Escape velocity $v_e = \sqrt{\frac{2GM}{r}}$

Earth	11 km/s
Mars	5.1 km/s
Moon	2.4 km/s
Mercury	4.2 km/s

Mean speed $\bar{v} = \sqrt{\frac{2CT}{m}}$

C = heat capacity

At 300 K H_2 has $\bar{v} \approx 2.5$ km/s

O_2 has $\bar{v} \approx 0.6$ km/s

But particles have a range of speeds .....

In age of Solar System, if $\bar{v} \simeq 0.2 v_e$, all molecules escape.

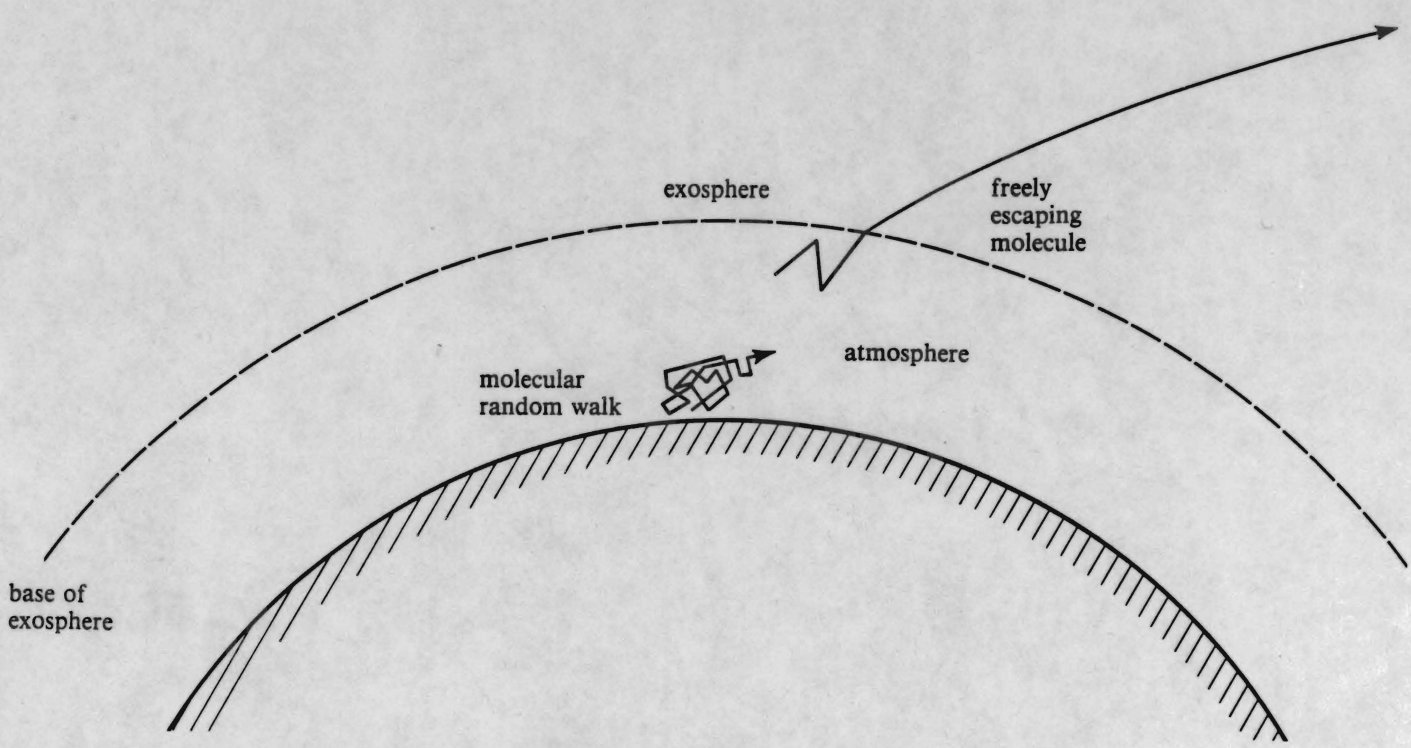


Figure 17.24. Deep in a planetary atmosphere, the mean free path for molecule-molecule collisions is so short that even a very fast molecule has no chance to escape from the planet. Above the base of the exosphere, the density of molecules has dropped low enough that the probability for escape becomes high for a sufficiently fast molecule. (Compare with Figure 5.7.)

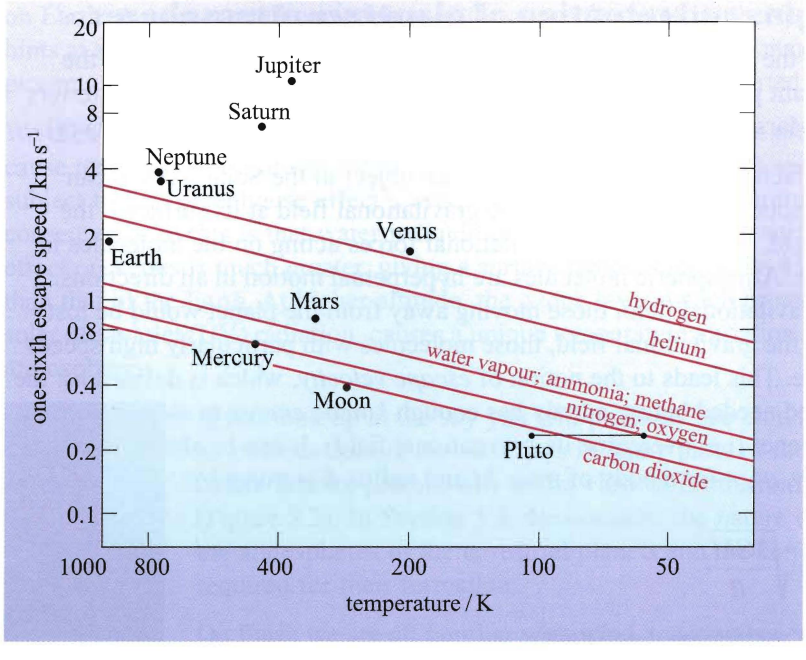
(i) Jeans escape

(ii) UV photo-dissociation

UV photo-dissociation

- UV photons hit molecules at Top of atmosphere
- Dissociate
- Give ~~en~~ kinetic energy to atoms ; can lose to atmosphere before slowed down.
- a way of removing water from atmospheres

Figure 5.4 Graph summarizing conditions of temperature and escape velocity for which planetary bodies can retain the common gases hydrogen H_2, helium He, water vapour H_2O, ammonia NH_3, methane CH_4, nitrogen N_2, oxygen O_2, and carbon dioxide CO_2 in their atmospheres for long periods. For bodies that do not have a substantial atmosphere, approximate surface temperatures are shown.



Q

Where does the Earth's atmosphere come from ?

→ VOLCANOS and outgassing from rocks

Plate tectonics help provide the atmosphere as new material is continually being brought up from the mantle

The Earth is remarkable amongst terrestrial planets for its O_2-rich atmosphere : oxygen is reactive & easily forms chemical compounds.

Plant life + bacteria takes in CO_2 & water, liberate O_2 (energy input from Sun)

Carbonate - silicate cycle

- CO_2 in atmosphere dissolves in rainwater making H_2CO_3
- Rain reacts with rocks containing Ca, Si, releasing Ca^{++} HCO_3^- ions
- In sea, plankton etc incorporate ions in shells ($CaCO_3$)
- Shells settle to sea floor, eventually subducted to interior of Earth
- Heat releases CO_2, comes out

in volcanos, mid-ocean ridges

This process changes as planet's temperature changes.

Q Imagine extreme case of oceans freezing entirely. What would happen?

→ no rainfall 'cos no evaporation from oceans

→ CO_2 builds up in atmosphere

Q With more CO_2 in atmosphere, what happens to surface temperature?

→ Greenhouse effect so temperature rises

→ Oceans melt

It is thought that this feedback has kept Earth's temperature constant even when the young Sun gave off ~ 30% less energy

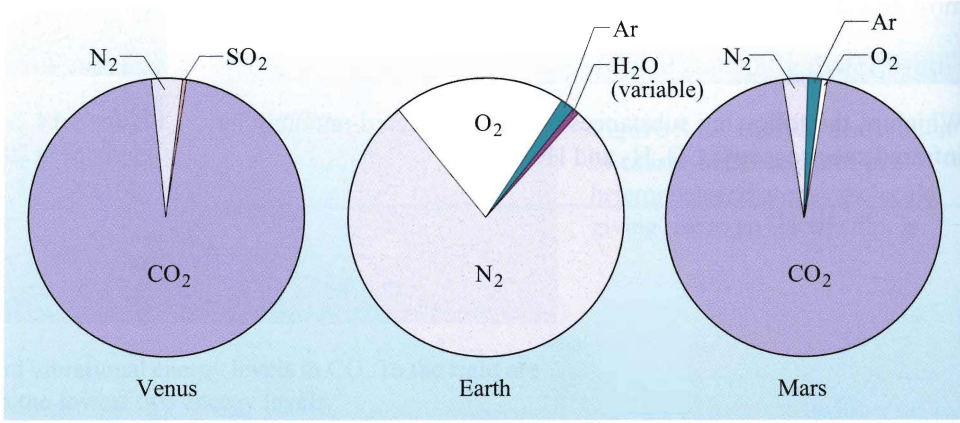


Figure 5.15 The major components of the atmospheres of Venus, Earth and Mars, as measured at the surfaces of the planets. The area of each slice of the pie chart is proportional to the volume ratio of the substance shown.

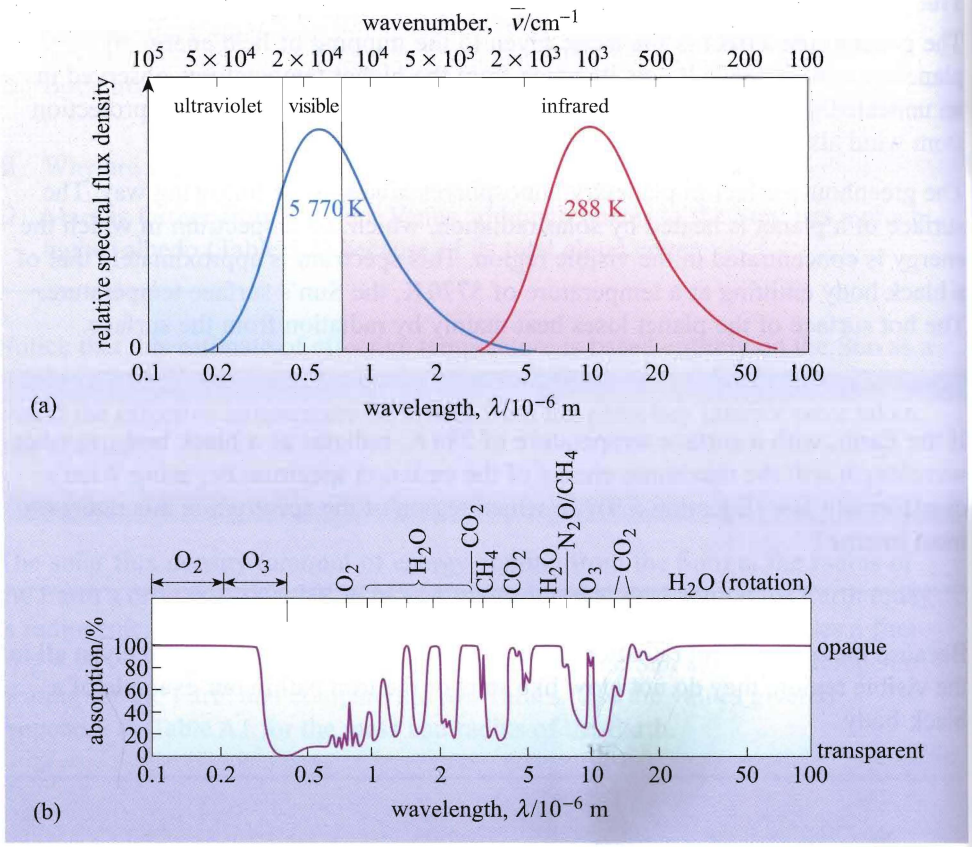


Figure 5.22 (a) Spectra of black-body sources at the temperatures of the Sun's surface (5770 K) and the Earth's surface (288 K). The vertical scales for the two spectra are not the same; the Sun's radiation is much more intense than that of the Earth. (b) The absorption spectrum of the Earth's atmosphere: the wavelengths at which some atmospheric gases absorb energy are indicated.