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Separation of Primary and Secondary * Particles In Mass Spectrometric Investigations of the Upper Atmosphere

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By: G. M. Martynkevich

We analyze the possibility of using - in a vertical sounding of the upper atmosphere layers two experimental methods for the separation of the primary and secondary particles. The first method uses the dependence of the preset line location of the mass spectrometer on the mass scale upon the normalized velocity in relation to the gas mixture investigated; it permits a complete separation of the primary particles from the secondary ones; the second method makes possible a significant decrease in partial concentrations of secondary and a considerable increase in the partial concentrations of chemically active particles in the ionization area.

* For the definition of "primary and "secondary" particles see articles (4 - 6).

In spite of the existence of a considerable number of articles on the methodology of mass spectrometric measurements in the upper atmosphere, published in the recent past** and of rather successful experiments (21,23) conducted with the same aim, a series of important methodological difficulties in the quantitative analysis have not been completely overcome. This reason explains the continuous interest in the considered problem.

The basic difficulty is in the correct accounting for the background - in a broad interpretation - as well as the selection of the arrangement on the carrier and of the geometry of the mass spectrometer, which would assure the optimal value of the gas-dynamics constant τ_{preset} and the effective "pumping out" of its analyzer without the aid of a pump. The separation of the primary and secondary particles would permit to overcome, to a large extent, this basic difficulty.

We shall consider two cases:

a) a complete separation of primary and secondary particles;

b) a partial separation of the same particles.

** See, for instance, articles (2 - 7,9-11,13,19,20,21,23) and others.

We shall consider full separation methods as being those methods which assure the obtaining, by one mass-spectrometer of a full resolution in the mass spectra of separated primary and secondary particles. The methods of partial separation are those methods which make possible a considerable decrease in the concentration of secondary particles in the ionization area of the mass-analyzer used.

The possibility of using normalized velocity of the mass spectrometer motion also for the attainment of a full separation was first reported by Nier (20). His idea was later developed in great detail by Istomin (7), who proved its applicability to the radio-frequency mass spectrometer of the Benneth type (15) and to the Sputnik velocities (about 8.10^5cm/sec); the basis of the full separation method does not therefore require additional explanations. We should like, however, to emphasize that a radio-frequency mass spectrometer (RMC) is not the only analyzer which brings about in principle, a complete separation. This can be proven directly from the correlations* for the radio-frequency at s = const, f = const and V = V (t)

$$M = \frac{eV}{2s^2f^2}, \qquad (1a)$$

$$\Delta M = \frac{e\Delta V}{2s^2f^2}, \qquad (1b)$$

$$\frac{\Delta M}{M} = \frac{\Delta V}{V}, \qquad (1c)$$

* All formulae - where not specially stated, are recorded according to the absolute unit system of Gauss.

of the simplest time-flight (VMC) at M = const and V = V (t)

(time-mass scale) $$t = D\left(\frac{M}{2eV}\right)^{\frac{1}{2}}, \qquad (2a)$$

$$\Delta t = -D\left(\frac{M}{e}\right)^{\frac{1}{2}} \frac{\Delta V}{(2V)^{\frac{3}{2}}}, \qquad (2b)$$

$$\frac{|\Delta t|}{t} = \frac{\Delta V}{V} \qquad (2c)$$

and of magnetic (MMC) mas spectrometers at r = const, H = const and V = V (t)

$$M = \frac{er^2H^2}{2c^2V}, \qquad (3a)$$

$$\Delta M = -\frac{er^2H^2}{2c^2}\frac{\Delta V}{V^2}, \qquad (3b)$$

$$\frac{|\Delta M|}{M} = \frac{\Delta V}{V}, \qquad (3c)$$

where the shift along the mass ΔM or the time scale Δt is determined by the expression. $$e\Delta V = \frac{Mu^2}{2}. \qquad (4)$$

In the expressions (1) - (4), M is the mass of the given component of the atmosphere, V is the accelerating difference of potentials, H - the magnetic field intensity in the magnet gap, r is the radius of curvature of the chamber of the sector-type mass spectrometer, c is the light velocity, e - the charge of the electron, t - the time, D - is the length of the VMC drift tube, f, is the oscillation frequency, s - the distance between the nets. In this manner, of the five types of analy - zers successfully used in vertical sounding (16, 20 -25) together with the RMC (radio-frequency mass spectrometer) two more spectrometers, namely the VMC and the MMC may be used in the separation of primary and secondary particles.

However, in the process of obtaining vertical cross-sections not every one of these three installations mentioned is equally efficient - due to its characteristics and small velocity values of u, compared to the velocity of the Sputnik. Small u values result in small ΔM values, which sharply augment requirements for the resolution force of the flight mass spectrometers and compels to a more detailed account of ion losses due to heat velocities.

These losses, in a circular diameter tube may be calculated according to the expression received in article (6)

$$\frac{q_x}{q_0} = 1 - \frac{2}{\pi R'} \int_0^x f(x)\, dx, \qquad (5)$$

where q_0 is the primary particles flux (in our case - the ion flux falling on the inlet section (in this case dropping on the inlet section of the mass-analyzer), q_x is the primary particles flux which reaches the section located at an x distance from the inlet section.

$$\chi(\beta) = e^{-\beta^2} + \sqrt{\pi}\,\beta[1 + \Phi(\beta)],\ \beta = \frac{u}{v_\infty},$$

$$v_\infty = \sqrt{\frac{2kT_\infty}{M}},\quad \Phi(\beta) = \frac{2}{\sqrt{\pi}} \int_0^\beta e^{-z^2}\, dz, \qquad (6)$$

$$f(x) = \frac{2}{\pi} \int_0^{\operatorname{arctg}\frac{2R'}{x}} \bar{\gamma}'_M(\vartheta)\left(1 - \frac{x^2 \operatorname{tg}^2\vartheta}{4R'^2}\right)\sin^2\vartheta\, d\vartheta,$$

$$\pi I_1 = \frac{n_\infty v_\infty}{2\sqrt{\pi}}\,\chi(\beta),$$

where I_1 is the radiation intensity of primary particles n_∞, v_∞, T_∞ is, respectively, the partial concentration, the most probable velocity and the temperature in the free atmosphere,

R_o is the tube radius $R' = \frac{4}{3} R_o$ (6).

$$\bar{\tau}'_M(\vartheta) = \frac{\sqrt{\pi}}{2v_\infty}\left\{\frac{2v}{\sqrt{\pi}} e^{-\beta^2}(1+\beta^2\cos^2\vartheta) + u\cos\vartheta\, e^{-\beta^2\sin^2\vartheta} \times \right.$$
$$\left. \times (3+2\beta^2\cos^2\vartheta)[1+\Phi(\beta\cos\vartheta)]\right\}, \qquad (7)$$

v is the most probable velocity of the secondary particle. Considering certain simplifying assumptions the expression (6) will read as follows for the outlet cross-section of an L long tube:

$$\frac{q_L}{q_0} = 1 - 2\nu\frac{L}{\gamma R'}; \quad L < \zeta; \quad \text{any values beta} \qquad (8)$$

$$\frac{q_L}{q_0} = 1 - 2\nu\frac{\zeta}{\gamma R'} - \frac{2\nu}{a}\left[1 - e^{-\frac{a}{\gamma R'}(L-\zeta)}\right]; \quad L > \zeta; \quad \text{any values beta} \qquad (9)$$

or

$$\frac{q_L}{q_0} = 1 - \frac{L}{\sqrt{\pi}\beta R'}; \quad L < \zeta; \quad \beta \gg 1; \qquad (8a)$$

$$\frac{q_L}{q_0} = 1 - \frac{1}{a\beta} - \left(1 - \frac{1}{a}\right)\left[1 - e^{-\frac{L-\zeta}{\left(1-\frac{1}{a}\right)\sqrt{\pi}\beta R'}}\right]; \; L > \zeta; \quad \beta \gg 1, \qquad (9a)$$

where

$$\zeta = \frac{\sqrt{\pi}\beta R'}{a} \approx 0{,}85R'; \quad a = 2{,}0959;$$

$$a = \frac{1}{\frac{1}{2\nu(\beta)} - \frac{1}{a}\left[\nu(\beta) - \frac{1}{2}\right]}; \quad \nu(\beta) = \frac{1}{2}[1+\Phi(\beta)].$$

Table 1

Таблица 1

	1	2	3	4	5	6	7	8	9	10	11
	H, км km	ΔH, км km	$u(H)$, см/сек cm/sec	$eV = \frac{M_{16}u^2}{2}$ эв	$M/\Delta M_{оси}$ axis	$M/\Delta M_{полуув}$ semi-altitude	$\xi_{эфф}$	$\beta_{эфф}$	q_{L_1}/q_0	q_{L_2}/q_0	q_Σ/q_0
1	150	50	$9{,}7 \cdot 10^4$	0,07	1270	635	1,97	1,74	0,94	0,8	0,75
2	200	100	$1{,}36 \cdot 10^5$	0,15	760	380	2,76	2,44	0,94	0,86	0,81
3	250	150	$1{,}65 \cdot 10^5$	0,28	516	258	3,31	2,96	0,94	0,89	0,84
4	300	200	$1{,}89 \cdot 10^5$	0,29	393	197	3,84	3,40	0,94	0,91	0,84
5	350	250	$2{,}1 \cdot 10^5$	0,35	318	159	4,26	3,77	0,94	0,91	0,85
6	400	300	$2{,}29 \cdot 10^5$	0,42	266	133	4,65	4,11	0,94	0,92	0,86
7	450	350	$2{,}47 \cdot 10^5$	0,49	230	115	5,02	4,44	0,94	0,92	0,86
8	500	400	$2{,}63 \cdot 10^5$	0,53	210	105	5,34	4,72	0,94	0,93	0,87

Table 1 presents results of the simplest calculations of the resolution force necessary in the vertical sounding to different altitudes and of heat losses for the RMC type* MX = 6407 (12).

The H in table 1 is calculated from the earth level; $\underline{\Delta}$ H = H - 100 km, as the mass spectrometer start a normal operation beginning at about H $\approx$ 100 km level;

$$u = \sqrt{2g(H)\Delta H},$$

g (h) is the acceleration of a free drop, as a function of the altitude (14);

$$eV = \frac{Mu^2}{2}$$

- is the energy of the ion macroscopic motion, computed for the mass number M = 16 a.e.m. of one of the most interesting components of the upper atmosphere - the atomic oxygen; $\frac{M}{\Delta M}$ in columns 5 and 6 is the resolution capacity at the base and the semi-altitude, respectively, which permits the separation - complete or partial - of the primary ion $^{16}O^+$ from the secondary ion, and, therfore, also the heavier ions of the

* The computations assume: a) R_0 coincides with the operational radius of the net; b) the ions reach the collector with an energy of only $eV = \frac{Mu^2}{2}$.

primary particles, whose lines are not overlappingthe spectrum lines of the secondary particles; the index 300° at 2 and 3 means that these magnitudes are computed for values $T_{\cdot 2.}$ = 300°; L_1 = the section length in the mass-analyzer MX-6407 per median masses ($\frac{M}{\Delta M}$ = 20, 12 cycles, s = 3 mm) from the outlet of the ion source to the first stop net; L_2 is the length of the section from the first stop-net to the ion collector; the summary value $\frac{q_\Sigma}{q_0}$ is presented in column 11.

The results of computations presented in data in table 1 were obtained for an RMC, not for a VMC or a MMC as the RMC ensures rather larger possibilites for a considerable increase in resolution without a change in the V. Regrettably, the ion losses in the RMC analyzer, due to the low summary transparency of a large number of nets may be quite significant (Transparency of 20% and less). However, these losses in sensitivity are easily compensated by using an electron multiplier.

A computation of heat losses without taking into account the harmonics level (which may always be decreased by increasing the number of cascades) for a 100-cycle analyzer with a total length of about 40 cm results in $\frac{M}{\Delta M}$ = about 180 at the base and $\frac{q_\Sigma}{q_0}$ = about 0.82

It is evident that the above calculations must be corrected and checked experimentally. However, they are sufficiently numerous to consider a total separation of primary and secondary particles in a vertical sounding as being a problem

capable of being solved. At that, the most expedient manner of solution is - in all likelihood, an increase in the number of cycles as well as the increase- to an effective limit - of the stop-potential.

At Sputnik velocities - as is easily seen from expressions (1) - (4) it is possible to utilize all three mass spectrometer types (RMC, VMC, and MMC). We should note, however, that the mass filter of Paul (22, 23) and the omegatron spectometer (18, 24, 26), in principle, could not be used in the methodology of complete separation.

Let us now investigate the method of partial separation. It can be realized in two ways:

The first manner consists in using the mass spectrometer with an open ion source and the introduction between the ion source and the analyzer of a "one-sided" resistance Z to the gas flow. Z must have a small value for the incoming flow of primary particles Z_+ (including the ions formed in the source and a large value for the reverse flow Z_{-1} (the flow of secondary particles which now became secondary ones are pumped out of the analyzer by a small ion-getter pump through the vacuum gauge of a $F \gg \frac{1}{Z}$ capacity. Such a scheme was successfully used by Nier at the launch of the sector MMC with a single focussing on the "Aerobee" Rocket (21). The use of the pump complicates the already complex flight experiment. Therefore, it is expedient to

attempt to eliminate the pump (second method). To achieve this it is necessary to design the mass spectrometer and install it on the carrier in such a way as to utilize the effective "pumping out" of the analyzer due to its connection with the preset vacuum area instead of the pump; or it may be caused by static pressure (which is much worse). The respective idealized analyzer designs are presented in Figs. 1 and 2*.

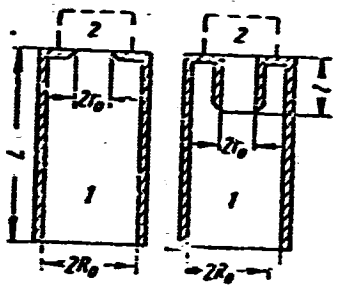

Fig. 1 Here and in Fig. 2, 4

1 - analyzer, 2 - ion source

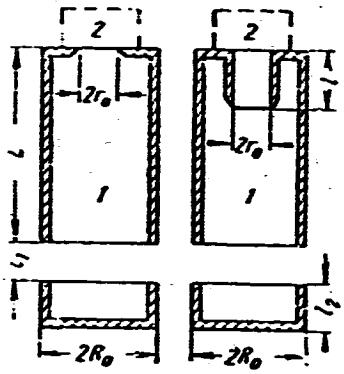

Fig. 2

It is easy to see that at

$$Z_{-r_0} \gg Z_{R\perp}, \quad Z_{-r_1} \gg Z_{R\perp}, \tag{10}$$

$$Z_{-r_1} \gg Z_{-r_0} \tag{11}$$

the second method can be easily realized comparatively. It is necessary to underline, at this point, that the system described

* At a sufficiently small relation $\frac{a}{S}$ the removal to a certain limit of the ionization are a from the inlet section of the analyzer permits additional decrease of the relative concentration of the secondary particles. This is connected with the fact that the reverse flow particles are subject to strong scattering and practically cease to reach it. However, we are not considering this problem at this time.

above may be used in operating various mass analyzers (for instance the mass-filter, the VMC, RMC, MMC and others). If the conditions in the formulae (10), (11) are fulfilled, the Fig. 1 diagram presents some advantages as compared to the diagram in Fig. 2.

In addition to a considerable decrease in the reverse flux, meaning the flux from the analyzer into the ionization area, the diagram in Figs.1 & 2 permits to:

a) substantially decrease the magnitude τ_{preset} and reduce it in the optimal case to a value on the order of about $2\frac{l_o}{v}$ (l_o is the largest linear dimension of the ion source);

b) somewhat decrease the altitude at which the mass spectrometer starts operations, due to the lowered pressure in the analyzer caused by the "pumping out" and its increase in the ion source caused by the deceleration of the incoming flux;

c) significantly decrease the probability of a recombination of chemically active components in the ion source as a result of its openwork structure, which reduces to a minimum the number (about 1 - 2) of collisions of the primary particles with the structural parts of the source, and, in this manner, sharply increase the concentration of chemically active components in the ionization area.

The increase - in the ionization area - in the relative concentration of any chemically active component in comparison to the relative concentration of primary particles of this same component is due to the contribution of those secondary particles which did not perish in the collisions with the ion source parts. This fact permits us to positively consider the partial separation method as a method of enrichment of the ionization area by chemically active components.

The above considerations point to the expediency of a quantitative investigation of the methodology of partial separation. We present therefore, below, the integral equation of the radiation intensity of secondary particles I_2 by the inner walls of the installation with the Fig. 1 geometry.

The symbols are introduced in Fig. 3.

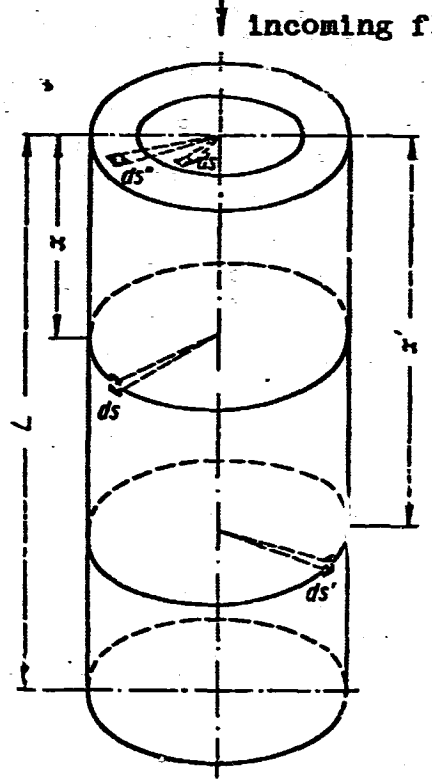

Fig. 3

In agreement with the symbols the equation for the platform on the inner surface of the cylinder ds is recorded as:

$$\int_{\Sigma'} I_2' \left(\frac{\cos\vartheta\cos\vartheta_1}{R^2}\right)' ds' + \int_{\Sigma''} I_2'' \left(\frac{\cos\vartheta\cos\vartheta_1}{R^2}\right)'' ds'' + \\ + I_1 \int_{\sigma} \bar{\gamma}_M \frac{\cos\vartheta\cos\vartheta_1}{R^2} d\sigma = \pi I_2', \tag{12}$$

where I_1, I_2', I_2'' - are the radiation intensities of the surface elements, respectively $\sigma = \pi r_0^2$, $\Sigma' = 2\pi R_0 L$, $\Sigma'' = \pi(R_0^2 - r_0^2)$; I'_2 and I''_2 are connected by the relation

$$I_2' = \frac{1}{\pi} \int_{\Sigma'} I_2' \left(\frac{\cos\vartheta\cos\vartheta_1}{R^2}\right)' ds'. \tag{13}$$

The relation (13) makes possible the recording of (12) as

$$I_1 \int_{\sigma} \bar{\gamma}_M \frac{\cos\vartheta\cos\vartheta_1}{R^2} d\sigma + \int_{\Sigma'} I_2' \left(\frac{\cos\vartheta\cos\vartheta_1}{R^2}\right)' ds' + \\ + \frac{1}{\pi} \int_{\Sigma''} \left\{ \int_{\Sigma'} I_2' \left(\frac{\cos\vartheta\cos\vartheta_1}{R^2}\right)' ds' \right\} \left(\frac{\cos\vartheta\cos\vartheta_1}{R^2}\right)'' ds'' = \pi I_2'. \tag{14}$$

The expression (14) differs from the analogous expression for the tube which connects the moving gas with the vacuum (5) by the last term in the left part.

Utilizing the symbols in Figs. 1 - 3 and partly the results of work described in (3,5) we can re-write (14) as

$$I_1 \int_0^{r_0} \int_0^{2\pi} \bar{\gamma}_M \frac{r\varphi (R_0 - r\cos\varphi)\, d\varphi dr}{(x^2 + r^2 + R_0^2 - 2rR_0\cos\varphi)^2} + \int_0^{L} \int_0^{2\pi} I_2(x') \frac{R_0^2 (1-\cos\varphi)^2\, dx' d\varphi}{[(x-x')^2 + 2R_0^2(1-\cos\varphi)]^2} + \\ + \frac{1}{\pi} \int_{r_0}^{R_0} \int_0^{2\pi} \left\{ \int_0^{L} \int_0^{2\pi} I_2'(x') \frac{R_0 (R_0 - r\cos\varphi')\, x' dx' d\varphi'}{[x'^2 + r^2 + R_0^2 - 2rR_0\cos\varphi']^2} \right\} \times \\ \times \frac{r\varphi (R_0 - r\cos\varphi)\, dr d\varphi}{(x^2 + r^2 + R_0^2 - 2rR_0\cos\varphi)^2} = \pi I_2'(x) \tag{15}$$

or, upon integration along φ, φ' and partly, r

$$f'(x)+\int_0^L \Phi(|x-x'|)\,I_2'(x')\,dx'+$$

$$+4R_0^2 x\int_{r_0}^{R_0}\int_0^L I_2'(x')\,\frac{(R_0^2+x'^2-r^2)(R_0^2+x^2-r^2)\,x'\,dx'\,dr}{[(x^2+r^2+R_0^2)-4r^2R_0^2]^{\frac{3}{2}}[(x'^2+r^2+R_0^2)^2-4r^2R_0^2]^{\frac{3}{2}}}=$$

$$=I_2'(x), \qquad (16)$$

where

$$\Phi(|x-x'|)=\frac{1}{2R'}\left\{1-\frac{|x-x'|\,[(x-x')^2+6R'^2]}{[(x-x')^2+4R'^2]^{\frac{3}{2}}}\right\},$$

$$\pi f'(x)=2I_1\int_0^{\operatorname{arctg}\frac{2r_0}{x}}\bar{\gamma}_M'(\vartheta)\sqrt{1-\frac{x^2\operatorname{tg}^2\vartheta}{4R'^2}}\sin^2\vartheta\,d\vartheta.$$

An exact solution (16) presents serious difficulties. It is, therefore, expedient to find an approximated solution for the evaluations, in the following manner:

Let us distribute uniformly along the cross-section $S = \pi R_0^2$ the intensities I_1 and I''_2, then, (12) presents the following aspect:

$$\int_0^L \Phi(|x-x'|)\,I_2'(x')\,dx'+I_{2\Phi\Phi}'\varphi(x)+f_1(x)=I_2'(x), \qquad (17)$$

where, in agreement with the articles (3 and 5)

$$\varphi(x)=\frac{1}{2R'}\left(\frac{x^2+2R'^2}{\sqrt{x^2+4R'^2}}-x\right),$$

$$f_1(x)=2\frac{I_1\sigma}{S}\int_0^{\operatorname{arctg}\frac{2R'}{x}}\bar{\gamma}_M'\sqrt{1-\frac{x^2\operatorname{tg}^2\vartheta}{4R'^2}}\sin^2\vartheta\,d\vartheta, \qquad (18)$$

$$I_{2\Phi\Phi}'=\frac{\overline{I_2'}\,\Sigma''}{S},$$

$$\overline{I_2'}=\frac{2}{R'}\int_0^L I_2'(x')\,\varphi(x')\,dx'. \qquad (18')*$$

* The basis for the (18') is presented in article (17).

Let us write $I_2^1(x')$ as the sum of:

$$I_2'(x') = I_{21}'(x') + I_{22}'(x'). \qquad (19)$$

then (17) can be written as two equations:

$$\int_0^L \psi(|x-x'|)\, I_{21}'(x')\, dx' + f_1(x) = I_{21}'(x), \qquad (20)$$

$$\int_0^L \psi(|x-x'|)\, I_{22}'(x')\, dx' + I_{2\,эфф}'' \varphi(x) = I_{22}'(x). \qquad (21)$$

According to data in article (5) the solution of the equation (20) is recorded as:

$$\begin{aligned} I_{21}'(x') = {} & \frac{R'+L}{2R'+L}\left[\frac{1}{R'^2}\int_0^\infty\int_0^\infty f_1\,dx'dx'' + \frac{1}{R'}\int_0^\infty f_1\,dx'\right] + \\ & + \frac{R'}{2R'+L}\left[\frac{1}{R'^2}\int_L^\infty\int_x^\infty f_1\,dx'dx'' - \frac{1}{R'}\int_L^\infty f_1\,dx'\right] - \\ & - \frac{x}{2R'+L}\left[\frac{1}{R'^2}\int_0^\infty\int_{x'}^\infty f_1\,dx'dx'' + \frac{1}{R'}\int_0^\infty f_1\,dx'\right] + \\ & + \frac{x}{2R'+L}\left[\frac{1}{R'^2}\int_L^\infty\int_{x'}^\infty f_1\,dx'dx'' - \frac{1}{R'}\int_L^\infty f_1\,dx'\right] - \frac{1}{R'^2}\int_x^\infty\int_{x'}^\infty f_1\,dx'dx'' + f_1. \end{aligned} \qquad (22)$$

According to data in article (3) the solution of the equation (21) is:

$$I_{22}''(x') = I_{2\,эфф}'' \frac{L+R'-x'}{2R'+L}. \qquad (23)$$

Substituting (22) and (23) consecutively into (18a) and (18) we obtain:

$$\begin{aligned} I_{2\,эфф}'' = {} & \frac{2\Sigma''}{SR'}\int_0^L (I_{21}' + I_{22}')\,\varphi(x')\,dx' = \frac{2\Sigma''}{SR'}\int_0^L I_{21}'(x')\,\varphi(x')\,dx' + \\ & + \frac{2\Sigma''}{SR'}\int_0^L I_{2\,эфф}''\frac{L+R'-x'}{2R'+L}\varphi(x')\,dx' = \frac{2\Sigma''}{SR'}\int_0^L I_{21}'(x')\,\varphi(x')\,dx' + \\ & + \frac{2\Sigma''}{SR''} I_{2\,эфф}''\int_0^L \frac{L+R'-x'}{2R'+L}\varphi(x')\,dx', \end{aligned} \qquad (24)$$

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Wherefrom:

$$I_{2\,эфф}^{*} = \frac{\frac{2\Sigma''}{SR'}\int_0^L I_{21}'(x')\,\varphi(x')\,dx'}{1-\frac{2\Sigma''}{SR'}\int_0^L \frac{L+R'-x'}{2R'+L}\,\varphi(x')\,dx'} \qquad (24)$$

The expression (24) may also be recorded as follows:

$$I_{2\,эфф}^{*} = \frac{\frac{2\Sigma''}{S}\chi(\beta)\left\{\frac{K\left(\beta_1\frac{L}{R'}\right)}{K\left(0,\frac{L}{R'}\right)}\frac{1+\frac{L}{R'}}{2+\frac{L}{R'}}-\frac{1}{2}K_1\left(\beta,\frac{L}{R'}\right)\right\}}{1-\frac{2\Sigma''}{S}\left(\frac{1+\frac{L}{R'}}{2+\frac{L}{R'}}-\frac{1}{2}\right)}, \qquad (25)$$

where $K_1\left(\beta,\frac{L}{R'}\right)$ is the Clausing multiplier for primary particles (6).

To a certain degree the magnitude presented below may serve as a measure of the concentration decrease in secondary particles:

$$\xi = \frac{I_{2\,эфф}''\left(\frac{L}{R'}\right)}{I_{2\,эфф}''\left(\frac{L}{R'}\infty\right)}.$$

This magnitude is presented for three different cases in table 2.

Data from this table show that, by decreasing the diameter of the inlet and increasing the velocity of the incoming flux it is possible to considerably decrease the background caused by the secondary particles.

Table 2

$\frac{L}{R'}$	$\frac{\Sigma''}{S}=0,9;$ $\beta=3,5$	$\frac{\Sigma''}{S}=0,9;$ $\beta=5$	$\frac{\Sigma''}{S}=0,8;$ $\beta=5$	$\frac{\Sigma''}{S}=0,99;$ $\beta=5$
2	0,1231	0,0620	0,1137	0,0068
3	0,1798	0,1074	0,1813	0,0116
5	0,2863	0,1915	0,3192	0,0233
10	0,4826	0,3819	0,5775	0,0550

Let us briefly compare the two methods. The method of complete separation in utilizing the analyzer's geometry, as it is schematically presented in Fig. 4, permits the measuring with one unit of at least the following magnitudes:

a) partial concentrations of chemically inert particles in the free atmosphere utilizing the mass spectrum of primary particles;

b) partial temperatures and pressures in the free atmosphere utilizing the mass spectrum of secondary particles;

c) partial concentrations and the effective ratio of destruction of chemically active components in the ionization area.

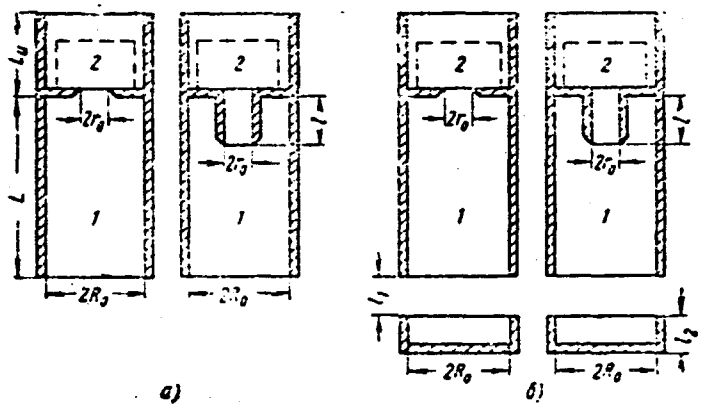

Fig. 4

It is regrettable to admit that such a considerable volume of information can be obtained only for a rather small section of the trajectory, close to the 100 km level, in other words, to the level where the macrovelocity U is sufficiently large to achieve complete separation. It would be expedient to utilize, on the remaining section of the trajectory, the system of linear equations (9, 11). In addition, the introduction of a tube with a L_{kn} will lead to the increase of the τ("usm"), yet fortunately, it will be less significant than the use of already known units with a "closed" ion source (8).

The partial separation method permits to measure with one spectrometer only partial concentrations in the free atmosphere and, at that, the background cannot be accounted for as precisely as in the case of complete separation. The technical and engineering realization of a partial separation is attained by simpler means, than the realization of a complete separation. Therefore, the method of partial separation is no less attractive.

In conclusion, we consider it to be our pleasant duty to express our gratitude to A.I. Ivanovskiy for his valuable advice and consultations.

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