# THE MICROMETEOROID IN THE UPPER ATMOSPHERE

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ABSTRACT. The temperature and the radius variation of micrometeoroids in the thermosphere and the mesosphere are calculated theoretically. If the radius and the initial velocity are 100 $\mu$ m and 30 km/sec respectively, the evaporation height and the velocity coincide almost exactly with those of the Capricornids and the Virginids from the meteor stream observation.

Moreover, it is shown that the not evaporated debris till the end of the sublimation may become spherules in the bottom of deep sea; and that fluffy micrometeoroids (10$\mu$ m size) floating in the stratosphere are also consistent with our calculation.

The recondensation and the coagulation of the evaporated gas molecules from the meteoroid are also calculated, and it is shown that these secondary particles are very small and few.

## 1. Introduction

There are two kinds of small meteorites.

1) The spherules which are found in the bottom of the deep sea Their shape is spherical and the typical size is about 100 $\mu$ m.

2) The micrometeoroids which are collected in the stratosphere by airplane. Their shape is not spherical and its typical character is that it is fluffy. The typical size is about 10 $\mu$ m.

We calculate the origin of these two types by a simple model.

## 2. The Method of Calculation

The assumptions of the calculation are:

1) The kinetic energy of the atmospheric molecules which collide the meteorite is converted entirely to heat up the collided meteorite.

2) The absorbed heat is changed to the elevation of temperature and the radiation loss (Stefan-Boltzmann) of the meteorite.

3) If the temperature of the meteorite becomes higher than the sublimation temperature, the absorbed heat is changed to the evapo-

ration heat and the radiation loss, while the temperature of the mete-
orite becomes constant.

3. The Result of Calculation

Three examples are  plotted in Fig.1.  The upper three curves  are the
variation of temperature (abscissa) of  three  meteorites  against the
hight  from the ground level (ordinate).  The initial velocity  v  and
the initial radius r are  v =30 km/sec,  r =10 $\mu$ m; 30 km/sec,100 $\mu$ m;
and 20 km/sec, 100 $\mu$ m; respectively.
   The most typical case (30 km/sec, 100 $\mu$ m) is shown as the second
curve. The temperature begins to become gradually higher at the height
of 120 km and reaches  the sublimation temperature at 97.2 km.
   After this point  variation of the radius  in percent  of the in-
itial radius (abscissa)  is plotted  against the height (ordinate)  in
the left lower part of Fig.1.
   Physical  constants  are assumed, corresponding to  silicates, as
follows: specific heat C= $10^7$ erg/K /g  ,sublimation heat L= $6*10^{10}$ erg
/g  and sublimation temperature is 2100 K.
   To explain the left-lower part of Fig.1, which is  rather compli-
cated, we take as an example 30 km/sec, 100 $\mu$ m particle. As mentioned
above, the temperature becomes  high enough  to reach  the sublimation
temperature  at Z=97.2 km.  From this point, the heat obtained  by the
collision  with  the  atmospheric  gas  molecules  is  converted  into
sublimation heat and temperature becomes constant.  The radius becomes
smaller  and  smaller  by  evaporation.  It  is plotted  in the second
curve of the left-lower part of Fig.1.
   Namely, 100 % (r = 100 $\mu$ m) at Z=97.2 km,
        50 % (r =  50 $\mu$ m) at Z=86.2 km.
   The radiation loss  becomes  gradually larger, compared with  the
sublimation loss,and at last at Z=81.3 km, where r = 8.3 $\mu$ m,the radi-
ation loss  is  large enough  to be equal to the energy gain. Thus the
sublimation stops there.
   In other words,the meteorite is observed as a meteor at 97.2 km >
Z > 81.3 km and radius of the debris : r = 8.3 $\mu$ m.
   Two other  cases are  also plotted  as  the first  and  the third
curves in Fig.1, and final r = 4.0 $\mu$ m and 24 $\mu$ m ,respectively.

4. Secondary Particle

"Secondary  particle"  means  the  recondensation  of  the  evaporated
vapour.  As  the surrounding temperature  is very low,  the evaporated
vapour condenses into grains soon after the evaporation.
   We have calculated  several cases, but to avoid  to integrate the
complicated equation of coagulation numerically, we adopt  "similarity
solution" (Onaka et al. 1978).
   The result of an example (30 km/sec, 100 $\mu$ m) at the height of 90
km is shown in Fig.2.  The ordinate is number ratio (log scale) of the
recondensed grains to the evaporated gas molecules,and the abscissa is
radius of the grain(on the top:number of atoms included in the grain).

$\tau$ ( 0.1 sec) is time duration  after the evaporation.  It is  clearly seen, that 10 sec after the evaporation, radius is about 100 A and the ratio of the number density to the gas molecule is $10^{-10}$

We have to conclude that the secondary particles are very few and small compared with the primary meteorite by this calculation,in which the meteorite is  very small  (micrometeoroid).  If  the meteorite is large and fast enough, secondary particles would be important.

## 5. Conclusion

1) The comparison  with the meteor stream observation  from the ground is very interesting.  Simultaneous observations from several points on the ground  can determine  the height  and  the velocity  of  a meteor stream:

   a) Virginids      96 km >Z> 78 km, 30.8 km/sec
   b) Capricornids   96 km >Z> 86 km, 25.6 km/sec

These observations  coincide almost exactly  with our (30 km/sec, 100 $\mu$m) particles.

2) It is guessed that the spherule's  origin  is  "debris" of our calculation.  The trouble  is that spherules, collected  in  the  deep sea bottom, have about 100 $\mu$m size. It is conjectured that  "sampling effect"  is  rather essential.  If we can collect also small ones this inconsistency may be solved.

3) If  the meteorite is (20 km/sec, 10 $\mu$m),  heating is not much enough  and it cannot reach the sublimation temperature, even if it is not fluffy. If the particle is fluffy, the heating is much smaller and it is quite natural that it is floating in the stratosphere  in original shape.

4) The secondary particles are very few and small.

## Reference

Onaka,T.,Nakada,Y.and Kanijo,F. : Experiment on the Clustering of Fine Particles,  Astrophys.& Space Sci.65,103(1978).

Figure captions are written precisely in the text.

Fig. 1

$V = 30 \text{km·sec}^{-1}$

$r = 10^{-3}$ cm



Fig. 2