DIFFUSIVE SEPARATION IN THE UPPER ATMOSPHERE

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(Received May 1, 1967)

Density and temperature measurements with magnetic mass spectrometer taken at two Aerobee flights have been analysed and interpreted using the equation for diffusive equilibrium. It is found that O(16) is in diffusive equilibrium starting from 130 km, whereas N_2(28) and O_2(32) from 110–115 km. The temperature measurements compare with the theoretical values very nicely within 1%.

Introduction

Neutral gas constituent measurements have been made on two Aerobee flights with magnetic mass spectrometers. Detailed data analysis has been given by Hedin *et al.*[1] for density and temperature measurements. The above analysis showed a more rapid decrease in densities of the heavier constituents with altitude, which is in qualitative agreement with expectations if the particles are in diffusive equilibrium.

However, there had been no attempt to see whether the individual constituents are in diffusive equilibrium at sufficient altitudes. In this paper the author has shown that N_2 is in diffusive equilibrium at 115 km while O_2 at 110 km and O at 130 km.

Technique and Discussion

Neutral density n is related to the density scale height H_n as

$$n = n_O e - Z/H_n \qquad (1)$$

when n_O refers at $Z = 0$,
Z, being the altitude. Hn is related to scale height H, as

$$H = H_n\,(1+\beta) = \frac{KT}{mig} \qquad (2)$$

where $\beta = dH/dZ$ is scale height gradient. Taking the experimental value of n for N_2, H is calculated from (1) and (2). A mean value of H is found at 160 km, from the fact that it gives the best agreement with the values found by Hedin *et al.*[1] Corresponding value of β is taken as a mean constant value. A mean value of "g" is taken from 110–205 km.

For an atmosphere in diffusive equilibrium with constant scale height gradient, n and H are related as $-(1+\beta)/\beta$

$$\frac{n}{n_O} = \left(\frac{H}{H_O}\right) \qquad (3)$$

where n_O and H_O refer to 160 km.

H can also be defined as

$$H = \beta(Z - Z_O) + H_O \qquad (4)$$

Knowing H_O, $(Z-Z_O)$ and β, we can find H corresponding to any altitude, and hence n.

Using H_O for N_2(28) H_O is calculated from (2) for O_2(32) and O(16). Figure 1 gives us the density variations with altitude for N_2, O_2 from both the flights.

The agreement between the theoretical and experimental curves is very good (Fig. 1), though

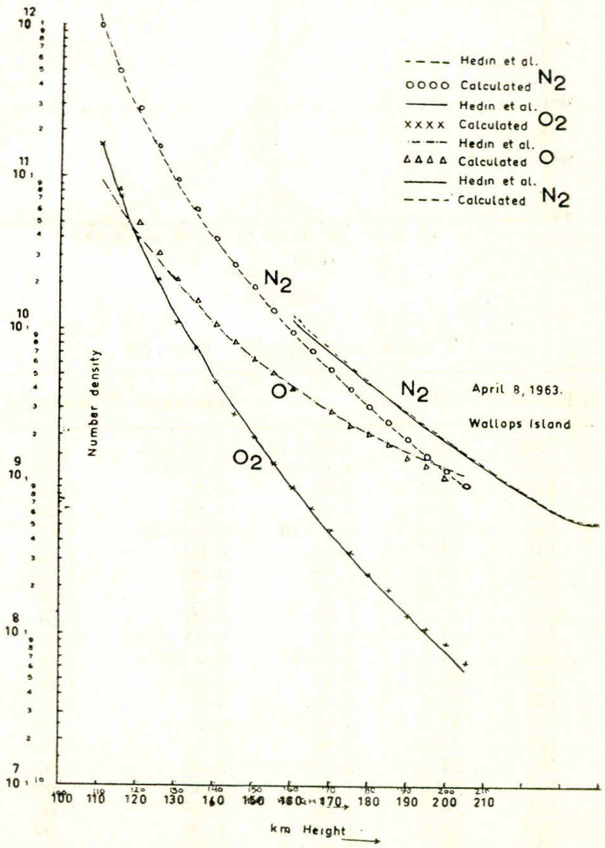

Fig. 1

Hedin *et al.*[1] have shown an error of 5% in density measurements.

Figure 2 is a plot between the ratio of observed n and calculated n against height. All the constituents are in diffusive equilibrium between

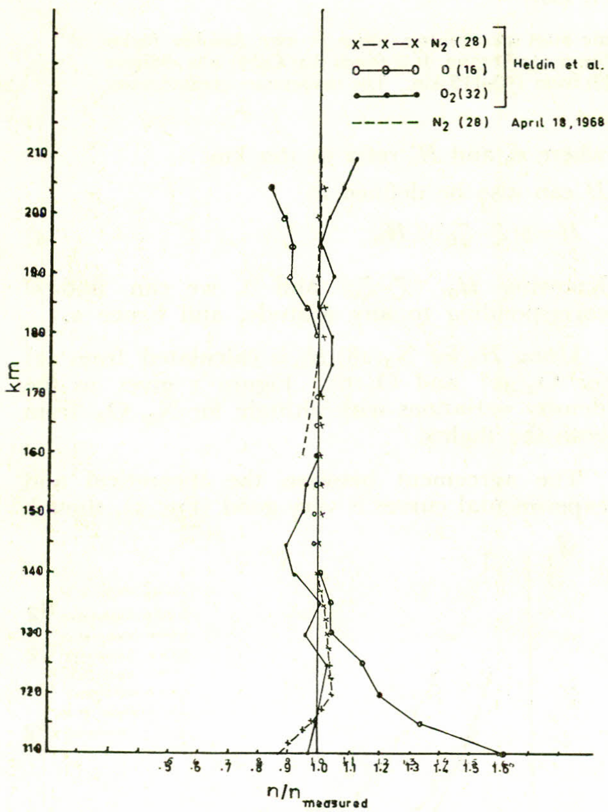

Fig. 2

TABLE 1.—$N_2(28)$ $\beta = .22$

Altitude	H	n	$n_{measured}$	$n/n_{measured}$
110	8.2	1.09+12	1.25+12	.87
115	9.3	5.39+11	5.5+11	.98
120	10.4	2.96	2.8	1.05
125	11.5	1.62	1.55	1.04
130	12.6	9.8+10	9.50+10	1.03
135	13.7	6.13	6.00	1.02
140	14.8	4.03	4.00	1.00
145	15.9	2.71	2.70	1.00
150	17.0	1.93	1.90	1.01
155	18.1	1.37	1.35	1.01
160	19.2	9.9+9	9.9+9	1.00
165	20.3	7.32	7.30	1.00
170	21.4	5.59	5.5	1.01
175	22.5	4.05	4.1	.98
180	23.6	3.16	3.1	1.01
185	24.7	2.47	2.40	1.02
190	25.8	1.88	1.90	.99
195	26.9	1.48	1.45	1.02
200	28.0	1.18	1.20	.99
205	29.1	9.00+8	9.70+8	1.01

TABLE 2.—O(16) $\beta = .46$

Altitude	H	n	$n_{measured}$	$n/n_{measured}$
110	10.6	1.71+11	1.05+11	1.62
115	12.9	8.7+10	6.40+10	1.35
120	15.2	5.1	4.20	1.21
125	17.5	3.27	2.80	1.16
130	19.8	2.16	2.05	1.05
135	22.1	1.53	1.48	1.05
140	24.4	1.11	1.10	1.01
145	26.7	8.35+9	8.40+9	.99
150	29.0	6.51	6.60	.99
155	31.3	5.20	5.20	1.00
160	33.6	4.20	4.20	1.00
165	35.9	3.40	3.40	1.00
170	38.2	2.90	2.85	1.00
175	40.5	2.35	2.40	.98
180	42.8	2.05	2.05	1.00
185	45.1	1.72	1.80	.96
190	47.4	1.43	1.60	.90
195	49.7	1.26	1.38	.91
200	52.0	1.05	1.22	.88
205	54.3	9.24+8	1.10	.84

TABLE 3.—$O_2(32)$ $\beta = .19$

Altitude	H	n	$n_{measured}$	$n/n_{measured}$
110	7.30	1.71+11	1.75+11	.97
115	8.25	7.63+10	7.70+10	.99
120	9.20	4.06	3.80	.85
125	10.15	2.18	2.10	1.03
130	11.10	1.16	1.21	.96
135	12.05	7.56+9	7.50+9	1.01
140	13.00	4.54	4.90	.93
145	13.95	2.78	3.10	.90
150	14.90	1.95	2.05	.95
155	15.85	1.30	1.35	.96
160	16.8	9.00+8	9.00+8	1.00
165	17.75	6.21	6.20	1.00
170	18.70	4.59	4.40	1.04
175	19.65	3.34	3.20	1.04
180	20.60	2.36	2.35	1.00
185	21.55	1.84	1.75	1.05
190	22.50	1.37	1.35	1.01
195	23.45	1.03	1.00	1.03
200	24.40	8.01+7	7.50+7	1.08
205	25.35	6.02	5.50	1.12

TABLE 4.—$N_2(28)$ $\beta = .14$ Wallop's Island. April 18, 1963

Altitude	H	n	$n_{measured}$	$n/n_{measured}$
160	22.2	1.18	1.24+10	.95
170	23.6	7.14+9	7.34+9	.98
180	25.0	4.52	4.52+9	1.00
190	26.4	3.03	2.90	1.04
200	27.8	1.94	1.89	1.02
210	29.2	1.26	1.26	1.00
220	30.6	8.58+8	8.55+8	1.00
230	32.0	5.87	5.91	.99
240	33.4	4.06	4.22	.96
250	34.8	3.16	3.03	1.04
260	36.2	2.17	2.15	1.00

130–200 km (within allowable errors). The maximum discrepancy is in O(16) value with maximum divergence of 10–15% from the diffusive equilibrium. The deviations of O_2 and O from diffusive seperation can be due to the errors involved in: (i) the actual measurements of the constituents, (ii) computational errors due to the technique used, and (iii) uncertainty in laboratory calibration of the mass spectrometer.

Acknowledgement.—The author is grateful to Dr. Z.A. Ansari and Dr. M.S. Ahmad of SUPARCO for their helpful discussions and suggestions in the preparation of this paper. He is also indebted to Dr. I.H. Usmani, Co-Chairman SUPARCO, for permitting the author to publish this paper.

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