ASTR/GEOL-2040-001: Midterm Sample model solutions
Search for Life in the Universe (October, 2017)

Work carefully, you'll have enough time. Give enough details, not just the numbers. Don't expect full credits if you forget to draw a sketch. For the multiple choice questions, there is only one correct/best answer! Mark it with a circle.

1. The age of lunar rocks has been determined by measuring the

   (a) isotope ratios (b) zircon crystals (c) mineral content (d) total uranium content

2. What is the third-most abundant element in the Earth atmosphere

   (a) oxygen (b) carbon (c) neon (d) argon (e) potassium

3. A blue-green cell is floating in a petri dish of ocean water. When exposed to sunlight, the cell is observed to grow, multiply, and excrete oxygen gas – these behaviors end shortly after the light source is removed. What kind of organism is this cell?

   (a) photolithoautotroph (b) chemolithoautotroph (c) photolithoheterotroph
   (d) chemoorganoheterotroph (e) chemolithoheterotroph

4. Which of the following rock types have been found on the Moon?

   (a) granite (b) basalt (c) marble (d) sedimentary rock

5. In the reaction $CH_4 + H_2SO_4 \rightarrow H_2CO_3 + H_2S + H_2O$,

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

   the electron donor is: ....CH_4....., which is (organic/inorganic), so (organo/litho),

   and the carbon source is: ....CH_4....., which is (organic/inorganic), so (hetero/auto),

   and so it is a: .....chemoorganoheterotroph.

6. Why does Venus have so much CO_2 in its atmosphere?

   (a) Venus has extreme volcanic activity leading to significant outgassing,
   (b) Venus has no rain water allowing CO_2 to be returned to the mantle,
   (c) Venus is no magnetic field allowing the CO_2 to be removed by the solar wind.
   (d) Venus has a strong greenhouse effect owing to its proximity to the Sun.

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

   - Igneous rock: forms from molten rock, which then cools and solidifies
   - Metamorphic rock: chemically/structurally altered by pressure/temperature, not molten
   - sedimentary rock: formed from compression of sediments

8. What do geologists mean by the "boring billion"?

   (a) The time when the ozone layer was too thin to protect life from hazardous UV radiation and life could only survive under water.
   (b) The epoch during the Archean eon before photosynthesis led to a rapid growth of atmospheric oxygen.
   (c) The snowball Earth event when most of the life forms on Earth got extinct under a thick layer of ice.
   (d) A time during the Proterozoic eon when atmospheric oxygen stagnated at about 1% of the present level.

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

   - Order
   - Reproduction
   - Growth & development
   - Energy utilization
   - Response to environment
   - Evolutionary adaptation

10. A tree grows, literally, from thin air — all the carbon that goes into a plant's roots, bark, and leaves comes from CO_2 in the atmosphere, gained through photosynthesis.

    - CO_2 has a density of $2\,\mathrm{g/L}$, so how many liters of CO_2 are needed to grow a redwood tree $10^6\,\mathrm{kg}$, of which 50% is carbon?
      (i) Ignoring the fact that only about 1/4 of the CO_2 contains carbon, we can would say Volume = Mass/density, where Mass $= 0.5 \times 10^6\,\mathrm{kg}$ is the mass of carbon, which is 0.5 times the mass of the tree. So,

      $$\text{Volume} = \frac{5 \times 10^5\,\mathrm{kg}}{2 \times 10^{-3}\,\mathrm{kg/L}} = 2.5 \times 10^8\,\mathrm{L}$$

      would be the answer. In reality, as alluded to above, the fraction of carbon is $12/(12 + 2 \times 16) = 12/(12 + 32) = 12/44 = 3/11$, so the more correct answer is

      $$\text{Volume} = \frac{5 \times 10^5\,\mathrm{kg}}{(3/11)2 \times 10^{-3}\,\mathrm{kg/L}} = \frac{11}{3} \times 2.5 \times 10^8\,\mathrm{L} \approx 9.2 \times 10^8\,\mathrm{L}$$

    - Assume you exhale 100 liters of CO_2 per hour, how long would it take you to generate the required amount of CO_2? [Hint: for the purpose of this estimate, assume that 1 year has 10^5 hours.] Time = Volume/rate, so

      $$\text{Time} = \frac{2.5 \times 10^8\,\mathrm{L}}{100\mathrm{L/\,h}} = 2.5 \times 10^6\,\mathrm{h} \approx 25\,\mathrm{yr}.$$

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

- How much ^{40}K will be left after 1.25 Gyr?
  half the original value, i.e., 40 mg.

- How much ^{40}Ca will be produced after 1.25 Gyr?
  90% of the other half of the original value of potassium, i.e., $0.9 \times 40\,\text{mg} = 36\,\text{mg}$.

- How much ^{40}Ar will be produced after 1.25 Gyr?
  After 1.25 Gyr, we have $(1 - 1/2) \times 8\,\text{mg} = 4\,\text{mg}$,

- After 1.25 Gyr, what is the total mass of ^{40}K, ^{40}Ca, and ^{40}Ar?
  After 1.25 Gyr, we have $40\,\text{mg} + 36\,\text{mg} + 4\,\text{mg} = 80\,\text{mg}$,