

pumps and the holes *c* and *d* are Tombac tubings provided with brass end pieces. The coupling between the Tombac tubing and the plate A is done in the same way as that of the electrodes and the vacuum-tight contact is obtained by rubber washers. On the pump side the Tombac tube is connected by carefully ground brass cones. With such arrangement the pumps are very quick acting and even with one pump a vacuum of 10^{-4} mms is reached within a short time after starting the pump.

The brass piece of one of the Tombac tubings is bigger in length and has a hole through which passes an ebonite block E (fig. 3) which can carry all the electrical connections inside the furnace.

The water-cooled sliding drum C contains a side-tube through which the inside of the furnace can be inspected.

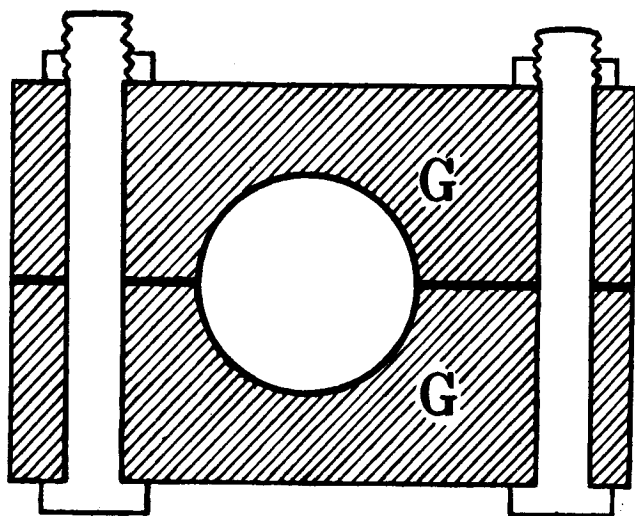


Fig. 4

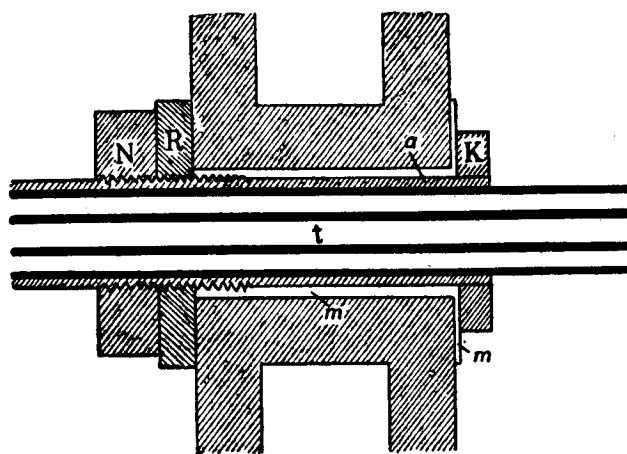


Fig. 5

This also enables the temperature of the furnace to be measured from outside by means of a disappearing-filament type of pyrometer. A thermo-couple can be inserted through this hole whenever required.

The movable plate B has a single hole through which a discharge tube can be inserted for giving an indication of the degree of vacuum.

The electrodes are connected by thick copper leads to a low-tension transformer (capacity 12 K. W.). A current of the order of 1000 amperes is allowed to flow through the graphite tube to raise it to a high temperature. The transformer has got four other ranges for giving less temperature.

We wish to express our sincere indebtedness to the Royal Society of London for giving us a grant of £150 which has enabled us to construct the furnace and to buy its accessories. Our thanks are also due to Messrs Allahabad Foundry for the casting of the plates and the water-cooled drum.

64. A STRATOSPHERE SOLAR OBSERVATORY

(*Harvard College Observatory Bulletin*, 905, 1937)

It is well known that our observations on the spectra of the Sun and the stars are limited to the redward side of $\lambda 2900$, the ultraviolet part being absorbed in the upper atmosphere, at a height of between twenty and fifty kilometers, by a layer of ozone (equivalent to 3 mm. of gas at N.T.P.) now known to arise from the photochemical action of the ultraviolet rays of the Sun on oxygen molecules. This amount of ozone, tiny as it is, is sufficient however to cut off the spectrum between $\lambda \lambda 2900$ and 2200 almost completely, though absorption begins to be perceptible from $\lambda 3200$. Below $\lambda 2060$, the extinction of the spectrum

is due to absorption by molecular oxygen and nitrogen. According to some investigators, there is a so-called window between $\lambda \lambda 2300$ and 2100, but evidence on this point is divergent.

The abrupt termination of solar and stellar spectra below $\lambda 2900$ has been a great handicap to the advancement of our knowledge of the heavenly bodies, because the information gained from study of the spectrum beyond $\lambda 2900$ is not sufficient to explain the problems of stellar mechanisms operative there. To take one example: the great intensity of the Balmer series and the associated

continuous spectrum in the chromosphere has given rise to a large number of speculative theories which have again and again been obliged to fall back upon certain plausible hypotheses regarding the strength of the Lyman lines. If these lines could have been observed, the problem of hydrogen excitation in the Sun and stars would probably have received complete elucidation, and the problems of stellar atmospheres would have been nearer solution.

It is therefore not surprising that when some years ago Cario (*Nature*, **122**, 810, 1928) made the suggestion that the North Polar region, being free from illumination by the Sun during the winter, might not contain any ozone, and therefore observations carried out there might extend stellar spectra much further on the violet side of $\lambda 2900$, the suggestion was greatly welcomed. It was a disappointment for the astronomical world when observations by Rosseland (*Nature*, **123**, 207, 761, 1929) did not confirm Cario's hypothesis. The reason for this failure is now well understood, for Dobson and Götz [*Proc. Roy. Soc., Ser. A*, **122** (1929) and **129** (1930)], in their survey of the ozone content of the atmosphere at different latitudes, have shown that the amount of ozone in the atmosphere fluctuates with the season, rising at Abisko (latitude 68°N) from 40 mm in the middle of September to 3.6 mm in the middle of March. There is thus actually an increase in the ozone content during winter. This fact, apparently at variance with the theory of the photochemical origin of O_3 , has been satisfactorily explained by S. Chapman (*Mem. Roy. Met. Soc.*, **3**, No. 26, 1930). The explanation is roughly as follows: The solar rays not only form ozone, but also destroy ozone. Every quantum of light between $\lambda 1750$ and 2060 produces, on being absorbed, two molecules of O_3 out of atmospheric oxygen. But this ozone absorbs strongly the light between $\lambda 2300$ and 3000 , and every quantum absorbed converts two O_3 molecules into three O_2 molecules after a number of subsidiary reactions. The actual number of ozone molecules existing at any time depends upon the equilibrium between these two groups of opposing reactions. It appears that during a polar winter, when sunlight no longer illuminates the upper atmosphere, the ozone molecules already formed continue to exist, the destructive agency having been withdrawn. One always incurs a risk in extrapolating, but, as far as evidence goes, it appears certain that during winter the atmosphere of regions a few degrees removed from the North Pole also retains its ozone screen, so that observations of stellar spectra (the Sun does not come into view, as it is below the horizon) will have no chance of taking us beyond the limit attainable in more hospitable climates.

Regener's Work.—The recent discovery by Götz, Meetham, and Dobson (*Proc. Roy. Soc., A* **145**, 416, 1934) that the ozone screen does not lie between fifty and one hundred kilometers as was formerly thought, but is confined between twenty and forty kilometers, affords a

definite opportunity of extending stellar spectra beyond $\lambda 2900$, as has actually been demonstrated by E. and V. Regener (*Phys. Zeits.*, **35**, 788, 1935). Professor Regener has developed a fine technique of sending into the upper atmosphere balloons carrying automatic recording apparatus for measurement of the intensity of cosmic rays. His highest record has been thirty-one kilometers where, according to the estimates of Dobson and Götz and confirmed independently by the Regeners, two-thirds of the total ozone remains below. In the course of his last reported work in 1934, he sent along with his cosmic ray apparatus a quartz-spectrograph provided with automatic shutters and pointed toward a matt surface below, which was illuminated by sunlight. The time of exposure was short, and the reflecting power of the matt surface for the ultraviolet rather feeble. In spite of these disadvantages they were able to show that with increasing altitude the spectrum extended further into the ultraviolet, and that at the greatest height reached by their apparatus the limit was extended by about a hundred units beyond the limit reached by the same apparatus for the same exposure on the ground. If the exposures had been longer, and the surface had had a better reflecting power for $\lambda 2800$, it is clear that the spectrum might have extended much further than the lowest limit attained so far. They also confirmed the finding of Dobson and Götz that most of the ozone is to be found between twenty and thirty-five kilometers, that above forty kilometers the total amount is one-twelfth of the whole, and that above fifty kilometers it is barely two per cent of the whole.

The pioneering work of Regener has shown the practical possibility of having a "Stratosphere Solar Observatory". It can now be confidently expected that if a regular program can be organized for sending balloons to a height of thirty-five to forty kilometers, provided with quartz, fluorite, and vacuum spectrographs of sufficient light-gathering power, our knowledge of the solar spectrum beyond $\lambda 2900$ will receive a great impetus. The Russian worker Moltchanoff claims that he has reached a height of forty kilometers with a balloon provided with Radio-Sonde signalling apparatus; it is therefore to be hoped that within the near future the problem of photographing the solar spectrum at a height of forty kilometers will be definitely solved.

Let us consider in some detail the practical possibility of such a program, and the extension of the solar spectrum that can be expected. The absorption coefficient of ozone (Ladenberg, *Journ. Opt. Soc. Am.*, **25**, No. 9, 1935) can be expressed by Beer's Law

$$D = \frac{I}{I_0} = e^{-a'l} = 10^{-a'l}.$$

The values of a' are given in the accompanying table

taken from Ladenberg's paper (*op. cit.*), together with the computed values of a .

	$\lambda=2300$	2400	2500	2600	2700	2800	2900
a'	50	95	120	120	100	48	15.5
a	115	219	278	278	230	111	35.8

The path length of ozone at (N.T.P.) necessary to reduce the rays to one-half of their original intensity, say for $\lambda\lambda 2500-2600$, is found from the relation

$$D = \frac{1}{2} = e^{-278l},$$

$$\text{or } l = \frac{\log_e 2}{278} = 2.4 \times 10^{-3} \text{ cm.}$$

A glance at the figures given by Götz and Dobson shows that at Arosa the amounts of ozone lying above the observer at different heights are (according to method B; total amount = 0.300 cm):

Height in km	4.9	13.1	20.6	28.1	35.9	45.1
Ozone in cm	0.263	0.186	0.1279	0.0389	0.0045	0

Thus at 36 km, the rays $\lambda\lambda 2500-2600$ will be reduced in intensity to about one quarter, while the rays on either side will be less absorbed. At a height of forty kilometers, recently announced to have been reached by a Soviet balloon carrying Radio-Sonde apparatus, the solar spectrum should be transmitted in practically undiminished intensity over most of the range from $\lambda\lambda 2900$ to 2300.

How Much Can Be Observed of Wave-lengths below $\lambda 2300$?—We may now discuss the question of absorption due to other constituents of the atmosphere. At these heights only O_2 and N_2 need be considered.

1. OXYGEN. It has been shown elsewhere (M. N. Saha, On the Action of Ultraviolet Solar Rays on the Upper Atmosphere, communicated to the Proc. Roy. Soc. London) that on certain plausible assumptions it is possible for us to calculate the amount of O_2 gas lying above two kilometers, in terms of a column at N.T.P. (1 cm at N.T.P. = 2.79×10^{19} molecules). The figures are quoted below:

Height in km	30	40	50	60	100
O_2 in cm	1200	200	7	0.60	0.044

Now from laboratory experiments we know that oxygen shows the following absorptions:

(a) A feeble set of bands at $\lambda\lambda 2429-2595$, which probably correspond to the dissociation of O_2 into O^3P , O^3P (Herzberg). This absorption is very feeble. Even a twenty five meter column of O_2 gas at N.T.P. shows hardly any absorption. Hence the superincumbent layer of O_2 above 30 km will transmit all rays between $\lambda\lambda 2400$ and 2900.

(b) The Runge-Schumann absorption bands. These bands extend from $\lambda\lambda 2060$ to 1700 and produce the following photochemical effect:



Hence it is certain that a solar spectrum taken at a height of 36 km will not show the region between $\lambda\lambda 1750$ and 1300.

At $\lambda 1750$ the band absorption passes into continuous absorption, extending to $\lambda 1250$ and giving rise to the photochemical dissociation of oxygen into a normal and an excited atom as follows:



Both these reactions, particularly (A), give rise to ozone. It has been shown elsewhere that the rays $\lambda\lambda 2060-1750$ are absorbed in the ozone layer between 35 and 20 km and give rise to ozone. Hence when we are making observations above 35 km, the region $\lambda\lambda 2060-1750$ is expected to come out strongly on the plates. This in itself will give us information about our atmosphere which is bound to be of great importance to meteorologists.

The continuous absorption at $\lambda\lambda 1750-1250$ is much stronger and rises to a maximum at $\lambda 1460$. At this wave-length, 1/500 cm of O_2 at N.T.P. according to Ladenburg reduces the light to half its intensity. As shown above, the absorption will be completed between 100 km and 200 km; this is in accordance with the Cabannes' observation (see report on the luminous night sky by Dejardin, Rev. Modern Phys., Jan. 1936) that the red auroral lines $O^3P-O^1D_2$, $\lambda\lambda 6363$ and 6300, originate from above a height of 200 km.

(c) Oxygen is found to have rather feeble absorption between $\lambda\lambda 1250-1100$. In fact, Lyman showed that these wave-lengths can easily pass through three to four centimeters of O_2 and N_2 at N.T.P. A glance at the above tabulation shows that at a height of fifty kilometers we can expect transmission of the region $\lambda\lambda 1250-1100$.

2. ABSORPTION BY NITROGEN.—The amounts of nitrogen over different heights are as follows:

Heights in km	20	30	40	50	60	100	200
Amount in meters	386	94.8	20	1.10		(E) 0.11	(F) 1.4×10^{-5}

The absorption by nitrogen has been treated elsewhere, and we can only summarize the results. There is no nitrogen absorption between $\lambda\lambda 2900$ and 1700. Beyond $\lambda 1700$, the Vegard-Kaplan bands are expected to be absorbed, but it is quite possible that on account of heavy absorption by O_2 in the region, these bands may not appear.

The region $\lambda\lambda 1500-1250$ will be blocked by O_2 absorption, as already described. But even if the oxygen absorption were absent, nitrogen would have blocked this region for which it shows strong absorption bands (Birge-Sponet bands).

Transmission below $\lambda 1250$.—On account of paucity of laboratory experiments below $\lambda 1250$ regarding absorption by O_2 and N_2 , we can speak with much less confidence. Price and Collins (Phys. Rev., 48, 780, 1935) obtain certain bands for O_2 between 1250 and 1000 Angstroms, which

they have not so far interpreted, at 1.5 cm of N_2 at N.T.P. It appears, therefore, that at 35 km (oxygen=200 cm), part of the solar spectrum which does not coincide with the O_2 bands may leak through. But the absorption of O_2 below 1000 to 650 is according to these authors very heavy, and nothing can be expected between these limits at 35 km. Below 650 Angstroms no prediction is possible, as laboratory data are not available, but one or two strips of continuous spectrum may be transmitted.

We conclude from the above discussion that a spectro-photogram of the sun, taken at a height of 40 km, will extend the spectrum to $\lambda 2000$, and probably no atmospheric bands will appear between $\lambda \lambda 2900$ and 2000 . Between $\lambda \lambda 2000$ and 1700 the Runge-Schumann bands of O_2 may appear in absorption. The region $\lambda \lambda 1700-1250$ will probably be completely cut off. A strip between $\lambda \lambda 1250$ and 1000 may be expected to be transmitted. Below $\lambda 1000$ no prediction can be made, as laboratory data are not available.

But access even to these limited regions will result in

invaluable additions to our knowledge, for they will afford information about the behavior of the resonance lines of most of the elements which occur in the Fraunhofer spectrum and thus ease our way for the final solution of the mysteries of solar physics; *e.g.*, we expect to get information (a) about $L\alpha$ $\lambda 1216$ of H; (b) about $\lambda 1640$ ($=4 R (\frac{1}{2^2} - \frac{1}{3^2})$), $\lambda 1215$ ($=4 R (\frac{1}{2^2} - \frac{1}{4^2})$) of He^+ ; (c) about the existence or otherwise of the Li-continuum at about $\lambda 2300$; (d) about the resonance lines of elements from Be to O (4 \rightarrow 8); we shall not probably obtain any information about F and Ne, but we may obtain the Na-continuum. (e) As regards Mg, we shall obtain much desired information about the resonance lines of Mg and Mg^+ which are just beyond $\lambda 2900$; (f) the same is true of the resonance lines of the elements Al to S. (g) We hope also to obtain very valuable information regarding transitional elements, particularly Fe^+ .

The above short account will indicate how much we should gain from a "Stratosphere Observatory".

65. EXPERIMENTAL DETERMINATION OF THE ELECTRON AFFINITY OF CHLORINE

M. N. SAHA AND A. N. TANDON

(*Proc. Nat. Inst. Sci. Ind.*, **3**, 287, 1937)

(*Read January 5, 1937*)

It is well known that halogens have an affinity for electrons and many methods have been proposed for calculating this quantity. Let us take a halide atom X . The affinity E is given by the relation:—

$$X + e = X^- + E.$$

E can be expressed in calories, volts or wave-length units. The following table gives the values in Kilo calories obtained by different workers:—

	F	Cl	Br	I
Mayer and Helmholtz ¹ (Theoretical)	95.3	86.5	81.5	74.2
J. E. Mayer ² (Experimental)	72.6 \pm 2
P. P. Sutton and J. E. Mayer ³ (Experimental)	72.4 \pm 1.5
Angerer and Müller ⁴ (Spectroscopic)	94	86.6 } 89.6 }	79.1 } 81.3 }	71.3
E. Lederle ⁵ (Spectroscopic)	95 \pm 2	90	82	73
Saha and Sharma ³ (Theoretical)	163.3			

There are several methods for calculating the electron affinity of the halogens. Theoretical calculations have been

made by E. Mayer and L. Helmholtz¹ from the crystal energies of the alkali halides. They used the formula for the grating energy of these salts derived by Max Born and E. Mayer². Saha and Sharma³ used an extrapolation method for calculating the electron affinities. They showed that the value of the ionisation potentials of Ne-like atoms Ne, Na^+ , Mg^{++} is given by the formula:—

$$E = (\mathcal{Z} - 6.745)^2 + 1.917 - \frac{42.8}{(\mathcal{Z} - 6.745)} + \frac{70.165}{(\mathcal{Z} - 6.745)^2}$$

If now \mathcal{Z} is put equal to 9, we get the electron affinity for fluorine. The value so obtained is 7.1 volts; though this value is high and is rather in violent disagreement with values calculated by other workers, it is in agreement with the value calculated by Mulliken.

On the experimental side, this subject has not been much investigated and the few data that are available have been obtained indirectly from spectroscopic methods. Only in a few cases direct experimental determination has been made. An attempt was made by Angerer and Müller⁴ to calculate the electron affinity from spectroscopic