Neutral Atmospheres:

Problem Sheet

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1: *State which bodies in the solar system have permanent atmospheres and name examples for those who don't. What basic parameters determine whether or not a body has an atmosphere and whether or not it hangs on to it?*

Permanent atmospheres:
Venus, Earth, Mars, Jupiter, Saturn, Titan, Uranus, Neptune, Triton, Pluto

Transient atmospheres:
Mercury, Moon, Callisto, Ganymede, Europa, Io, Comets

$$F_{esc} = \frac{n\,r}{2\sqrt{\pi}} \cdot \left(\frac{2\,k\,T}{m}\right)^{\frac{1}{2}} \cdot (\lambda + 1)\, e^{-\lambda}$$

Jeans escape flux

$$\lambda = \frac{gravitational\ potential\ energy}{random\ kinetic\ energy} = \frac{r_{exobase}}{H}$$

Lambda parameter indicates how transient an atmosphere is

2: For the terrestrial planets solar radiation constitutes overall the major energy source. The solar constant denotes the energy flux per unit area (in W/m²) at 1 AU distance from the Sun. A typical value is 1366 W/m².

a. Calculate the average energy flux you expect to find for Venus and Mars

Venus: d = 0.72 AU => $F = 1366\ W/m^2 * (1 / 0.72)^2 = 2635\ W/m^2$
Mars: d = 1.55 AU => $F = 1366\ W/m^2 * (1 / 1.55)^2 = 569\ W/m^2$

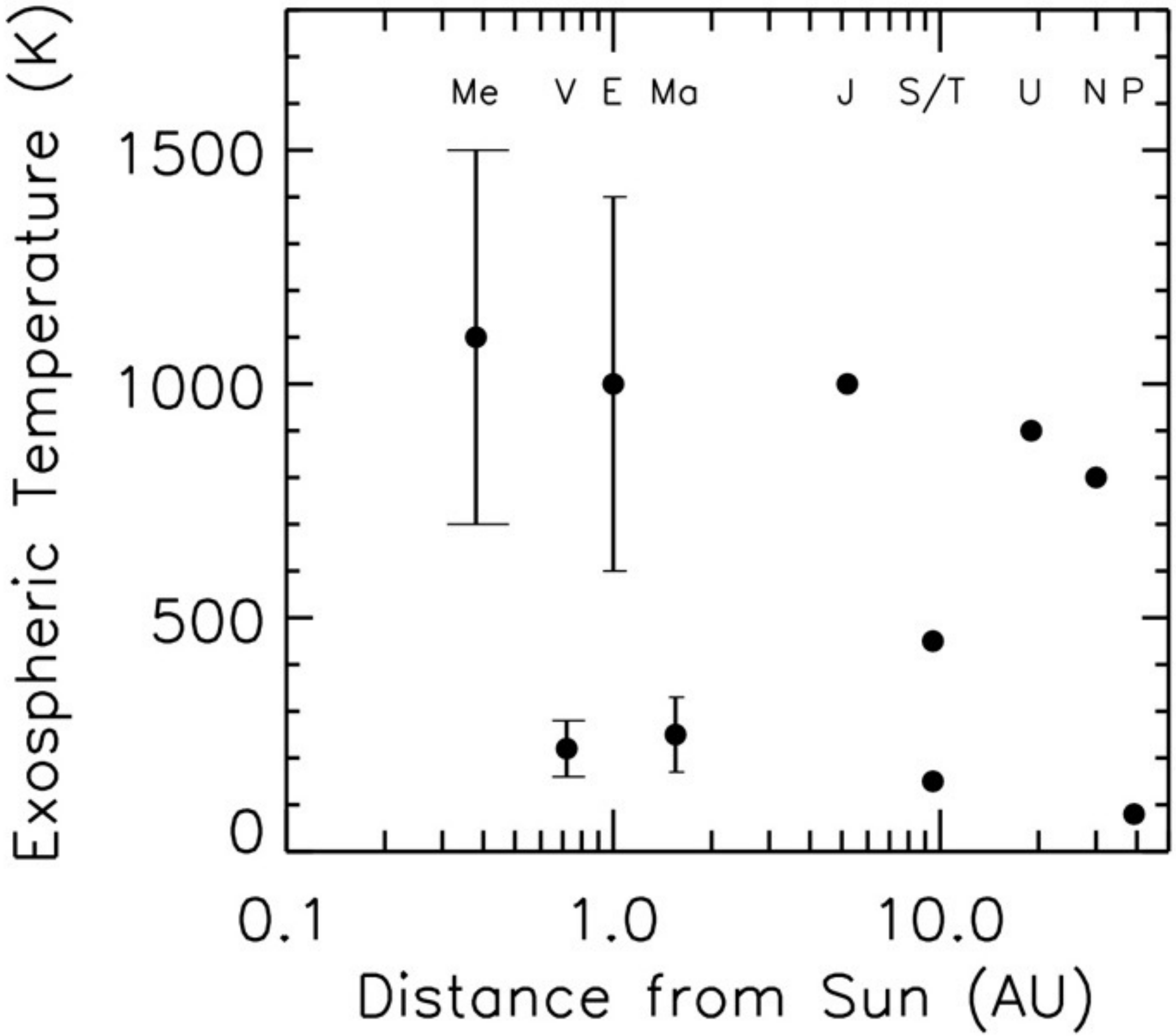
b. Calculate and compare the average solar energy that you would expect to be intersected by Earth, Mars and Venus (using cross sections of each planet)

Earth: R = 6371 km => $E = F * A = F * \pi R^2 = 1.8\times10^{17}\ W$
Venus: R = 6052 km => $E = F * A = F * \pi R^2 = 3.0\times10^{17}\ W$
Mars: R = 3380 km => $E = F * A = F * \pi R^2 = 2.0\times10^{16}\ W$

c. Compare values under (a) with actual exospheric temperatures in the atmospheres of Earth, Mars and Venus. Do the temperatures follow the same trend with distance from Sun as the energy flux? If not, briefly discuss any possible reasons for discrepancies.

T_{exo} (Earth) = 1000±400 K
T_{exo} (Mars) = 250±80 K
T_{exo} (Venus) = 220±60 K

} CO_2 15 μm cooling - modulated by O atoms


Me
V
E
Ma
J
S/T
U
N
P
1500
1000
500
0
0.1
1.0
10.0
Exospheric Temperature (K)
Distance from Sun (AU)

3: Assume an atmosphere composed of gases O and CO_2 with molecular weights of m_1=16 AMU and m_2=44 AMU. Assume a height-independent gravity of g=8.47 m/s^2 and constant temperature of T=300 K. The mixing ratio X_i of gas i is defined as $X_i = n_i/n$, where n_i and n are number densities of gas i and of the total atmosphere, respectively. At the homopause (120 km) the gas densities are $n_1=3.17\times10^{10}$ cm^{-3} and $n_2=1.64\times10^{13}$ cm^{-3}.

a. Calculate the CO_2 and O densities and mixing ratios at 200 km altitude. One efficient way of doing this is with a small computer routine, or alternatively an Excel spreadsheet. Use a vertical integration step of 5 km.

b. At which altitude are both gases equally abundant?

Basic quantities

T=	300.0000	K
X10=	0.0020	
X20=	0.9980	
m1=	16.0000	amu
m2=	44.0000	amu
Grav=	8.4700	m/s2
z0 =	120.0000	km
ztop =	160.0000	km
delta_z=	5.0000	km
R=	8313.2530	
CO2 =	1.64E+13	cm-3
O =	3.17E+10	cm-3
BZ =	1.38E-23	[S.I.]

Z	HCO2	HO	CO2	O	X(CO2)	X(O)
120.0	6.6920	18.4030	1.640E+13	3.170E+10	0.99807	0.00193
125.0	6.6920	18.4030	7.769E+12	2.416E+10	0.99690	0.00310
130.0	6.6920	18.4030	3.680E+12	1.841E+10	0.99502	0.00498
135.0	6.6920	18.4030	1.743E+12	1.403E+10	0.99202	0.00798
140.0	6.6920	18.4030	8.258E+11	1.069E+10	0.98722	0.01278
145.0	6.6920	18.4030	3.912E+11	8.149E+09	0.97960	0.02040
150.0	6.6920	18.4030	1.853E+11	6.210E+09	0.96758	0.03242
155.0	6.6920	18.4030	8.779E+10	4.733E+09	0.94885	0.05115
160.0	6.6920	18.4030	4.159E+10	3.607E+09	0.92019	0.07981
165.0	6.6920	18.4030	1.970E+10	2.749E+09	0.87756	0.12244
170.0	6.6920	18.4030	9.332E+09	2.095E+09	0.81669	0.18331
175.0	6.6920	18.4030	4.421E+09	1.596E+09	0.73470	0.26530
180.0	6.6920	18.4030	2.094E+09	1.217E+09	0.63254	0.36746
185.0	6.6920	18.4030	9.920E+08	9.271E+08	0.51691	0.48309
190.0	6.6920	18.4030	4.699E+08	7.065E+08	0.39944	0.60056
195.0	6.6920	18.4030	2.226E+08	5.384E+08	0.29250	0.70750
200.0	6.6920	18.4030	1.054E+08	4.103E+08	0.20445	0.79555
205.0	6.6920	18.4030	4.995E+07	3.127E+08	0.13774	0.86226
210.0	6.6920	18.4030	2.366E+07	2.383E+08	0.09033	0.90967
215.0	6.6920	18.4030	1.121E+07	1.816E+08	0.05813	0.94187

c. On Venus' nightside temperatures can reach 200 K. What are the CO_2 and O mixing ratios at 200 km on Venus' nightside? At which altitude are both gases equally abundant?

d. Compare your results from (c) with those from (a) and (b) and briefly discuss your findings.

e. What would happen, qualitatively, to the mixing ratios at 200 km if vigorous mixing took place in Venus' atmosphere, possibly due to waves, and the homopause moved to a higher altitude?

Basic quantities

T=	200.0000	K
X10=	0.0020	
X20=	0.9980	
m1=	16.0000	amu
m2=	44.0000	amu
Grav=	8.4700	m/s2
z0 =	120.0000	km
ztop =	160.0000	km
delta_z=	5.0000	km
R=	8313.2530	
CO2 =	1.64E+13	cm-3
O =	3.17E+10	cm-3
BZ =	1.38E-23	[S.I.]

Z	HCO2	HO	CO2	O	X(CO2)	X(O)
120.0	4.4613	12.2687	1.640E+13	3.170E+10	0.99807	0.00193
125.0	4.4613	12.2687	5.347E+12	2.109E+10	0.99607	0.00393
130.0	4.4613	12.2687	1.743E+12	1.403E+10	0.99202	0.00798
135.0	4.4613	12.2687	5.684E+11	9.334E+09	0.98384	0.01616
140.0	4.4613	12.2687	1.853E+11	6.210E+09	0.96758	0.03242
145.0	4.4613	12.2687	6.042E+10	4.131E+09	0.93600	0.06400
150.0	4.4613	12.2687	1.970E+10	2.749E+09	0.87756	0.12244
155.0	4.4613	12.2687	6.423E+09	1.829E+09	0.77839	0.22161
160.0	4.4613	12.2687	2.094E+09	1.217E+09	0.63254	0.36746
165.0	4.4613	12.2687	6.827E+08	8.093E+08	0.45759	0.54241
170.0	4.4613	12.2687	2.226E+08	5.384E+08	0.29250	0.70750
175.0	4.4613	12.2687	7.258E+07	3.582E+08	0.16848	0.83152
180.0	4.4613	12.2687	2.366E+07	2.383E+08	0.09033	0.90967
185.0	4.4613	12.2687	7.715E+06	1.585E+08	0.04640	0.95360
190.0	4.4613	12.2687	2.515E+06	1.055E+08	0.02329	0.97671
195.0	4.4613	12.2687	8.201E+05	7.017E+07	0.01155	0.98845
200.0	4.4613	12.2687	2.674E+05	4.668E+07	0.00569	0.99431
205.0	4.4613	12.2687	8.718E+04	3.106E+07	0.00280	0.99720
210.0	4.4613	12.2687	2.842E+04	2.066E+07	0.00137	0.99863
215.0	4.4613	12.2687	9.267E+03	1.375E+07	0.00067	0.99933