Self-assessment questions for *An Introduction to the Solar System*

Question 1

This question is about the conditions on the surface of Venus, relates mainly to Chapters 1–3.
A major space agency is planning a mission to Venus code-named ‘LN-Hi-water’, which will involve a robotic lander imaging the landing site, and also determining the pressure, temperature and meteorological conditions at the planet’s surface.

(a) Outline the basic design requirements that will enable the lander’s sensitive instruments to survive long enough to send data back to the orbiting spacecraft. (*4 or 5 sentences*)

(b) Describe the types of surface features and conditions that the lander’s cameras are likely to observe. (*8–10 sentences*)

Question 2

This question is about the internal heating and volcanism of terrestrial-like planetary bodies and relates mostly to An Introduction to the Solar System, Chapters 2 and 3.

(a) Both the Earth and Io are volcanically active terrestrial-like bodies with broadly similar bulk (i.e. chondritic) compositions. In each case, identify the most common (i.e. volumetrically significant) lava products currently erupted on these two bodies. (*2 or 3 sentences*)

(b) Describe what is meant by the term ‘primordial heat’, and briefly outline its causes in terms of energy conversion processes. (*4 or 5 sentences*)

(c) Tidal and radiogenic heating are together responsible for the long-term internal heating of terrestrial-like bodies (e.g., Table 1). Briefly describe these processes, and outline how they might vary during the lifetime of such a body. (*5 or 6 sentences*)

(d) Complete Table 1 by entering the appropriate rates of current global heating for each process on Io and Earth, and from these data indicate the relative importance of the main sources of ongoing internal heating that contribute to this volcanism. (Note: you will need to calculate the rate of heat production in watts (W) generated by tidal and radiogenic heating within the Earth using the data in Chapter 2 and Appendix A. Show your working where appropriate, and express your answer to 1 significant figure.)

Table 1 Current global heat production in Io and the Earth.

Body	**Tidal heat production/W**	**Radiogenic heat production/W**
Io		
Earth		

(e) Which of Io and Earth is likely to lose its internal heat more efficiently? Explain your reasoning, and illustrate your answer with calculations based on the radii of each body.

Question 3

This question is about the nature of meteorites, and composition of terrestrial-like planetary bodies. It relates mostly to An Introduction to the Solar System, Chapter 2.

(a) Using the data provided in *An Introduction to the Solar System*, Figure 2.2, determine, in the correct order:

(i) the three elements that are most abundant in CI carbonaceous chondrites

(ii) the three elements that are most scarce in CI carbonaceous chondrites.

(b) Explain why the composition of CI carbonaceous chondrites is thought to represent the original 'primitive' composition of the solar nebula. (*1 or 2 sentences*)

(c) Three samples (A, B and C) have been discovered in a drawer in a famous natural history museum. Three unattached labels also lie in the drawer. On one is written 'Shergottite–Martian meteorite', on the second, 'L-Group chondrite', and the third is labelled 'lunar basalt'.

The museum curator has requested chemical analyses of all three samples in order that they may be labelled correctly and put on display. By comparison with previous finds, it is anticipated that the lunar basalt will be enriched in Ti and depleted in Na, and that the Martian sample will be enriched in K and Na relative to chondritic values. The results of the chemical analyses are given in Table 2.

Table 2 Concentration (in ppm) of selected elements in a typical CI carbonaceous chondrite in unknown samples in A, B and C, and chondrite normalized values for the samples (to be completed).

Element (ppm)	**Chondrite**	**Sample A**	**Sample B**	**Sample C**	***Chondrite normalized value (Sample A)***	***Chondrite normalized value (Sample B)***	***Chondrite normalized value (Sample C)***
Si	162 117	86 621	199 607	112 191			
Ti	445	438	15 600	4900			
Al	17 359	6616	40 752	19 264			
Fe	212 772	151 360	165 070	105 617			
Mn	1471	2323	2323	4010			
Mg	151 188	90 882	88 047	33 651			
Ca	19 082	9577	57 890	49 028			
Na	3709	5045	1484	7641			
K	545	739	600	1440			
Cr	3975	3011	1727	1350			

Using the data provided in Table 2, determine the chondrite normalized values for the elements of samples A, B and C, and tabulate your results. Express your answers to 3 significant figures.

(d) Using Figure 1, or by otherwise entering the data into (and using the functions in) a suitable spreadsheet program, plot your chondrite-normalized data for each sample on a log–normal graph (i.e. similar to *An Introduction to the Solar System*, Figure 2.3).

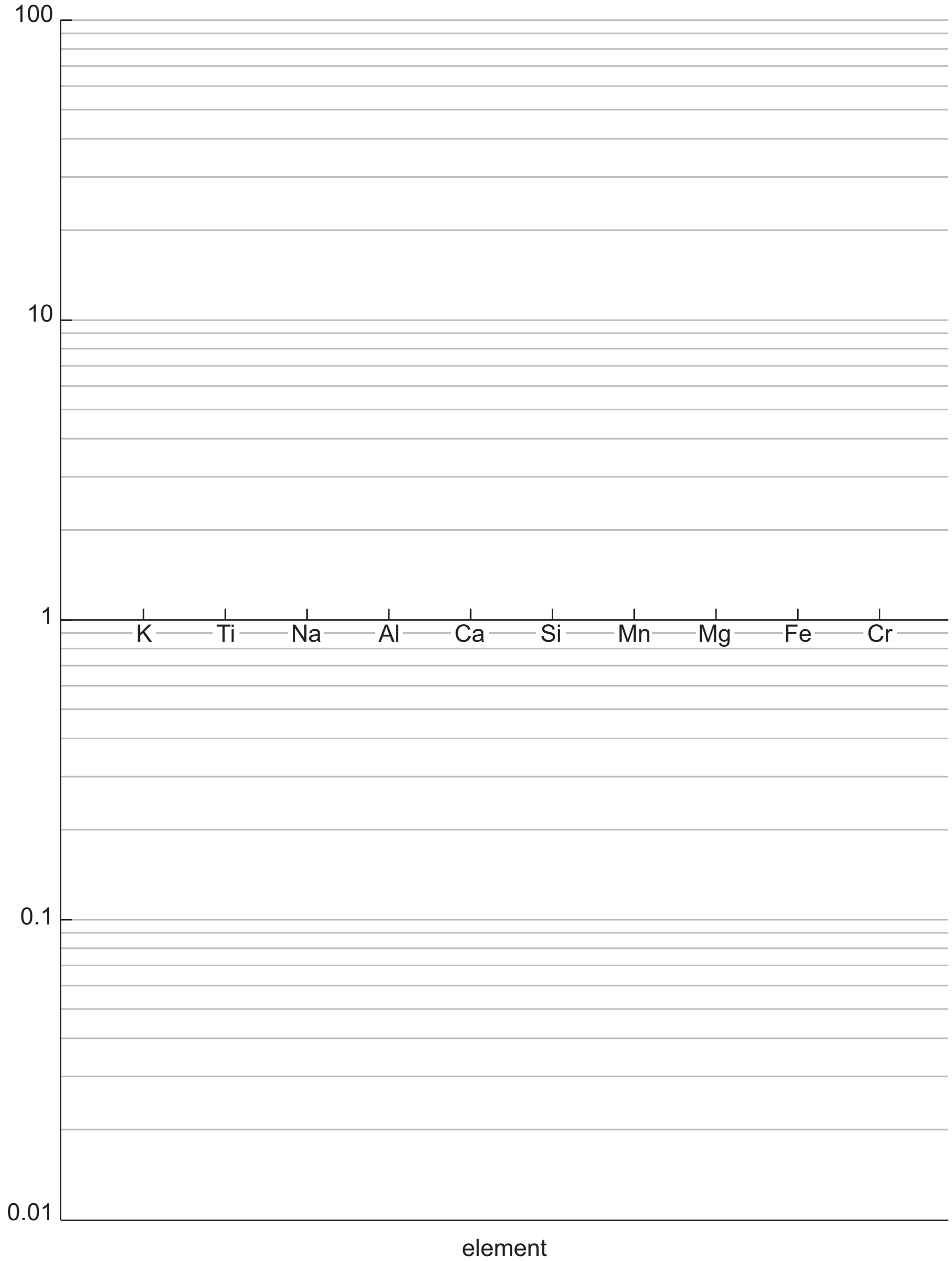

Figure 1 For use (if required) in Question 3.

(e) Briefly outlining your reasoning, indicate the correct labelling for the three samples. (*2 sentences for each sample*)

Question 4

This question is about the formation of impact craters. It relates to An Introduction to the Solar System, Chapters 1–4.

Examine, in particular, the following images of impact craters (and their captions) at the JPL Photojournal website http://photojournal.jpl.nasa.gov/

- PIA00210 and PIA00209– Golubkina crater, Venus
- Figure 2 (here)
- PIA00702. – Tyre, Europa
- PIA01088 – Nergal, Ganymede

Complete Part (a) of Table 3 (overleaf), describing the morphology of each crater listed at the start of this question and stating whether it is simple, complex or a basin.

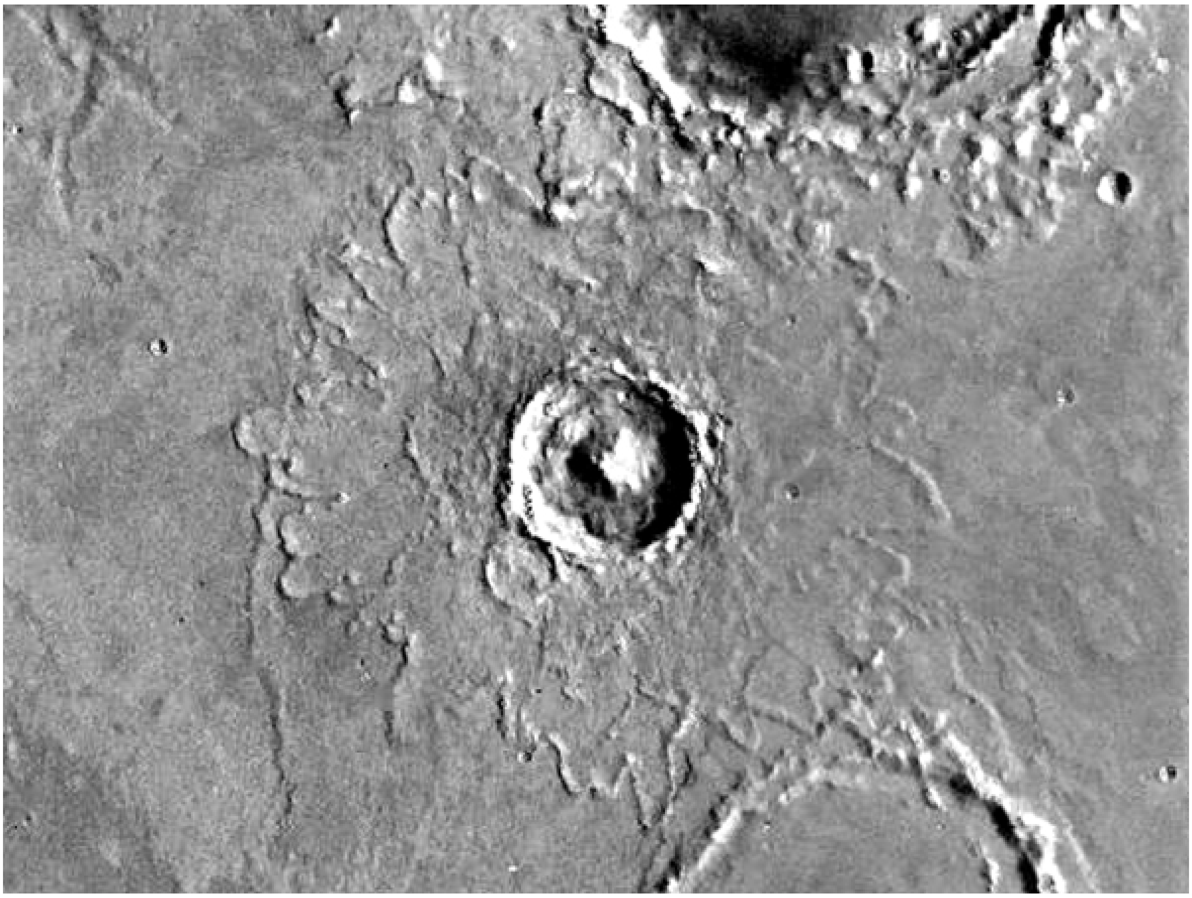

Figure 2 For use in Question 4. Yuty crater, Mars. The crater is about 20 km across. (Source: NASA).

Table 3 Crater morphology and impact data for selected craters.

Body	**Venus**	**Mars**	**Europa**	**Ganymede**
Crater name	*Golubkina*	*Yuty*	*Tyre*	*Nergal*
Central uplift peak (yes/no)				
Collapse terraces (yes/no)				
Crater type (simple/complex/basin)				

Question 5

This question is about the atmospheres of terrestrial planets, and relates to An Introduction to the Solar System, Chapter 5.

(a) In an atmosphere of a terrestrial planet, what is the troposphere, and why is the troposphere well-mixed? (*2 or 3 sentences*)

(b) As the altitude above the surface of a terrestrial planet increases, the atmospheric pressure decreases. By considering a ‘parcel’ of air, warmed by the surface and rising through the troposphere, explain why the decreasing pressure leads to a cooling of the troposphere as a function of altitude, and therefore define the adiabatic lapse rate. (*3 or 4 sentences*)

(c) The summit of Mount Everest is 8.8 km above sea level. Assuming a value for the temperature of air at sea level of 25 ºC and an adiabatic lapse rate of 9.8 K km^{-1}, calculate the temperature of air at the summit of Everest. Show your working.

(d) A climbing expedition reaches the summit of Mount Everest and attempt to boil water for a celebratory cup of tea. Unfortunately, they discover that the water boils at a temperature of 69 ºC rather than the sea-level value of 100 ºC, meaning that it is impossible to make good tea.
Water boils when its *vapour pressure becomes equal to the atmospheric pressure above its surface*, so that bubbles of water vapour (i.e. steam) can form in the body of the water. Using *An Introduction to the Solar System*, Figure 5.31 (Chapter 5, p. 187), estimate the atmospheric pressure at the summit of Everest, explaining your reasoning. (*2 or 3 sentences, plus working*)

(e) Curiously, on the Earth, the temperature above the troposphere rises with altitude, giving rise to a stratosphere. This situation is unique among the terrestrial planets, as shown in *An Introduction to the Solar System*, Figure 5.17 (Chapter 5, p. 174).
Briefly describe why this temperature profile occurs on Earth but not on the other terrestrial planets, and explain why this result prevents convective mixing of the stratosphere. (*4 or 5 sentences*)

Question 6

This question relates to An Introduction to the Solar System, Chapter 6.

Magnus is a newly discovered (fictional) giant planet, and has an atmosphere similar to those of Jupiter and Saturn. Answer the following questions about this planet. Where relevant, specify the equation you are using to derive your answer, show your working in detail (including units at each stage) and quote all results to a justifiable number of significant figures.

(a) (i) State four general characteristics of giant planets.

(ii) Describe the way in which the lowest level of the atmosphere is defined in a giant planet. (*1 or 2 sentences*)

(b) Explain how radio waves can be used to determine the average relative molecular mass of gases in the atmosphere. (*2 or 3 sentences*)

(c) State the three most commonly used wavelengths for determining the composition of the atmosphere remotely from orbit. Name an alternative type of instrument for making compositional measurements within the atmosphere itself.

(d) The ratio of Hydrogen (H_2) to Helium (He) for Magnus is 0.82:0.18.

(i) Explain why He is difficult to detect by the methods mentioned in parts (b) and (c) and summarise how these problems are overcome. (*2 or 3 sentences*)

(ii) Assuming the relative molecular mass of H_2 is 2.0 and He is 4.0, calculate the average relative molecular mass of Magnus' atmosphere.

(iii) Calculate the average mass (in kg) of a molecule in Magnus' atmosphere.

(e) The density of the atmosphere at the 1 bar pressure level is 0.65 kg m^{-3}. Calculate the temperature at the 1 bar level, showing your working and making the units explicit.

Question 7

This question relates mainly to An Introduction to the Solar System, Chapter 7.

(a) Define the following characteristics for orbiting bodies using your own words (*1 or 2 sentences for each*):

(i) aphelion

(ii) perihelion

(iii) major axis

(iv) semi-major axis

(v) eccentricity

(b) State Kepler's three laws (*1 sentence for each*). In addition, define the third law as an equation, and specify the units of all the quantities involved.

(c) A newly discovered asteroid, named Maia, is observed in a telescopic survey. Astronomers have analysed its orbit, which is found to have an eccentricity of 0.60 and a semi-major axis of 3.1 AU.

(i) Calculate the perihelion and aphelion distances, and the orbital period for Maia. (*Show your working, and quote your result to an appropriate number of significant figures*.)

(ii) State whether this asteroid, with its current orbit, could pose a risk to the Earth, and explain your reasoning. (*2 or 3 sentences*)

(d) Describe how lightcurve variations can reveal the shape and spin rate of asteroids. (*2 or 3 sentences*)

(e) Maia is found to have a ‘red’ appearance when observed. State the likely taxonomic class of Maia, and suggest the range of typical albedo values expected for the asteroid. (*2 or 3 sentences*)

Question 8

This question relates to An Introduction to the Solar System, Chapter 8. You are required to demonstrate your knowledge and understanding of the key stages of the nebula hypothesis for the origin of the Solar System, the differences in the formation of planets in the inner and outer Solar System and the timescales involved in Solar System formation.

This question requires you to demonstrate your skill in extracting and summarising information.

Write a short essay of approximately 600 words (*700 words maximum*) that describes the formation of our Solar System. In your answer you should keep in mind the evidence that has been gathered from astronomical studies (within and beyond the Solar System) and from chemical studies (e.g. of meteorites) of our Solar System and other systems nearby in our Galaxy.

In your account you must:

(i) Briefly describe the solar nebula model, and the formation of the early Solar System as suggested by this model

(ii) Summarise the key evidence supporting the solar nebula model and discuss the uncertainties in our understanding of Solar System formation.

In your account of the formation of the early Solar System you must consider the formation of the Sun, but you are not required to discuss the formation of planetary satellites nor explain the formation of the asteroids and the Kuiper belt. You do not need to provide timescales for the formation of the early Solar System.

Further advice about writing your account is provided below.

Advice for writing your account

Write your account at a level suitable for helping a prospective reader of this book who has not yet studied this material.

Scientific content

- You may, if you wish, take information from sources other than this book, where these are *relevant* to your answer, but you will be able to completely achieve the necessary outcomes without doing so.

Written communication skills

- You are *strongly recommended* to prepare a plan for your account before you begin writing it.
- You may feel that the use of diagrams and/or tables would enhance your account (and save you words), but they are *not* essential to achieve the outcomes on which you will be assessed.
- When planning your answer you will find it useful to note the page numbers (from the module materials or other sources) of the relevant items of information you plan to use. Doing this means that you will be able to refer back to them more easily when you begin to write your account. You do not need to include these personal notes in your answer.

It might also be helpful to consider the following in any essay writing:

- Include an *appropriate* introduction and conclusion.
- Try to be *coherent* (i.e. present the main topics in a logical order and clearly link them to the themes in the question).
- The *clarity* of your writing (i.e. the meaning is clear and contains no ambiguities) and your use of English is correct, (i.e. your essay is divided appropriately into paragraphs, and your spelling, punctuation, grammar and sentence construction are correct).
- Answer in a *concise* manner (i.e. within the word limit specified, and avoid including material that is irrelevant to the theme(s) of the question).
- Write at a *level* that is suitable for your target audience, using scientific language correctly and your own words.

Question 9

This question relates to An Introduction to the Solar System, Chapter 9.

(a) List the three main classes of meteorite and describe how they can be distinguished on the basis of their principal constituents. (*3 or 4 sentences*)

(b) Name the main technique that is most commonly used to link specific meteorite types with asteroid type. Support your arguments with at least one suitable example. (*2 or 3 sentences*)

(c) What are calcium–aluminium-rich inclusions (CAIs)? Describe the three competing theories for their origin, and briefly explain the two main techniques that scientists employ to distinguish between these theories. (*About 100 words*)

(d) Describe the role of the proposed ‘x-wind model’ in the formation of planetary systems around low-mass stars, such as our own Sun. (*6–8 sentences*)