Mie Theory Assignment : Task 7

Name: Jayendra Praveen Kumar Chorapalli
Matriculation Number: 03736602

Question 1:How many collisions of an air molecule occur in 1 sec?

Given r=0.15nm, P=10^5Pa, T=273K and Nitrogen molecule (N_2) is considered for composition of air.

Answer:

To find the collision frequency, time between 2 successive collisions for a N2 molecule for the given radius of the air molecule,pressure and temperature values the following code is written to derive the final values:

```
import numpy as np;

# radius of the air molecule (m)
r= 0.15/(np.power(10,9));

# atmospheric pressure (Pa)
P=100000;

# temperature (Kelvin)
T=273;

# molecular mass considering Nitrogen molecule (kg)
M=28/(np.power(10,3));

# Boltzmann constant (kg m^2 s^-2 K^-1)
k=1.38/(np.power(10,23));

# Universal gas constant (J mol^-1 K^-1)
R=8.314;

# number density
n=P/(k*T);

# root mean square velocity of Nitrogen molecule (m/s)
vrms=np.sqrt((3*R*T)/M);

# collision cross section
sigma=np.pi*np.power((2*r),2);

# approximate mean free path (m)
a_mfp=1/(n*sigma);

# mean free path (m)
mfp=(k*T)/(np.sqrt(2)*np.power((2*r),2)*P);

# collision frequency (sec^-1)
frequency=vrms/l ;

# time between successive collisions (sec)
time=1/f ;
```

The above code gives the following results:

a_mfp = 1.3324e-07 m = 133.24 nm;

mfp = 2.9599e-07 m = 295.99 nm;

frequency = 1.6660e+09 sec^{-1};

time = 6.0023e-10 sec;

Results:

No of Collisions for one air molecule in 1 second = 10^9

No of Collisions for all air molecules in 1 second = 10^{34}

Question 2: What happens to the blue colour of the sky if the atmosphere 10 times more thicker?

Answer:

Sunlight is scattered in all directions by the tiny molecules of air in Earth's atmosphere. During daytime the blue light is scattered more than other colors because it travels as shorter, smaller waves. During the day, we assume that the optical thickness is lower than it is at night, so we can roughly consider only one scattering of the blue wavelength. However, as the optical thickness of the atmosphere increases (during sunrise or sunset), the blue light experiences multiple strong scattering as it travels a longer path, so that only the light that is less scattered is enriched, such as the red and yellow light, and reaches the eye. Due to this, all of the blue light is scattered, leaving only the red end of the visual spectrum visible between dawn and sunset.

The Rayleigh scattering phenomenon states that the shorter wavelengths such as blue light in the electromagnetic spectrum produces more oscillations compared to the regions with higher wavelengths (red band portion of EMR). These high number of oscillations for the blue light results in more scattering than any other bands in the visible spectrum of light. As a result, the oscillations are inversely correlated with the light's frequency. The intensity of the scattered light increases with oscillation frequency. The relationship thus discovered states that the scattered light's intensity is proportional to the fourth power of frequency. This is related to the optical thickness of the atmosphere, and we may say that as optical thickness increases, light intensity decreases. Hence, with increasing optical thickness the wavelength shifts towards the higher wavelength portions of EMR like red as higher frequency colour gets scattered more.

$$\tau = \frac{0.00877}{\lambda^{4.05}}$$

The above formulae shows the relation between optical thickness of the atmosphere and the wavelength of incoming radiation

The color we perceive would change if we significantly raised the air density. The blue light rays from the Sun would be absorbed or scattered in the extremely high atmosphere if the amount of dust in the upper atmosphere were to increase enough; they could have to bounce or scatter more than once before they could reach the ground. They might hardly ever touch the ground if the atmosphere were sufficiently dense. That would mean that the light rays we might see when we looked in the sky away from the Sun would be the shortest rays which could still reach the ground after scattering just once or twice. If the atmosphere were much thicker, such light rays might have yellow or green wavelengths rather than blue. Only those really long wavelengths of light could pass through the atmosphere to reach the ground at all, **thus if the atmosphere were extremely thick like 10 times thicker than now, we might observe a dull orange or reddish glow from the entire sky.**

This can also be theoretically calculated by multiplying 10 times with the tau value (0.2306 , this is calculated using blue wavelength ~0.46 micrometers) using the above mentioned formulae. The corresponding wavelength of the calculated tau value (2.306) will gives us a wavelength of 0.81 micrometers which is close to near infrared / red band of the spectrum.