

**PART A: Multiple choice questions. CIRCLE THE MOST CORRECT ANSWER (1 mark each)**

1. Which pair of planets have atmospheres with nearly identical chemical compositions, both being primarily carbon dioxide?
  - (a) Venus and Earth
  - (b) Venus and Mars \*
  - (c) Mars and Earth
  - (d) Mercury and Venus
  - (e) Jupiter and Saturn
  
2. In which pair are the planets nearly identical in size?
  - (a) Venus and Earth \*
  - (b) Venus and Mars
  - (c) Jupiter and Uranus
  - (d) Neptune and Saturn
  - (e) Mercury and Earth
  
3. Which of the following is farthest from the Sun?
  - (a) Pluto.
  - (b) The inner edge of the main asteroid belt.
  - (c) The Kuiper belt.
  - (d) the outer edge of the Oort cloud. \*
  - (e) Eris.
  
4. According to the nebular theory of solar system formation, we should expect:
  - (a) Planets with higher iron content to be farther from the Sun than those with less.
  - (b) All jovian planets to have at least fifty moons.
  - (c) All planets in the same solar system to rotate on their axes in the same direction.
  - (d) Most planets to be located within nebulae.
  - (e) All planets to orbit their parent stars in the same direction. \*
  
5. Sunshine breaks chemical bonds, causing reactions which produce “smog” in the atmospheres of jovian planets and their moons. Which type of photons in sunshine is most likely to be responsible for breaking chemical bonds?
  - (a) Infrared.
  - (b) Radio.
  - (c) Visible.
  - (d) Ultraviolet. \*
  - (e) Microwave.

6. Which of the following forms of electromagnetic radiation has the longest wavelength?
- (a) Radio waves \*
  - (b) X-rays
  - (c) Visible light
  - (d) Infrared radiation
  - (e) Microwaves
7. All of a star's absorption lines are seen to periodically move slightly to the red and then to the blue, and then repeat the cycle. What can we say for sure about this star?
- (a) It is getting periodically hotter and colder.
  - (b) It is moving periodically away and toward us. \*
  - (c) Its surface composition is changing.
  - (d) It is rotating on its axis.
  - (e) It is made of radioactive elements.
8. On my electric stove, one element is glowing yellow-orange and another is glowing a deep red. Their sizes are the same. Which of these must be true?
- (a) The orange element is brighter at all wavelengths than the red one. \*
  - (b) The orange element is cooler than the red one.
  - (c) The orange element has been on longer than the red one.
  - (d) The orange element is made of a different material than the red one.
  - (e) My dinner is burnt.
9. A star's spectrum is mostly continuous, but shows both absorption and emission lines. The **emission** lines could mean that:
- (a) There is cold matter between us and the star.
  - (b) The star is rotating very rapidly, shedding an opaque disk from its equator.
  - (c) The star is "burning" hydrogen
  - (d) The star has fewer heavy elements than the Sun.
  - (e) A hot cloud of transparent gas or plasma contributes light to the spectrum. \*
10. In the Nebular Theory for planet formation, why does Earth have to obtain its water from elsewhere?
- (a) Water came to Earth in vapour form, and water vapour only existed inside Earth's orbit.
  - (b) Water molecules were not present in the Solar Nebula.
  - (c) Earth was not large enough capture water vapour, and there was no other water inside the frost line. \*
  - (d) Young Earth was too smooth to retain any water.
  - (e) Earth prefers fashionable bottled water to the local stuff.

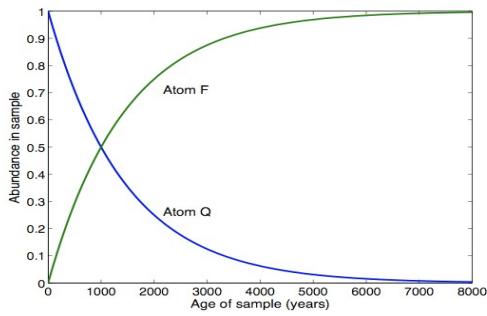


Figure 1.

11. Figure 1 shows a radioactive element and its daughter product which is used to date objects thousands of years old. Which of the following statements is most likely to be true?
- Atom F decays into Atom Q with a half-life of 3000 years.
  - Atom Q decays into Atom F with a half-life of 3000 years.
  - Atom F decays into Atom Q with a half-life of 1000 years.
  - Atom Q decays into Atom F with a half-life of 1000 years. \*
  - Atoms F and Q are not related.
12. Why does Earth have many fewer impact craters than Mars?
- Our thicker atmosphere filters small impactors, and tectonics and erosion erase big craters. \*
  - Our thicker atmosphere filters the largest impactors, and our stronger magnetic field protects us from smaller ones.
  - Insects bore into Earth's crater walls, weakening them, and they collapse in earthquakes.
  - Earth has a smaller surface area and weaker gravity, leading to a lower impact rate.
  - Earth is better protected from comet impacts by Jupiter's gravity field.
13. The Moon's *maria* were formed billions of years ago, when large impacts left giant craters which then filled with lava from the Moon's interior, leaving dark rock. If the Moon suffered a similar-sized impact today, what would happen to the newly-formed crater?
- It would be swallowed up by the Moon, because the Moon's core has contracted.
  - It would also fill with lava, leaving behind a new dark *mare*.
  - It would fill with lava, but the *mare* would stay light in colour because the Moon has lost its oxygen atmosphere.
  - It would not fill with lava, because the Moon's lithosphere is now too thick to be broken by such an impact. \*
  - The Moon would turn so the new crater faces the Earth, because tidal forces from Earth's gravity are now stronger.

14. Suppose the Earth has a very serious ice age, in which water freezes over the entire surface. What would happen next?
- (a) Nothing could warm the Earth up again.
  - (b) Ultraviolet sunshine would heat the upper layers of the ice and melt them.
  - (c) Earth would stop generating a magnetic field, wreaking havoc on the climate.
  - (d) Volcanoes would continue to spit CO<sub>2</sub> into the atmosphere. Without rain to remove it, CO<sub>2</sub> would build up, warming the planet until the ice melts. \*
  - (e) Ice-eating worms would take over the planet.
15. It is almost always colder at the peak of a mountain than at its base. Why?
- (a) The top of the mountain is cooled by clouds.
  - (b) The top of the mountain is closer to space, which is cold.
  - (c) The bottom of the mountain is closer to the centre of the Earth, which is hot.
  - (d) Rising air cools, because it expands as the pressure goes down. \*
  - (e) Faster winds at the top make it feel colder.
16. Mars rotates on its axis about as fast as Earth. Which is a good reason that Mars does not maintain a strong magnetic field like Earth does?
- (a) Mars' magnetic field is consumed by chemical reactions in its stratosphere.
  - (b) Being farther from the Sun, Mars is older than the Earth, and core convection decays over time.
  - (c) Mars does not have a metallic core.
  - (d) Mars' core does not convect because it is heated more weakly by radioactive elements.
  - (e) Mars' core does not convect because, being smaller than Earth, Mars cooled down earlier. \*
17. On the Earth, the Sun (which is white) appears yellowish or reddish because air scatters blue light away from the line of sight. What colour would the Sun appear to someone flying in the atmosphere (above the clouds) on Uranus or Neptune?
- (a) Blueish, because methane in those atmospheres scatters blue light more than red light.
  - (b) Reddish, because methane in those atmospheres scatters red light more than red light.
  - (c) Blueish, because methane in those atmospheres absorbs red light \*
  - (d) Reddish, because methane in those atmospheres absorbs blue light
  - (e) Blueish, because those atmospheres are hot and glow blue.

18. What special conditions allow for the larger jovian moons to be geologically active?

- (a) These moons cool very slowly thanks to a greenhouse effect from water atmospheres.
- (b) These moons have very radioactive cores.
- (c) Orbital resonances maintain heating from tides, and water ice melts more easily than rock. \*
- (d) They are strongly warmed by cooling radiation from the giant planets they orbit.
- (e) The question is false: they have all been solid snowballs since the early Solar System.

**PART B: Short answer questions. Answer ALL of the following questions in the spaces provided. Point form is acceptable where appropriate. Marks may be deducted for lack of clarity or conciseness.**

1. Draw a **CLEARLY LABELLED** diagram of a hypothetical solar system from the perspective of someone looking from the top down. Your solar system should obey the tenets of the nebular theory for the formation of solar systems. Assume the solar system contains only one star and that this star is identical to the Sun. Your diagram should include all of the following: the central star, and three planets at plausible distances from the star:

Planet A: made mainly of hydrogen,

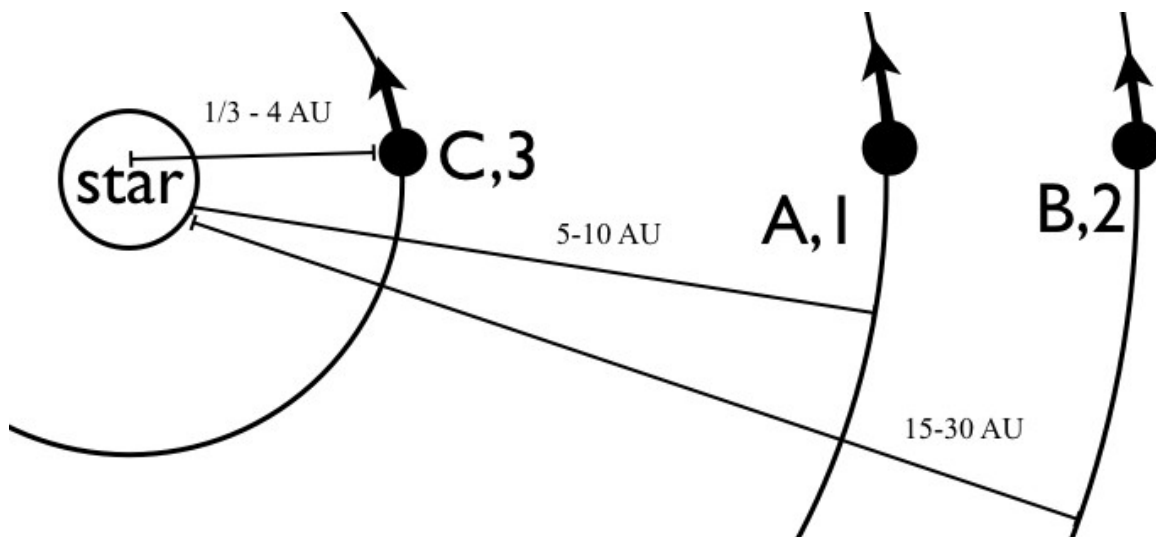
Planet B: mainly of ice,

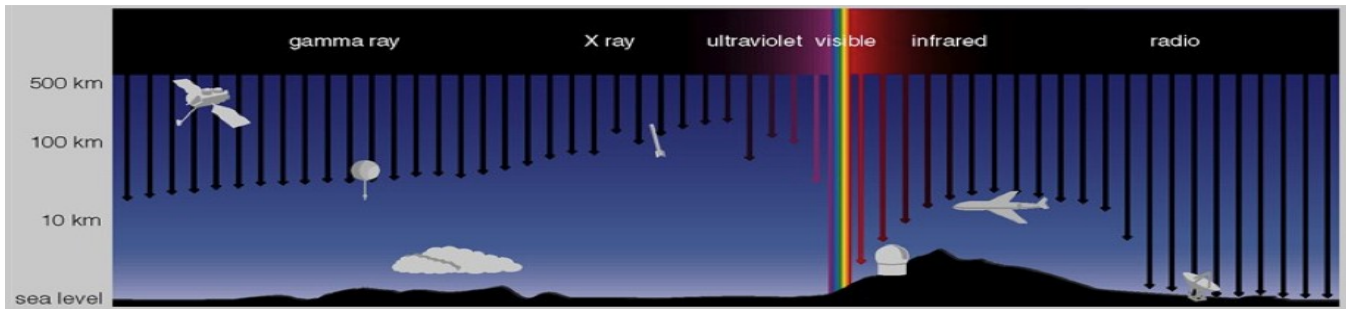
Planet C: made mainly of heavier elements.

(i) [1 point]: Show labels indicating the distance of each planet from the star in AU. (These should be consistent with the planets' compositions.)

(ii) [1 point]: Show the orbits of these planets, with arrows indicating which way each is orbiting.

(iii) [1 point]: Show labels ranking the planets according to their radii: 1 for the largest planet, 2 for the middle one, and 3 for the smallest planet.





2. The above figure shows how light travels through Earth's atmosphere. Where an arrow doesn't meet the ground, it means the atmosphere is opaque to light going either down or up. Use this information to **briefly and clearly** explain:

(a) [1 mark] Why human sight has evolved to sense what we call “visible” light.

Visible light, which is a primary form of electromagnetic radiation produced by the Sun, makes it through the Earth's atmosphere to the surface and can illuminate the world around us. (And, unlike radio waves, its wavelength is small compared to human beings; this allows our eyes to focus it.)

(b) [1 mark] Why the ground cannot cool off completely at night.

The ground is heated to a temperature for which its cooling radiation is infrared. However, the atmosphere is opaque to infrared radiation. The ground therefore cannot cool by radiating directly out to space.

(c) [1 mark] Why both the upper atmosphere and the ground are heated by sunshine during the day.

The Sun's hot surface produces visible light, which penetrates the atmosphere to warm the ground, but also ultraviolet and infrared radiation, which are caught in the upper atmosphere and heat the air. Both of these heat sources depend on sunlight, so they only occur during the day.

(d) BONUS [1 mark] If the Sun turned into a much hotter object which emits the same amount of light energy, but mostly at ultraviolet wavelengths, what might happen to Earth's atmosphere? Any well-reasoned answer will suffice.

If the Sun's radiation comes out mainly in ultraviolet wavelengths, then more of it would be caught in the upper atmosphere. This would lead the upper atmosphere to heat up more than it does now. Also, UV light can break chemical bonds, so there should be more chemical reactions in the upper atmosphere. At the same time, since the amount of sunlight energy is the same, less must be in the visible. Therefore there will be less direct heating of the Earth's surface by visible sunshine (which is now faint and blue). As a result, we can expect the Earth's surface to freeze. Over the long term, the shut-down of the carbon cycle could lead to enough carbon dioxide in our atmosphere to melt the surface once again.

3. The Nebular Theory implies that giant collisions (1) were common in the early Solar System, and (2) have greatly declined in frequency and severity but have not stopped. Give three pieces of evidence for points (1) or (2) in the current Solar System.

(a) [1 mark]

(b) [1 mark]

(c) [1 mark]

(d) [BONUS: 1 mark each for 1 or 2 more]

Any of the following, and possibly others: *individual craters and impacts*: Lake Manicouagan (Quebec), Meteor Crater (Arizona), Sudbury (Ontario), Chicxulub Crater (Yucatan Peninsula, Mexico), the Tunguska Event (Siberia, 1908); Herschel Crater on Mimas; the impact of comet Shoemaker-Levy 9 with Jupiter in the mid-1990s. Also: the giant impacts which formed the *maria* on the Moon; the giant impact which formed the Moon itself; the giant impacts thought responsible for the retrograde rotation of Venus and the sideways rotation of Uranus. *Less specific*: The impacts which caused craters on any rocky body, including the “late heavy bombardment”. The impacts of comets thought to have brought water to the Earth's surface. The fact that the terrestrial planets appear to have been built up by collisions of planetesimals, which were themselves built from collisions of dust particles.

4. [3 points] For the following three examples in our Solar System, briefly explain what allows (or allowed) abundant liquid water to exist there.

Current Earth:

The planet is large enough to retain an atmosphere, and produces a magnetic field thanks to convection and rotation in its core. Water was probably delivered to it by comets arriving from outside the frost line. The planet is neither too close to the Sun for water to be liquid, nor so far out that water must freeze. The thick atmosphere provides enough pressure for water to exist as a liquid. Most importantly, the atmosphere contains greenhouse gases which raise the average surface temperature from below freezing to above freezing.

Jupiter's moon Europa:

Water is frozen at the surface, but heat from the interior is thought to create a sub-surface ocean. The heat comes from tides which deform the moon's shape as it orbits. An orbital resonance with other moons keeps the moon's orbit eccentric and the tidal heating active.

Early Mars:

Judging from the evidence of past liquid water, Mars must have been like Earth: endowed with a thick atmosphere whose greater pressure would allow water to be liquid, and whose greenhouse effect raised the surface temperature above freezing.

**THE END**