

**Answer THREE questions**

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

1. Show that the equilibrium temperature of a body in space is given by

$$T_{eq} = \left( \frac{F(1-A)}{4\sigma} \right)^{1/4}$$

Where  $F$  is the solar heat flux,  $A$  is the planetary albedo and  $\sigma$  is the Stefan-Boltzmann constant.

[6]

The heliocentric distance  $R$  in AU, albedo  $A$  and measured atmospheric temperatures  $T_m$  of Venus and Jupiter are shown in the following table. Calculate the equilibrium temperature in each case and compare it to the measured atmospheric temperature. Comment on the relative values and the reasons for them.

	$R$ (AU)	$A$	$T_m$ (K)
Venus	0.72	0.77	230
Jupiter	5.2	0.58	130

[8]

The surface temperature on Venus is 750 K. Discuss why this is so much larger than the measured atmospheric temperature.

[6]

[Solar constant at 1AU is  $1370 \text{ Wm}^{-2}$   
Stefan-Boltzmann constant is  $5.67 \times 10^{-8} \text{ Wm}^{-2}\text{K}^{-4}$ ]

2. What is meant by hydrostatic equilibrium in an atmosphere? Using this concept show that the adiabatic lapse rate in 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. Why is the word 'adiabatic' appropriate here? [10]

Using a sketch, discuss why a steeper gradient than this is unstable.

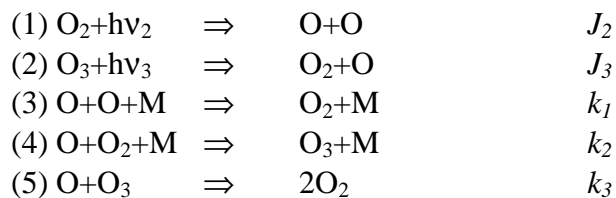
[5]

What is the heating mechanism in such an atmosphere and why is there an upper altitude for this type of temperature profile? [5]

3. Sketch the temperature profile as a function of height in the Earth's atmosphere, naming each layer and boundary region. Discuss briefly the important physical and chemical processes at work in each layer. [8]

Provide similar sketches and discussion for the cases of Venus and Mars, drawing particular attention to the significant differences from Earth and the reasons why these occur. [12]

4. Classical Chapman theory of the formation of ozone in the stratosphere is based on the balance of five chemical reactions:



where  $J_2$  and  $J_3$  are dissociation rates per molecule per second and  $k_1$ ,  $k_2$  and  $k_3$  are the reaction rates.

Write down equations giving the rate of change of concentrations of  $\text{O}_2$  and  $\text{O}_3$ . Show that in equilibrium the concentration  $n_3$  of  $\text{O}_3$  is proportional to the concentration  $n_2$  of  $\text{O}_2$  as follows: [12]

$$n_3 = n_2 \left( \frac{J_2 k_2 n_m}{J_3 k_3} \right)$$

Discuss four major reasons why these equations are inadequate to describe the concentrations of ozone in the Earth's stratosphere? [8]

5. Why are the isotopes of the noble or inert gases such important indicators of the origin of planetary atmospheres? What do the isotopes from stable and radiogenic sources tell us about the planets and their atmospheres? [8]

Which potential explanations for the source of the atmospheres of the terrestrial planets do they eliminate and why? What is now thought to be their principal source? [6]

On Mars why is the ratio  $^{15}\text{N}/^{14}\text{N}$  much larger than on the Earth while the ratio  $^{18}\text{O}/^{16}\text{O}$  is comparable in magnitude? [6]