SIO 40 Fall 2007 Homework 1 **Due Oct 5th**

This homework covers materials presented in lectures 1,2 and 3, as well as the accompanying reading assignments for those lectures (see syllabus). These are primarily short answer questions. In most cases, a few sentences should suffice. Please try to answer all questions in the space provided, use the back of the page if you have to. Be careful to answer each part of multi-part questions. **Note:** Homeworks will be graded on the basis of a *random subset* of these questions – so your best strategy will be to answer all the questions to the best of your ability.

1) Earth formed approximately 4.6 billion years ago. The first life forms are thought to have arisen about 3 billion years ago. Mankind (ie. *Homo sapiens sapiens*) arrived on the scene about 50,000 years ago. What if you were to compress this entire timeline into 60 minutes? Assuming the formation of the Earth occurred at time zero, at what time would the first life forms appear? When would mankind appear?

Assume 4.6 billion years ago was time 0.

4.6×10^9yrs/60 min = 3×10^9 yrs/39 min → 60 – 39 = 21 mins (time that first life appears)

4.6×10^9yrs/60 min = 5×10^4yrs/ 0.00065 min → 60 – 0.00065 = 59.999 mins (time that humans appear)

2) In this course we sometimes use “CH_2O” as a formula to symbolize “organic carbon” or “biomass” in chemical reactions. Does this chemical formula actually include all of the major elements which make up living tissue? Explain.

CH_2O is just a symbolic, shorthand representation of the organic molecules that make up living organisms, which on average contain the same relative ratios of C, H, and O atoms. N, P, and S are additional elements which also make up a significant component of biomass, but these are not included in the simplified “CH_2O” formula.

3) Given the following pairs of elemental compounds, circle the *more oxidized* form of each element:

for oxygen: [✓ O_2] or H_2O

for carbon: “CH_2O” or [✓ CO_2]

for nitrogen: NH_4^+ or [✓ NO_3^-]

for iron: [✓ Fe_2O_3] or FeS_2

4) Element X is found in two reservoirs on planet Earth: there are 10^{20} atoms of X in the lithosphere, and X is lost from this reservoir via volcanic eruption at a rate of 10^6 atoms per year.
Once erupted from volcanoes, X resides in the atmosphere, in which there is a stable inventory of 10^9 atoms of X. In which reservoir (the lithosphere or the atmosphere) does X have the longest mean residence time? (You should determine this not by guessing, but by calculating the residence time of X in each reservoir. Show your work.)

Residence time = Inventory/Flux
Since atmospheric reservoir of X is at steady state, the flux in must equal the flux out. So you can use the flux in (from the lithosphere, given above) to calculate the residence time of X in the atmosphere.
Lithosphere: Inventory = 10^{20} atoms; Flux out = 10^6 atoms/yr; Residence time = 10^{20} atoms/10^6 atoms/yr = 10^{14} yrs
Atmosphere: Inventory = 10^9 atoms; Flux in = 10^6 atoms/yr; Residence time = 10^9 atoms/10^6 atoms/yr = 10^3 yrs
Lithosphere has the longest residence time.

5) Name three “greenhouse gases” that are currently increasing in concentration in the Earth’s atmosphere. What is the primary source of these gases? Which of these geological archives is used to determine pre-industrial levels of these gases in the atmosphere? a) tree rings b) ocean sediment cores [✓ c) ice cores] d) zircon crystals

Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are all greenhouse gases which are currently increasing in concentration. The major sources of CO_2 are the burning of fossil fuels and land use changes (deforestation). The major sources of both CH_4 and N_2O are related to agriculture.

6) Is there currently scientific consensus regarding the overall effect that anthropogenic activities (ie. humans) have had on Earth’s climate, in terms of global warming? Explain.

Yes, there is a consensus. The most recent version of the IPCC Assessment Report states that there is a very high confidence that the global average net effect of human activities since 1750 has been one of warming.

7) What do glacial/interglacial records (going back about 400,000 years) indicate about the relationship between atmospheric CO_2 concentration and Earth surface temperature?

Glacial/interglacial records show that atmospheric CO_2 levels have varied in concert with changes in Earth’s surface temperature – when CO_2 levels were high, so were temperatures. This makes sense in that CO_2 is a greenhouse gas, and so higher CO_2 would be expected to correlate with higher surface temperatures. The relative timing of the changes in CO_2 concentration vs. changes in surface temperature concentrations is less clear – which came first?

8) Name the four fundamental components of the Earth system. According to the Gaia Hypothesis, which of these components is most important in terms of regulating Earth’s climate? Explain.

The four components of the Earth system are the atmosphere, lithosphere, hydrosphere, and biosphere. According to the Gaia Hypothesis, the biosphere plays a central role in regulating Earth’s climate by acting to keep conditions on Earth optimal for life. This theory that the biosphere is actively able to manipulate the Earth System is difficult to prove. In any case, living things do play an important role in the overall functioning of the Earth System by influencing the biogeochemical cycling of energy and materials through the system.

9) How is the Earth’s moon thought to have formed? What is one piece of available evidence to support this hypothesis?

The moon is thought to have formed from a giant, glancing impact between earth and a Mars-sized planetesimal shortly after Earth began to differentiate into different layers. The ring of debris from the impact orbited around the early Earth and eventually coalesced into the moon. Evidence for this includes similarities in oxygen isotope compositions between the Earth and the moon, and the fact that the moon is depleted in volatiles and iron relative to the Earth.

10) As we discussed in class, the Earth’s early atmosphere and oceans were produced during the bombardment period that lasted until about 3.8 billion years ago. What were the major constituents of the early atmosphere, and where did these volatiles come from?

The early atmosphere was primarily composed of CO_2, N_2, and H_2O. A major source of these volatiles was the impacts on the Earth of icy, rocky bolides coming from the outer part of the solar system. Volcanic emissions from the Earth’s interior provided an additional source of these compounds. One current controversy in earth science involves estimations of the amount of H_2 which might have been present in this early atmosphere, depending on how much atmospheric H_2 would have been retained from the period of earliest Earth accretion and hydrogen gas capture (vs escaping into space).

11) Name and briefly explain two important factors conducive to the development of life on Earth.

i) temperatures - between 0 and 100°C, to maintain the bulk of earth's water in a liquid state.
ii) the reducing atmosphere, with no O_2, was important in stabilizing the complex organic molecules that led to early life.

12) Although Venus and Earth are a similar distance from the sun and were similar in terms of their initial size and chemical composition when first formed by planetary accretion, the surface temperature of Venus is now about 400°C hotter than the surface temperature of Earth. Why is Venus so hot? Is the development of the Venusian atmosphere an example of a positive or negative feedback loop?

Being closer to the sun than the Earth is, Venus received significantly higher levels of solar radiation. Presumably this kept temperatures elevated to the point that all of the water on the surface of Venus, unlike on Earth, remained as water vapor in the atmosphere. The presence of water vapor, a greenhouse gas, caused atmospheric heating which further elevated the surface temperature. Eventually Venus lost all of its water to space (the water vapor migrated to the top of the atmosphere where it was dissociated by UV light, allowing the H atoms to escape). Lack of water is one factor that allowed CO_2 to build up to such high levels in the Venusian atmosphere, because there was no liquid water to dissolve the CO_2 and get it out of the atmosphere. Volcanism also contributed to the CO_2 and sulfur gases in the atmosphere. The development of the climate on Venus is an example of a positive feedback loop – a runaway greenhouse effect which destabilized the climate regulating system to cause uncontrolled heating.