

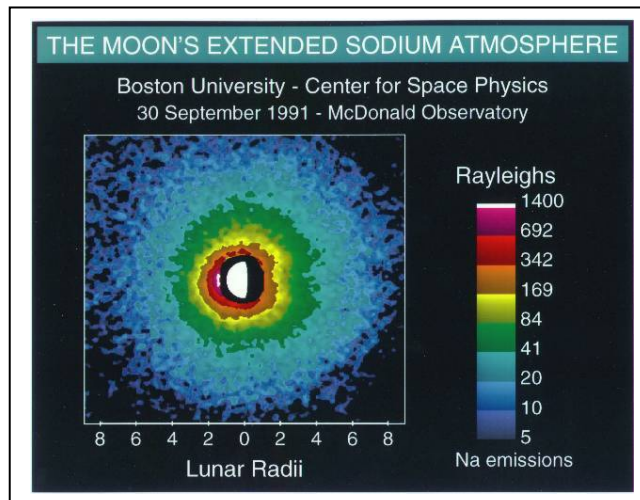


Courtesy: T.A.Rector, I.P.Dell'Antonio  
(NOAO/AURA/NSF)

Experiments performed by Apollo astronauts were able to confirm that the moon does have a very thin atmosphere.

The Moon has an atmosphere, but it is very tenuous. Gases in the lunar atmosphere are easily lost to space. Because of the Moon's low gravity, light atoms such as helium receive sufficient energy from solar heating that they escape in just a few hours. Heavier atoms take longer to escape, but are ultimately ionized by the Sun's ultraviolet radiation, after which they are carried away from the Moon by solar wind.

Because of the rate at which atoms escape from the lunar atmosphere, there must be a continuous source of particles to maintain even a tenuous atmosphere. Sources for the lunar atmosphere include the capture of particles from solar wind and the material released from the impact of comets and meteorites. For some atoms, particularly helium and argon, outgassing from the Moon's interior may also be a source.



Problem 1: The Cold Cathode Ion Gauge instrument used by Apollo 12, 14 and 15 recorded a daytime atmosphere density of 160,000 atoms/cc of hydrogen, helium, neon and argon in equal proportions. What was the density of helium in particles/cc?

Problem 2: The atomic masses of hydrogen, helium, neon and argon are 1.0 AMU, 4.0 AMU, 20 AMU and 36 AMU. If one AMU =  $1.6 \times 10^{-24}$  grams, a) How many grams of hydrogen are in one cm<sup>3</sup> of the moon's atmosphere? B) Helium? C) Neon? D) Argon? E) Total grams from all atoms?

Problem 3: Assume that the atmosphere fills a spherical shell with a radius of 1,738 kilometers, and a thickness of 170 kilometers. What is the volume of this spherical shell in cubic centimeters?

Problem 4. Your answer to Problem 2E is the total density of the lunar atmosphere in grams/cc. If the atmosphere occupies the shell whose volume is given in Problem 3, what is the total mass of the atmosphere in A) grams? B) kilograms? C) metric tons?

## Answer Key:

**Problem 1:** The Cold Cathode Ion Gauge instrument used by Apollo 12, 14 and 15 recorded a daytime atmosphere density of 160,000 atoms/cc of hydrogen, helium, neon and argon in equal proportions. What was the density of helium in particles/cc?

Answer: Each element contributes 1/4 of the total particles so hydrogen = 40,000 particles/cc; helium = 40,000 particles/cc, argon=40,000 particles/cc and argon=40,000 particles/cc

**Problem 2:** The atomic masses of hydrogen, helium, neon and argon are 1.0 AMU, 4.0 AMU, 20 AMU and 36 AMU. If one AMU =  $1.6 \times 10^{-24}$  grams, a) How many grams of hydrogen are in one cm<sup>3</sup> of the moon's atmosphere? B) Helium? C) Neon? D) Argon? E) Total grams from all atoms?

Answer: A) Hydrogen =  $1.0 \times (1.6 \times 10^{-24} \text{ grams}) \times 40,000 \text{ particles} = 6.4 \times 10^{-20} \text{ grams}$

B) Helium =  $4.0 \times (1.6 \times 10^{-24} \text{ grams}) \times 40,000 \text{ particles} = 2.6 \times 10^{-19} \text{ grams}$

C) Neon =  $20.0 \times (1.6 \times 10^{-24} \text{ grams}) \times 40,000 \text{ particles} = 1.3 \times 10^{-18} \text{ grams}$

D) Argon =  $36.0 \times (1.6 \times 10^{-24} \text{ grams}) \times 40,000 \text{ particles} = 2.3 \times 10^{-18} \text{ grams}$

E) Total =  $(0.064 + 0.26 + 1.3 + 2.3) \times 10^{-18} \text{ grams} = \underline{3.9 \times 10^{-18} \text{ grams per cc.}}$

**Problem 3:** Assume that the atmosphere fills a spherical shell with a radius of 1,738 kilometers, and a thickness of 170 kilometers. What is the volume of this spherical shell in cubic centimeters?

Answer: Compute the difference in volume between A sphere with a radius of  $R_i = 1,738 \text{ km}$  and  $R_o = 1,738 + 170 = 1,908 \text{ km}$ .  $V = \frac{4}{3} \pi (1908)^3 - \frac{4}{3} \pi (1738)^3 = 2.909 \times 10^{10} \text{ km}^3 - 2.198 \times 10^{10} \text{ km}^3 = 7.1 \times 10^9 \text{ km}^3$

$$\begin{aligned} \text{Volume} &= 7.1 \times 10^9 \text{ km}^3 \times (10^5 \text{ cm/km}) \times (10^5 \text{ cm/km}) \times (10^5 \text{ cm/km}) \\ &= 7.1 \times 10^{24} \text{ cm}^3 \end{aligned}$$

Note: If you use the 'calculus technique' of approximating the volume as the surface area of the shell with a radius of  $R_i$ , multiplied by the shell thickness of  $h = 170 \text{ km}$ , you will get a slightly different answer of  $6.5 \times 10^9 \text{ km}^3$  or  $6.5 \times 10^{24} \text{ cm}^3$

**Problem 4.** Your answer to Problem 2E is the total density of the lunar atmosphere in grams/cc. If the atmosphere occupies the shell whose volume is given in Problem 3, what is the total mass of the atmosphere in A) grams? B) kilograms?

A) Mass = density x volume =  $(3.9 \times 10^{-18} \text{ gm/cc}) \times 7.1 \times 10^{24} \text{ cm}^3 = 2.8 \times 10^7 \text{ grams}$

B) Mass =  $2.8 \times 10^7 \text{ grams} \times (1 \text{ kg}/1000 \text{ gms}) = 28,000 \text{ kilograms.}$

C) Mass =  $28,000 \text{ kg} \times (1 \text{ ton} / 1000 \text{ kg}) = 28 \text{ tons.}$

Teacher note: You may want to compare this mass to some other familiar objects. Also, the Apollo 11 landing and take-off rockets ejected about 1 ton of exhaust gases. Have the students discuss the human impact (air pollution!) on the lunar atmosphere from landings and launches.