Question 3

This question relates to Block 2, Chapters 1–3, and carries 18% of the marks available for this assignment.

Before you attempt this question, you need to read the following text, which is extracted from an article that appeared in the popular science magazine *New Scientist* in 1992. This extract covers various aspects of the formation of the Solar System, with some of which you should already be familiar from your study of Block 2, Chapters 1–3 (especially Chapter 2).

'We believe that we understand quite well how one particular fragment of gas collapsed to form our Solar System. The cloud fragment initially had a mass of about 2.5 times that of the Sun today, and it was about 100 times the width of the Solar System. It gradually shrank to the present size of Neptune's orbit, which has a radius of about 30 astronomical units (one AU is the average distance between the Earth and the Sun). Then the cloud became opaque and the heat generated as it continued to shrink could no longer escape. The temperature at its centre rose about 2000 °C, breaking up the molecules of hydrogen and then ionising both the hydrogen and helium atoms. This "sink" of energy destroyed the supporting pressure inside the core of the fragment, so it collapsed suddenly. The radius dropped precipitously from about the orbit of Neptune to that of Mercury in only a few years.

During this collapse, a huge amount of potential energy was released, making the collapsed core shine brilliantly as a "protostar". For a few years its luminosity flared up to about 10 000 times the present-day luminosity of the Sun.

The central temperature of the protostar rose steadily until it was sufficiently high for hydrogen nuclei to interact and fuse into helium. This generated thermonuclear energy which balanced the inward gravitational force. The protostar stopped contracting — it was now a star, the Sun.

The nebula cloud surrounding the protostar had a mass of between about 3 and 10 per cent of the Sun. It was hottest near the inner edge, and much cooler further out. As it cooled, nongaseous material in the nebula condensed into dust particles and snowflakes. These orbiting particles collided with each other, and ended up forming a flat disc of growing "planetesimals". In the mid-1980s, astronomers made infrared observations of just such a disc around the young star Beta Pictoris.'

(a) *(14 marks)*

(i) The second sentence of this extract suggests a total mass for the cloud fragment that formed the Sun and the solar nebula. With reference to Section 2.2 of Book 2, discuss which variety of the nebula theory is being described in this paragraph. *(1 or 2 sentences)*

(ii) There has evidently been a considerable loss of mass from the system as a whole between the stage described in the *first* paragraph and the stage described in the *last* paragraph. Based on what you have learned in Chapter 2 of Book 2:

- suggest ways in which this mass loss could have occurred between these two stages,
- state the processes of mass loss from the nebula covered in Chapter 2 that are *inappropriate* for the period between the two stages, giving your reasons for discounting them.

(No more than about 150 words)

(b) *(4 marks)* The last paragraph of the extract refers to the condensation of dust particles and snowflakes, the latter presumably meaning water ice. At what distance outwards from the Sun would you expect water ice to become able to condense, and what evidence is there that this did in fact take place? *(2 or 3 sentences)*

Question 4

This question relates to Block 2, Chapters 1–3, and carries 12% of the marks for this assignment.

Karla is a recently discovered icy body about 200 km in diameter, which orbits the Sun at 44 AU.

(a) *(10 marks)* Supposing that Karla accreted homogenously from a mixture of about 80% ice and 20% rocky material, discuss (non-numerically) the potential sources of heating, and whether any of these are likely to have ever been of sufficient magnitude to allow Karla to become differentiated.

(No more than about 200 words)

(b) (2 *marks*) If a body of Karla's proposed composition were differentiated, what would be the compositions of:

(i) its core, and

(ii) its mantle?

(No more than two or three words each)

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