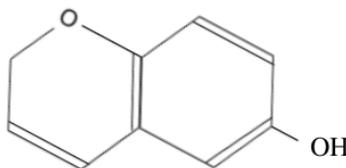


*Some of these questions you have seen before. Some of the questions for the actual final will be similar, but there will also be new ones. For the multiple choice questions, there is only one correct/best answer! Mark it with a circle.*

- Life produces
  - more order inside the cell
  - more disorder outside the cell
  - more disorder over all of the Universe
  - all of the above
- H<sub>2</sub>O is a
  - polar molecule
  - nonpolar (or apolar) molecule
- Which of the following macromolecules can act as an enzyme?
  - polysaccharides
  - proteins
  - lipids
  - DNA

4. What kind of macromolecule is



- (a) lipid (b) carbohydrate (c) protein (d) nucleic acid

5. What kind of macromolecule is



- (a) lipid (b) carbohydrate (c) protein (d) nucleic acid

6. Granite belongs to which of the following three basic rock types:

- (a) igneous rock (b) metamorphic rock (c) sedimentary rock

7. The discovery of 4.4 Gyr old zircons has been regarded as evidence for

- (a) sterilizing impact (b) stable continents (c) early water oceans (d) photosynthesis

8. In the icy bodies of the solar system, the mantle consists mostly of
- (a) water ice (b) liquid water (c) water vapor (d) ammonia
9. Finding exoplanets with the radial velocity (or Doppler) method allows one to obtain
- (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
- (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. Which of these chemical reactions occurs in alkaline vents to produce the energy for autotrophs?
- (a)  $3\text{Fe}_2\text{SiO}_4 + 2\text{H}_2\text{O} \rightarrow 2\text{Fe}_3\text{O}_4 + 3\text{SiO}_2 + 2\text{H}_2$   
 (b)  $3\text{Fe}_2\text{O}_3 + \text{H}_2 \rightarrow 2\text{Fe}_3\text{O}_4 + \text{H}_2\text{O}$   
 (c)  $\text{CO}_2 + \text{H}_2\text{S} \rightarrow \text{CH}_2\text{O} + 2\text{S}$   
 (d)  $\text{CaSiO}_3 + \text{CO}_2 \rightarrow \text{CaCO}_3 + \text{SiO}_2$
12. Earth's first atmosphere was chemically similar to those of Mars and Venus. How did our current atmosphere become so drastically different from our nearest neighbors'?
- (a) Life – early photosynthetic organisms converted  $\text{CO}_2$  to  $\text{O}_2$ .  
 (b) Volcanism & Tectonics – Earth's numerous volcanoes expel  $\text{O}_2$  gas while plate tectonics undertakes carbonate rocks.  
 (c) Asteroids – Impacts from space debris converted  $\text{CO}_2$  into  $\text{O}_2$  by impact ablation and high energy explosions.  
 (d) Water – Earth's liquid oceans provide a natural filter that strips the carbon from  $\text{CO}_2$ , leaving the  $\text{O}_2$ .
13. Measuring the mass of the satellites of Jupiter and Saturn during fly-bys has been important for the realization that the satellites
- (a) are tidally locked  
 (b) have significant geological activity  
 (c) have significant amounts of water in frozen or liquid form
14. "RNA world" refers to
- (a) the possibility that life migrated from Mars,  
 (b) the idea that RNA was life's genetic material before DNA,  
 (c) the idea that early life was made exclusively from RNA, needing no other organic chemicals

15. Why does Venus have so much CO<sub>2</sub> in its atmosphere?
- (a) Venus has extreme volcanic activity leading to significant outgassing,
  - (b) Venus has no rain water allowing CO<sub>2</sub> to be returned to the mantle,
  - (c) Venus is no magnetic field allowing the CO<sub>2</sub> to be removed by the solar wind.
  - (d) Venus has a strong greenhouse effect owing to its proximity to the Sun.
16. Stromatolites are
- (a) iron-reducing lithotrophs extracting energy from the rocks they are living on,
  - (b) photosynthesizing cyanobacteria growing on top of each other,
  - (c) hydrothermal alkaline vents harboring methanogens that life of hydrogen and CO<sub>2</sub>,
  - (d) sedimentary rocks in Western Australia where the oldest microfossils have been found.
17. In their original experiment, Miller/Urey used the gases H<sub>2</sub>, NH<sub>3</sub>, and CH<sub>4</sub>. They were chosen because they are all
- (a) reducing gases
  - (b) oxidizing gases
  - (c) polar molecules
  - (d) apolar molecules
18. In later experiments of Miller/Urey type, sulfur and carbon dioxide were also added, because on the early Earth they would be produced by
- (a) photosynthesis
  - (b) volcanoes
  - (c) lightning
  - (d) photolysis
19. A planetary system with a big Jupiter-sized planet could increase the possibility of finding life on an inner terrestrial planet, because it
- (a) prevents synchronous rotation on the inner planets
  - (b) helps reducing the rate of bombardment on the inner planets
  - (c) protects the inner planets from electrically charged particles
  - (d) facilitates panspermia on the inner planets
20. The Search for Extraterrestrial Intelligence has traditionally been conducted at or around the 21 cm radio wavelength, because
- (a) those waves penetrate dust and planetary atmospheres
  - (b) it is the wavelength used by any civilization to observe hydrogen in the galaxy
  - (c) any technically developed civilization would have sensitive receivers
  - (d) all of the above
21. Which of these nucleobases is a component in DNA but not in RNA?
- (a) Uracil [U]   (b) Cytosine [C]   (c) Adenine [A]   (d) Thymine [T]

22. The dense core of an Earth-like planet is found to occupy  $8/27$  the volume of the planet – what fraction of the planet’s radius does the core occupy?
- (a)  $2/27$       (b)  $4/9$       (c)  $2/3$       (d)  $1/9$
23. Two powders, one yellow and one purple, are stirred into a beaker of liquid *methane*. The purple powder dissolves completely, but the yellow powder collects on the bottom. What can you reasonably state about the chemical nature of these powders?
- (a) Purple is polar; yellow is apolar  
(b) Neither powder is polar  
(c) Yellow is polar; purple is apolar  
(d) Both powders are apolar
24.  $^{40}\text{K}$  decays into two daughter products:  $^{40}\text{Ca}$  and  $^{40}\text{Ar}$ . Why are we only concerned with the measurement of the second of these,  $^{40}\text{Ar}$ ?
- (a)  $^{40}\text{K}$  decays principally into  $^{40}\text{Ar}$   
(b)  $^{40}\text{Ca}$  from radioactive decay is indistinguishable from most other calcium  
(c)  $^{40}\text{Ca}$  is solid and can’t be measured in a laboratory  
(d)  $^{40}\text{Ar}$  is twice as massive as  $^{40}\text{Ca}$  and is easier to detect
25. In which of these environments would you likely find a xerophile?
- (a) A high-altitude desert  
(b) An Amazon rain forest log  
(c) A deep-sea vent  
(d) A wall in the Chernobyl reactor
26. Which of these is not necessarily needed for terrestrial life to function?
- (a) Free  $\text{O}_2$  gas    (b) Liquid water    (c) A carbon source    (d) Nitrogenous bases
27. Where do we think the Moon came from?
- (a) Earth captured the Moon after a close encounter between the two.  
(b) The Moon formed at the same time as the Earth, already in orbit.  
(c) A giant impact launched material into orbit around Earth which coalesced into the Moon.  
(d) The Moon was “spat out” by a rapidly rotating liquid Earth.
28. Marble is created when limestone is subducted beneath the surface and repeatedly folded over itself in the hot mantle (without melting). Knowing this, what kind of rock is marble?
- (a) Sedimentary.    (b) Metamorphic.    (c) Igneous.    (d) Marble is none of these types.

29. Why do we think life didn't begin in Earth's early oceans?

- (a) Earth's early oceans were too hot for life to form.
- (b) Nutrients in the ocean were too dispersed to be useful.
- (c) Earth's early oceans were actually liquid ammonia, not liquid water.
- (d) Early ocean water didn't contain dissolved carbon.

30. In the reaction  $\text{CO}_2 + \text{H}_2\text{O} + \text{energy} \rightarrow \text{CH}_2\text{O} + \text{O}_2$ ,

the energy comes from: (sunlight/molecules), so the relevant prefix is (photo/chemo)

the electron donor is: ....., which is (organic/inorganic), so (organo/litho),

and the carbon source is: ....., which is (organic/inorganic), so (hetero/auto),

and so it is a: .....troph.

31. In the reaction  $\text{CO}_2 + 4\text{H}_2 \rightarrow \text{CH}_4 + 2\text{H}_2\text{O}$ ,

the energy comes from: (sunlight/molecules), so the relevant prefix is (photo/chemo)

the electron donor is: ....., which is (organic/inorganic), so (organo/litho),

and the carbon source is: ....., which is (organic/inorganic), so (hetero/auto),

and so it is a: .....troph.

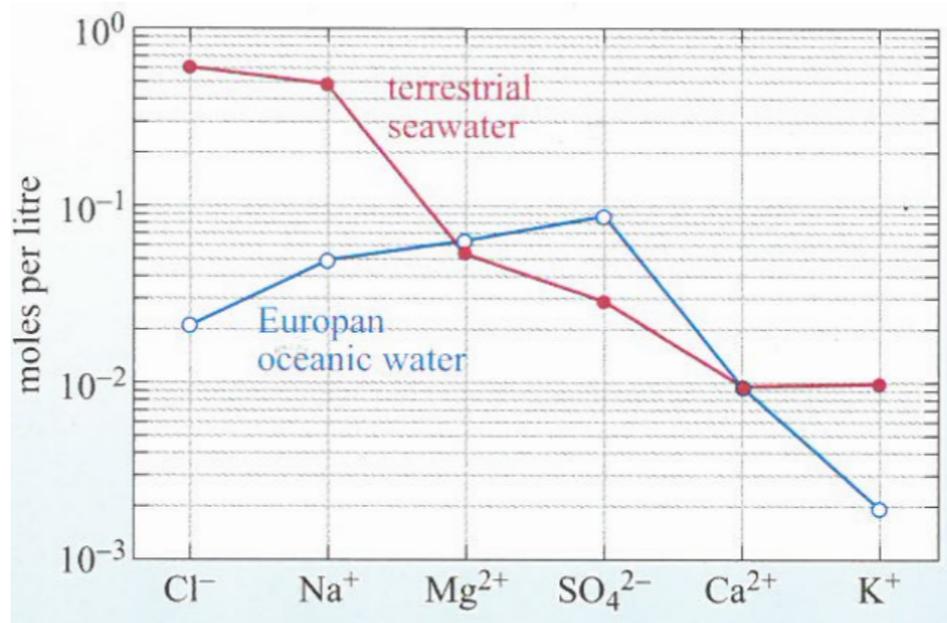
32. Explain why the simultaneous detection of oxygen (or ozone) together with methane in the infrared spectrum of an exoplanet's atmosphere constitutes strong evidence for life on that planet? (*Hint: can oxygen and methane coexist under equilibrium conditions?*)

33. We know that diseases evolve in response to the medicines designed to combat them. Explain briefly why this constitutes evidence supporting the theory of Darwinian evolution. Mention clearly the assumptions in Darwin's theory that you need for your argument.

34. List some of the arguments suggesting that carbon might be a central element also in extraterrestrial biochemistry.

35. What are the cell walls of life on Earth made of? Sketch them and list their important properties.

36. According to the figure below, how many more times greater is the concentration of chloride ( $\text{Cl}^-$ ) in terrestrial seawater than in Europa's ocean? (*Check carefully the numbers on the vertical axis, write down the two concentrations, and then divide.*)



37. A strain of gray slime producing bacteria is recovered from a deep gold mine in South Africa. This strain was found within a rock crevasse next to an active lava tube where pressures and temperatures routinely reach 10 atm and 190°F; moreover, this gold mine has an unusual concentration of other heavy metals like Zn, Cu, and Pt.

(i) What kind of extreme environments does this gold mine possess?

(ii) What kind of extremophile is this gray slime?

38. An alien genome is found to encode information using DNA very much like ours – however, this genome uses six bases (A,T,C,G,M,S) rather than the usual four (A,T,C,G).

(i) How many possible amino acids could this alien genome uniquely encode for?  
*(Explain how you calculate this; don't write just numbers!)*

(ii) How many possible amino acids could this genome encode for if each amino acid had three possible corresponding codons? *(Again, explain what you are doing!)*

39. What are three of Darwin's primary tenets for evolution by natural selection?

40. List some key properties of life as we know it.

41. Using your answer to the problem #40, answer the following, making special note of how *each of these* succeeds or fails:

(i) Is a star alive?

(ii) Is a virus alive?

42. The temperature  $T$  on a planet at a distance  $d$  from the Sun with radius  $R_S$  and surface temperature  $T_S$  is given by

$$T(d) = \sqrt{\frac{R_S}{2d}} T_S. \quad (1)$$

- (i) Show that

$$\frac{d(T)}{d(273 \text{ K})} = \left( \frac{273 \text{ K}}{T} \right)^2. \quad (2)$$

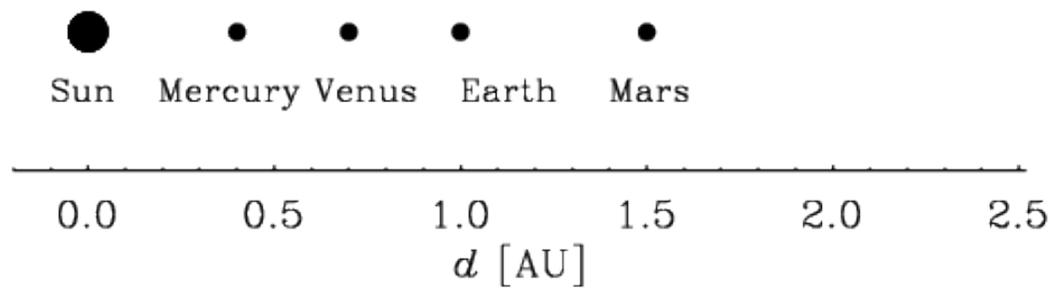
where  $d(273 \text{ K})$  is the distance where water freeze at 273 K temperature.

- (ii) Compute  $d(190 \text{ K})/d(273 \text{ K})$ , where  $d(190 \text{ K})$  is the distance from the Sun where ammonia freezes, which is at 190 K temperature. *You may use Equation (2) even if you weren't able to derive it.*

- (iii) Compute  $d(190 \text{ K})$ , assuming that  $d(273 \text{ K}) = 1.05 \text{ AU}$ .

(iv) As (iii), but now locate the boiling distance of ammonia, which occurs at 240 K temperature.

(v) Shade the habitable zone of ammonia on the plot below.



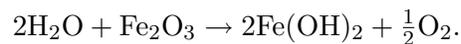
(vi) Do any of the Sun's planets fall within this ammonia habitable zone?

43. As Cassini flew over the “tiger stripes” on the surface of Enceladus, it recorded enhanced levels of periodic variations of hydrogen. Why is this thought to be evidence for hydrothermal vents at the subsurface ocean floor of Enceladus? (*Hint: inspect the reactions in question 11 above!*)

44. The second law of thermodynamics states that the degree of disorder of all of the Universe can only increase. Explain what life does to the degree of disorder and why this is not in conflict with the second law of thermodynamics.

45. Name the three basic rock types and explain them in a few words.

46. Iron-reducing bacteria make their biological living by performing the following reaction



In this reaction, iron (Fe) plays the same role that inorganic carbon (C) would play in “regular” biological reactions like photosynthesis. (Thus, instead of a carbon source, look for an iron source instead when making your choice.)

With this in mind, determine what kind of -troph this iron-reducing bacteria would be. Justify each of the prefixes used in your answer.

47. A sample of lunar rock had 80 mg of  $^{40}\text{K}$  at its formation. Assume for its half-life 1.25 Gyr and that 90% decays into  $^{40}\text{Ca}$  and 10% into  $^{40}\text{Ar}$ .

- How much  $^{40}\text{K}$  will be left after 2.5 Gyr?
- How much  $^{40}\text{Ca}$  will be produced after 2.5 Gyr?
- How much  $^{40}\text{Ar}$  will be produced after 2.5 Gyr?
- After 2.5 Gyr, what is the total mass of  $^{40}\text{K}$ ,  $^{40}\text{Ca}$ , and  $^{40}\text{Ar}$ ?

48. On the Earth, the carbon dioxide cycle between atmosphere and mantle operates in such a way that it regulates its temperature. Explain how this works with words and a diagram and why rain water and carbonate minerals are important for the  $\text{CO}_2$  cycle.