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 σ 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 so much larger than the measured atmospheric temperature. **[6]**

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

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:

(1) $O_2+h\nu_2$	$\Rightarrow$	$O+O$	J_2
(2) $O_3+h\nu_3$	$\Rightarrow$	O_2+O	J_3
(3) $O+O+M$	$\Rightarrow$	O_2+M	k_1
(4) $O+O_2+M$	$\Rightarrow$	O_3+M	k_2
(5) $O+O_3$	$\Rightarrow$	$2O_2$	k_3

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 O_2 and O_3. Show that in equilibrium the concentration n_3 of O_3 is proportional to the concentration n_2 of O_2 as follows: **[12]**

$$n_3{}^2 = n_2{}^2\left(\frac{J_2 k_2 n_m}{J_3 k_3}\right)$$

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 terrestial planets do they eliminate and why? What is now thought to be their principal source? **[6]**

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

END OF PAPER