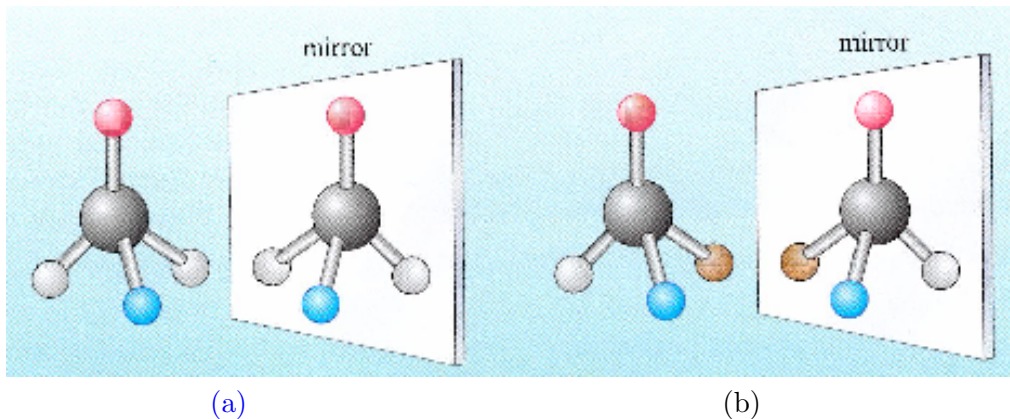


For the multiple choice questions, there is only one correct/best answer! Mark it with a circle. For text answers, short phrases are acceptable (and preferable) to short novels.

1. “RNA world” refers to [2pts]
 - (a) the idea that RNA was life’s genetic material before DNA,
 - (b) the idea that life originated in a hydrothermal vent
 - (c) the idea that life developed first in a deep biosphere
2. Which of these two compounds (also shown in the mirror) is *achiral* (or non-chiral). [2pts]



[On the left, there are 2 gray balls so the mirror image looks the same!]

3. In which of these environments would you likely find a psychrophiles? [2pts]
 - (a) A high-altitude desert
 - (b) An Amazon rain forest log
 - (c) A deep-sea vent
 - (d) A deep subsurface lake in the antarctic
 - (e) A wall in the Chernobyl reactor
4. Granite belongs to which of the following three basic rock types: [2pts]
 - (a) igneous rock
 - (b) metamorphic rock
 - (c) sedimentary rock
5. In the icy bodies of the solar system, the mantle consists mostly of [2pts]
 - (a) water ice
 - (b) liquid water
 - (c) water vapor
 - (d) ammonia
6. Halophiles are able to live in environments with a high level of salt because [2pts]
 - (a) they have protective proteins outside their cell walls
 - (b) they accumulate a highly alkalic liquid inside their cells
 - (c) they produce an at least equally salty liquid inside their cells
 - (d) their cells shrink so as to adopt to the osmotic pressure

7. On the Earth, the CO₂ cycle regulates the temperature by [2pts]

- (a) removing CO₂ through increased precipitation when it is hot
- (b) enhancing volcanic CO₂ output when the Sun was fainter
- (c) increased plate tectonics when the CO₂ level increases
- (d) increased outgassing when the mantle has accumulated enough limestone

8. The ¹³C isotope is [2pts]

- (a) enhanced in old trees
- (b) deficient in old trees
- (c) enhanced in biogenic carbon deposits
- (d) deficient in biogenic carbon deposits
- (e) enhanced in abiogenic carbon deposits
- (f) deficient in abiogenic carbon deposits

9. Finding exoplanets with the radial velocity (or Doppler) method allows one to obtain [2pts]

- (a) the radius of the planet
- (b) the mass of the planet
- (c) a lower limit on the mass of the planet

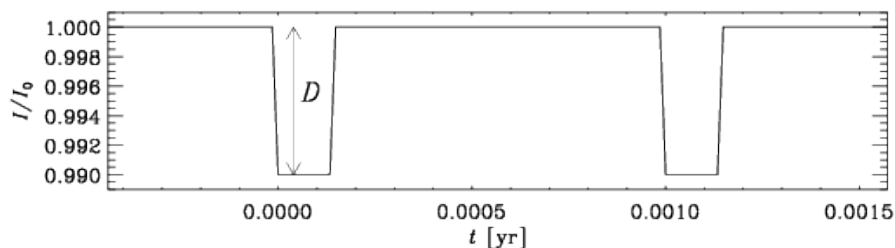
10. Finding exoplanets with the transit method allows one to obtain [2pts]

- (a) the radius of the planet
- (b) the mass of the planet
- (c) a lower limit on the mass of the star system
- (d) the mass of the star

11. Measuring the mass of the satellites of Jupiter and Saturn during fly-bys has been important for the realization that the satellites [2pts]

- (a) are tidally locked
- (b) have significant geological activity
- (c) have an extended icy crust
- (d) have a liquid subsurface ocean
- (e) have significant amounts of water in frozen or liquid form

12. Below is a light curve of a star with periodic dips with a relative depth Δ . The intensity I is normalized by the maximum value, I_0 .



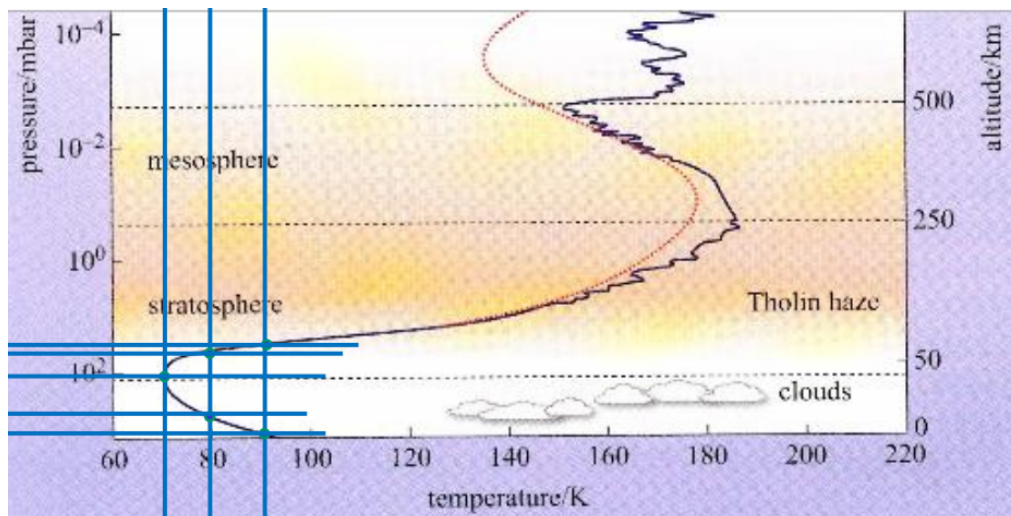
What is the ratio of the radius of the transiting planet to the radius of the star that the planet is orbiting? Remember that the occulted area scales quadratically with the radius. [2pts]

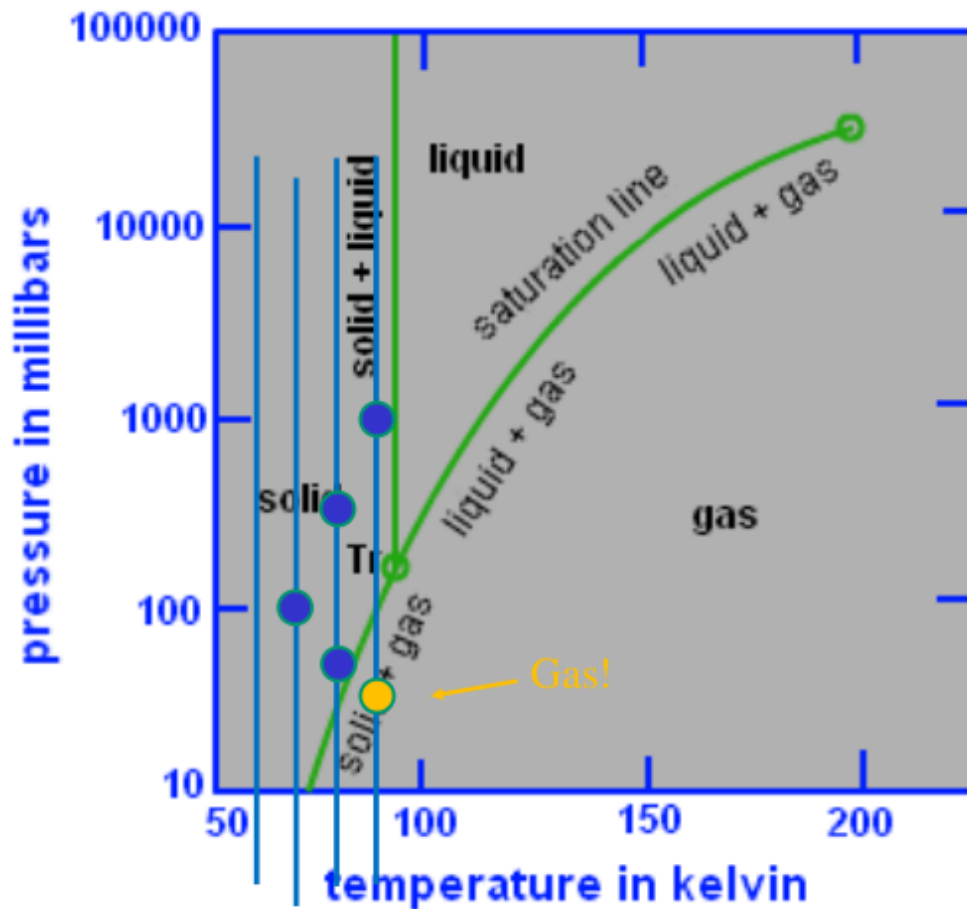
- (a) 1/2
- (b) 1/10
- (c) 1/100

13. Why does Venus have so much CO₂ in its atmosphere? [2pts]
- (a) Venus has extreme volcanic activity leading to significant outgassing,
 - (b) Venus has no rain water allowing CO₂ to be returned to the mantle,
 - (c) Venus is no magnetic field allowing the CO₂ to be removed by the solar wind.
 - (d) Venus has a strong greenhouse effect owing to its proximity to the Sun.
14. Stars are classified as O, B, A, F, G, K, and M stars, in that order. Which of the following statements is correct. [2pts]
- (a) O stars live longer and are more massive than M stars
 - (b) O stars live longer and are less massive than M stars
 - (c) O stars live shorter and are more massive than M stars
 - (d) O stars live shorter and are less massive than M stars
15. Name the corresponding counterparts for icy bodies. [10pts]

in terrestrial planets	in icy bodies
iron core	rocky core
mantle	water ocean
crust	ice layer
lava	slush ice or even water
volcanic CO ₂	CH ₄ (=methane)

16. The black line in the figure below shows the run of temperature (on the x axis) with altitude (y axis on the left). The pressure is also indicated on the left (second y axis). The next figure on the other page shows the phase diagram of methane (CH₄). *Note the log scale in both plots! Indicate intermediate tick marks where necessary.*





- (a) Mark the points on the black line on the left plot where the temperature is 90 K (two points), 80 K (two points), and 70 K (only one point).
 See the blue points in the figure above. [2pts]
- (b) Read off the corresponding pressures on each of the five points and write them in the empty fields in Table 1.
 See the blue numbers in the table below. [2pts]

Table 1: Fill in your *approximate* answers (in mbar) to items (b) and (d) in the fields below.

temperature	pressure (1st point)	phase?	pressure (2nd point)	phase?
90 K	1000	S	30	G
80 K	300	S	50	S
70 K	100	S	—	—

- (c) Mark all the five points in the phase diagram above with dots.
 See the blue points. [2pts]
- (d) Determine the phase for all five points. Write the corresponding answer in the five corresponding fields of Table 1. Use S for solid, L for liquid, and G for gas.
 See the blue and orange points. [2pts]
- (e) Where in the atmosphere do you expect methane in the gas phase?
 In the upper layers which is denoted by "Tholin haze", see the orange dot in the figure below. [2pts]

