ASTR4C12 Planetary Atmospheres

Answer THREE Questions

The numbers in square brackets on the right hand side indicate the provisional allocation of maximum marks per sub-section of a question.

1. Show that the adiabatic lapse rate, Γ_d for a dry, transparent atmosphere in hydrostatic equilibrium is given by

$$\Gamma_d = -\frac{g}{C_p}$$

where g is the acceleration due to gravity and C_p is the specific heat of the gas at constant pressure. Explain with the aid of a diagram why the atmosphere is just stable when the temperature decreases upwards at this rate. **[10]**

In the tropospheres of Venus, Earth and Jupiter the temperature decreases upwards at the adiabatic lapse rate or more slowly. Compare the physical mechanisms involved in the heating, the transport of heat and the ultimate cooling through radiation to space in the three atmospheres. **[10]**

2. What is the difference between a geostrophic wind system and a cyclostrophic wind system, and give examples from as many planets as you can? **[10]**

Compare the global atmospheric circulation patterns on Venus and Earth paying particular attention to the energy sources and the influence of the planetary rotation. **[10]**

3. Last year some scientists announced that, from a study of the chemical and mineralogical structure of a rock found on Earth, there was a possibility that primitive biological forms had existed on Mars in the past. Without going into details of the recent mineralogical analysis, answer the following questions.

a) How was this rock, found on Earth, linked to Mars? **[5]**

b) At what period in the past on Mars were the atmospheric conditions potentially suitable for the development of life and why? **[5]**

c) What has happened to Mars subsequently which would probably have prevented further significant biological developments? **[5]**

d) How would you design an unmanned space project to look for more evidence of such life forms? **[5]**

4. Show that in order for a planet or planetary satellite to have a significant atmosphere then itÕs surface temperature T_s must obey the following inequality

$$T_s << \frac{2GMm}{3ka} \qquad (1)$$

where k is BoltzmannÕs constant, G is the gravitational constant, M the mass of the planet, m the mass of a gas molecule and a the planetary radius. **[4]**

Putting

$$V = \frac{2GMm}{3kaT_s}$$

it is possible to compile the following table of the values of V based on the present atmospheric composition and surface temperature at the various planets and planetary satellites.

Planetary body	V
Mercury	6.6
Titan	50
Io	70
Mars	200
Earth	520
Venus	580
Neptune	960
Saturn	1200
Jupiter	2600

Use this table to make a quantitative estimate of how much less T_s should be in the inequality in equation (1) above for the planetary body to have a significant atmosphere. **[4]**

If Jupiter has a rocky core whose radius is 20% of the present radius and whose mass is 5% of the present mass show that it would have been big enough to attract and hold an atmosphere of hydrogen and helium from the solar nebula. **[5]**

What mechanisms provided the terrestrial planets, whose rocky cores did not reach this mass during the formation of the solar system, with their atmospheres and which gases are most abundant? **[7]**

5. On a planet in the solar sytem,

a) a teacher is drawing **[5]**
b) a diagram of the temperature profile in the atmospheres of the terrestrial planets **[5]**
c) on a blackboard using a piece of chalk. **[5]**

From what you have studied in this course, what processes must have occurred, or not occurred, in the past to make this possible?

Why could it only be happening on Earth? **[5]**