elements in the top part of the periodic table by methods similar to those undertaken by BOWEN. After trying to solve the problem with the ionised elements, with negative results, a systematical investigation was made with the neutral elements. The following paragraphs will show that the atom of neutral oxygen is responsible for the main lines of the mysterious "coronium".

3. *The spectrum of neutral oxygen.*

The spectrum of neutral oxygen has been investigated and analysed by several authors namely RUNGE and PASCHEN [10]), HOPFIELD [11]), MC. LENNAN [12]), PASCHEN [13]) but especially by FRERICHS [14]). FRERICHS

[1]) NICHOLSON, M. N. 1911 1916.
[2]) PANNEKOEK, B. A. N. **1**. 127. 1922.
[3]) FREEMAN. Astr. Journ. **68**. 177. 1928.
[4]) MECKE a. WILDT, Zs. f. Phys. **59**. 501. 1930.
[5]) ROSENTHAL, Zs. f. Astr. **1**. 115. 1930.
[6]) BOWEN, Astr. Journ. **67**. 1. 1928.
[7]) Mc. LENNAN, Proc. R. S. London. **120**. 327. 1928.
[8]) BOWEN a. MENZEL, Pub. Astr. Soc. Pac. **40**. 335. 1928.
[9]) EDDINGTON, M. N. R. A. S. **88**. 134. 1927.
[10]) RUNGE a. PASCHEN, Ann. d. Phys. **61**. 641. 1897. Astr. J. **8**. 70. 1898.
[11]) HOPFIELD, Astr. J. **59**. 114. 1924. Phys. Rev. **29**. 923. 1927. **37**. 160. 1931.
[12]) Mc. LENNAN, Proc. R. S. London. **1**. 1927. Phil. Mag. **6**. 558. 1928.
[13]) PASCHEN, Die Naturw. **18**. 752. 1930. Zs. f. Phys. **65**. 1. 1930.
[14]) FRERICHS, Phys. Rev. **34**. 1239. 1929. **36**. 398. 1930. **36**. 1460. 1930.

measured the spectrum with high dispersion (6.5 m. grating) between $\lambda 8800$ and $\lambda 3800$ and in the ultra violet between $\lambda 1200$—700 (1 m. grating). The deepest terms in the spectrum are:

$2p\,^3P_{210}$: 109837, 109679 109610 and the metastabile terms $^1D_2 = 93970$ and $^1S_0 = 76045$. These terms are of special interest because the $^1D_2$—$^1S_0$ combination, the line 5577, has been found to be by Mc. LENNAN the typical green Auroral line. The combinations $^1D_2$—$^3P_2$ 6300 and $^1D_2$—$^3P_1$ 6364 detected by PASCHEN and HOPFIELD in the laboratory are, as the green line 5577, typical lines for the spectra of the Nebulae [1]) and Novae [2]).

Practically all the O 1 lines have been classified by FRERICHS. Still there are a few isolated groups of lines not classified or connected with known O I terms. These groups are:

I.	(4)	6654.121	15024.14	II. (1)	6266.692	15952.98
	(5)	6374.292	15683.64	(2)	6264.346	15958.95
	(4)	6366.282	15703.42	(5)	6261.314	15966.68
				(1)	6258.965	15972.67
				(3)	6256.616	15978.67

III.	(3)	5995.198	16675.43
	(1)	5993.102	16681.24
	(2)	5991.852	16684.72
	(1)	5991.255	16686.39

and in the far ultra violet:

IV. A group of 5 lines around 756 A.
V. The triplet: (0) 770.70 (1) 770.28 (2) 769.39.
VI. A doublet at 756 A.
IV. A group of 5 lines around 792 A.

The groups III and V can be interpreted as combinations of a new high term $5s\,^3D_{321}$ —20135.3; —20141.1; —20142.8 with the known terms $3p\,^3P_{2\,10}$ —3459.8; —3456.4 and the ground triplet. The assignment of inner quantumnumbers in the $^3P_{2\,10}$ needs further investigation. The groups IV, VI and VII are combinations with new high terms —16506; —22473; —23780 and the ground triplet. At present it seems however not possible to check these new high terms. Only the groups I and II need further interpretation and just these groups are connected with radiation in the solar corona.

4. *Coronal lines connected with new deep terms in O I.*

Far the most interesting groups of lines in the neutral oxygen are the groups of lines I and II. These lines can be written in the following multiplet. It should be noticed that the termvalues of the new deep terms

[1]) PASCHEN, Zs. f. Phys. **65**. 1. 1930. BOWEN, Phys. Rev. **36**. 600. 1930. GROTRIAN, Zs. f. Phys. **60**. 302. 1930.

[2]) GROTRIAN, Zs. f. Astr. **2**. 78. 1931.

P, Q, R, X, Y, Z are fixed by assuming that the remaining line of the group 6654.121; 15024.14 is a combination with the known deep metastabile level $^1D_2$.

Without speculation it seems at present not possible to determine the nature of the new terms *P, Q, R, X, Y, Z*. We do hope that the Zeeman-effect of the line 6374 will give us the answer. Plans are projected in this laboratory for an investigation in this direction.

Combinations between the levels *XYZ* and the ground triplet ^3P would give lines under λ 3300. In this region the observation data of the coronal spectrum is very poor. Only exist measurements by DESLANDRES 1893

NEW MULTIPLET IN 0 I.

		R	Q	P	$^1D_2$
		94898	94905	94925	93970
X	79221	—	5. 6374.292 15683.64	4. 6366.282 15703.42	—
Y	78946	1. 6266.692 15952.98	2. 6264.346 15958.965	3. 6256.616 15978.67	4. 6654.121 15024.14
Z	78932	5. 6261.314 15966.68	1. 6258.95 15972.67	—	—

(Annales du Bureau des Longitudes t. V) λλ 3164; 3170; 3237 and by LEWIS (1908) λ 3288. It should be noticed that the combination $^3P_2$—*Y* gives 3236.3 and $^3P_3$—*X* 3289.7.

Now it is possible from the new terms *P, Q, R* and the known deep terms: $^3P_2 = 109837$ $^1D_2 = 93970$ $^1S_0 = 76045$
$^3P_1 = 109679$
$^3P_0 = 109610$
to deduce the characteristic lines of the solor corona in the red and the famous green "coronium" line 5303.

Int.	Corona		Laboratory		Termcombination
	λ obs.	ν obs.	ν calc.	λ calc.	
8	6776	14754	14754	6776	2p $^3P_1$ — P
4	6704	14912	14912	6704	2p $^3P_2$ — P
15	6374	15684	15684	6374	Q —X
20	5303	18852	18853	5302.7	R — S

5. *Calculation of coronal lines from laboratory data.*

At present no high precision can be claimed for the coronal wavelengths. Several reasons have influence on the data as: diffuse nature of the lines, instruments with small dispersion, spectrograms on films, slitless photographs, incertainty in applying the DOPPLER correction, because at the present time we know nothing regarding the rotation of the corona.

But also some of the wavelengths of neutral oxygen necessary for the calculation of coronal lines need higher precision especially the red Nebulae lines 6300 and 6364. However we will see which values of the coronal lines can be deduced from all the laboratory data at present available.

Coronal line 6776.

This line can be determined from the following lines of neutral oxygen.

1	6363.88	15709.35	HOPFIELD
3	6364.07	15708.88	PASCHEN
4	6654.121	15024.14	FRERICHS
3	6256.616	15978.67	FRERICHS
4u	6256.60	15978.71	PASCHEN.

From these data and the termscheme (see figure) a simple calculation gives as minimum and maximum values 6775.58 and 6775.82, with a mean of *6775.70*. There are only *two* determinations of this new detected red line. MITCHELL finds a mean of 6775.90 No DOPPLER-correction has been applied. The calculated value 5775.70 agrees certainly with the observation because MITCHELL remarks: "The last digit means nothing, and that in tenths of angstroms means little. We shall therefore assume the wavelength to be 6776."

Coronal line 6704.

For the calculation of this coronal line we have the following neutral oxygen lines.

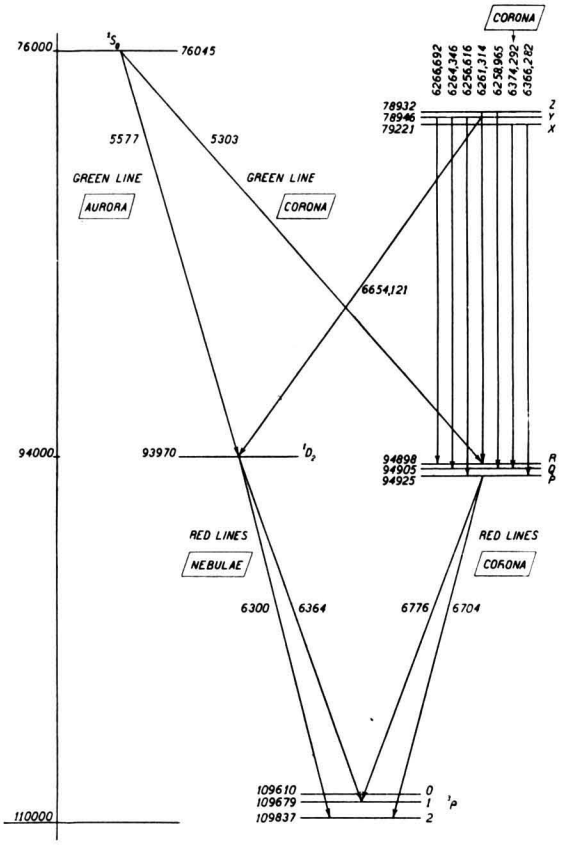
4	6300.23	15868.05	HOPFIELD
5	6300.03	15868.56	PASCHEN
4	6654.121	15024.14	FRERICHS
3	6256.616	15978.67	FRERICHS
4u	6256.60	15978.71	PASCHEN

Calculation from these wavelengths gives as minimum and maximum values 6703.25 and 6703.50 with the mean of *6703.37*. For this coronal line two determinations are available. GROTRIAN who discovered this line gives 6704 ± 2. After the detection of this line DAVIDSON and STRATTON measured the line on old plates of the 14 Jan. 1926 eclips (Observatory 53.211.1930) and give the value 6703.36. Both determinations agree with the calculated value.

Coronal line 6374.

This is the only line observed in the laboratory. FRERICHS gives the value

6374.292, PASCHEN's value is 6374.83. The last value however can not have high precision. MITCHELL measured this line in the coronal spectrum and



DEEP ENERGY LEVELS IN NEUTRAL OXYGEN, OI.

finds as a weighted mean from 6 determinations on 6 films running between 6374.09 and 6374.51 a mean of 6374.28. Also this value agrees with the data from the laboratory.

Coronal line 5303.

In the calculation of this coronal line is involved the famous green Aurora line 5577. High precision measurements are for this line available.

5577.350	17924.70	BABCOCK [1])
5577.341	17924.73	MC. LENNAN [2])
5577.348	17924.70	CARIO [3])

[1]) BABCOCK, Astr. J. **57**. 209. 1923.
[2]) Mc. LENNAN Mc. LEOD, Proc. R. S. **London**, 115. 515. 1927.
[3]) CARIO, Zs. f. Phys. **42**. 15. 1927.

Coronal line	Author	Eclips	Apparatus	Comparison	Wavelength	References	Remarks	Wavelength from laboratory data
6776	MITCHELL	Oct. 1930 Niuafoou	4 inch grating : 6 „ grating 1e order. Dispersion : ± 10.9 A/m.m. slitless.	Chromospheric lines	6775.90	Astr. J. **75**. 1. 1932	2 determinations on 2 films : 6775.80 and 6776.00	6775,58 – 6775,82
6704	GROTRIAN	May 9, 1930 Takengon	*a*). 3 prisms. Dispersion : 6700—4400 150—16.4 A/m.m. *b*). 3 prisms. Dispersion : (6000)—3900 120—12 A/m.m.	Prominence lines and atmospheric lines	6704 ± 2	Zs. f. Astr. 2. 106. 1931	6704 by extrapolation of HARTMANN formel	6703.25—6703.50
	DAVIDSON and STRATTON	Jan. 14, 1926 Benkoelen			6703.36	Obs. 53. 211. 1930.	The line has been measured after the discovering by GROTRIAN	
6374	CARRASCO	Aug. 21. 1914 Theodosia	Plane grating 7 c. M. 15000 lines per 5 c.M.	Only the reference lines $H\alpha$ D_3 and H_β	6373.87 ± 0.036	C. R. Paris. **159**. 741. 1914		6374.292 (FRERICHS) 6374.24 (HOPFIELD) 6374,83 (PASCHEN)
	BOSLER and BLOCK	Aug. 21. 1914 Strömsund	3 prisms. Dispersion : 6560—5180. Length = 6.4 c.M.	Diffuse light of the sky	6374.5 ± 0.2	C. R. Paris. **159**. 768. 1914		
	MITCHELL	See above	See above	See above	6374.28	Astr. J. 75. 1. 1932	6 determinations on 6 films. Values run between : 6374.09—6374.51	
	DAVIDSON and STRATTON	Jan. 14. 1926 Benkoelen	2 prisms ; 60° ; $4^1/_2$ inches base ; slit.	Prominence lines	6374.8 ± 0.2	Mem. R.A.S. Vol. LXIV. part. IV. p. 105. 1927		
	LYOT	Without eclips 1931	1 prism ; dispersion 11 A/mm.	?	6374.75 ± 0.15	C. R. 5. **443**. 1932	width of the line ± 1.3 A.	
5303	CAMPBELL and MOORE	June 8. 1918 Goldendale	3 prisms ; slit. Dispersion : 28.4 A/mm.	Iron arc	5302.78	Lick Obs. Bull. x. 318. p. 13. 1918.	Correction for solar rotation —0.035	5302.56—5302.70
	DAVIDSON and STRATTON	Jan. 14. 1926 Benkoelen	See above	Prominence lines	5302.8 ± 0.2	Mem. R.A.S. Vol. LXIV. part. IV. p. 105. 1927		
	MITCHELL	Oct. 1930 Niuafoou	See above	See above	5302.91	Astr. J. 75. I. 1932	8 determinations on 8 films. Values run between : 5302.63—5303.04	
	LYOT	Without eclips 1931	Conc. grating 14.5 c.M. Dispersion : 1.2 A/mm.	?	5302.85 ± 0.03	C. R. 5. **443**. 1932	Width of the line 1.3 A.	

For the calculation of the green coronal line we need further the following oxygen lines:

4	6654.121	15024.14	FRERICHS
1	6266.692	15952.98	FRERICHS
5	6266.85	15952.58	PASCHEN

Minimum and maximum values derived from these data give 5302.56 and 5302.70 with a mean of 5302.63.

For this line more measurements in the corona spectrum are present but even for this line no very high precision can be claimed. Some authors apply an estimated value for DOPPLER shift other do not.

ADAMS, ST. JOHN and WARE [1]) give 5303.06. CAMPBELL and MOORE [2]) give 5302.78. DAVIDSON and STRATTON [3]) give 5302.80 $\pm$ 0.2. SLIPHER [4]) gives 5302.8. The new determinations of the 1930 eclips run between 5302.63 and 5302.98.

It is a pitty that several authors do not give their probable error. The older determinations before 1918 give mostly 5303 as a round value. However sometimes a much lower value 5302.4 (NAEGAMWALA 1898) has been found. It seems to have no meaning to take a mean of all the known values because the dispersion and resolving power of the several instruments are quite different and also the circumstances. One gets the impression that the determination of this green line has a tendency to lower value as already CAMPBELL and MOORE notice: "Our wavelength of the green line (5302.78) places it farther to the violet than we had expected." The agreement between the value calculated from oxygen lines and the observed values can be said to be sufficient. It is hoped that in the future new and still better data can be obtained from the coronal spectrum.

Further it should be noticed that in all the calculations the oxygen line 6654.121 comes in, only determined by FRERICHS. An error in this wavelength determination is involved in all the calculated coronal lines. At present nobody has succeeded to produce the green coronal line in the laboratory. If so it could give us another check [5]).

Recently LYOT { C. R. PARIS **191**, 1930. p. 834 / C. R. PARIS N^0. 5. Feb. 1932 } succeeded to photograph the green coronal line 5303 and the red line 6374 without an eclips. He used very large dispersion. LYOT found that the width of the coronal lines is of the order of 1.3 A. His determinations and those of other authors are given in the following table.

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[1]) ADAMS, ST. JOHN, Miss WARE, Publ. Astr. Soc. Pac. **30**. 251. 1918.

[2]) CAMPBELL a. MOORE, Lick. Obs. Bull. N^0. 318, p. 13. 1918.

[3]) DAVIDSON a. STRATTON, Mem. R. A. S. p. 143. 1927.

[4]) SLIPHER,

[5]) It should be noticed that the older measurements are given in Rowland scale. For reducing to international scale one have to abstract 0,18 A:

6. *Unidentified coronal lines in the violet.*

Although the three red lines and the green coronal line now are identified as having their origin in neutral oxygen, in the violet part of the coronal spectrum are still several unidentified lines. It seems quite possible that some of these lines are due to neutral nitrogen. Some indications point in that direction. If so it turns out that the mysterious "coronium" recognized over half a century is identical with the most important gases of our own atmosphere although the conditions in the suns atmosphere are certainly quite different.

Finally the writer is particularly indebted to Professor P. ZEEMAN who took the greatest interest in the progress of the work.

University of Amsterdam, Laboratory "Physica".

March 22, 1932.

Physics. — *On a method of correcting for incomplete thermal isolation in measurements of small heat capacities.* By W. H. KEESOM and J. A. KOK. (Communication N°. 219c from the Kamerlingh Onnes Laboratory at Leiden.)

(Communicated at the meeting of April 2, 1932.)

§ 1. *Introduction.* In measuring heat capacities at the lowest liquid helium temperatures after NERNST and EUCKEN's method it is sometimes difficult to obtain a thermal isolation of the calorimeter block that is sufficiently high so as to determine the correction for the heat exchange with the surroundings after the simple methods used till now.

As a matter of fact, we only lately succeeded in obtaining regularly at temperatures below 2° K such a high vacuum in exhausting the helium gas admitted in the process of cooling the block.

In previous experiments in this laboratory this was not always possible.

The consequence of this, owing to the extremely small heat capacities [1]) that occur at these temperatures, was that the time-rate of the temperature after the heating was rather large and that the temperature increase caused by the heating vanished in a few minutes, if not seconds.

To be able to perform measurements also in this case, we worked out an accurate method for correcting for the heat exchange during the measurement.

§ 2. *The heat exchange law at extremely low temperatures and high vacua.*

a. Application of the method just-mentioned being only allowed if the

[1]) So the measuring core used in experiments on the specific heats of tin and zinc (Comm. Leiden, No. 219a, These Proceedings **35**, 143, 1932) had a heat capacity at 1.76° K of 0.00084 cal/°K.