Homework set #1 (assigned 27 January, due 5 February)

Instructions. These homework questions have many parts to them. Make sure you read the entire question and answer each and every part! You do not get any credit for problems or parts of problems that you do not even attempt. Please consult the course syllabus for general instructions on working together: I encourage you think, work, and discuss together, but you should *write your homework assignments individually, not together*. Your homeworks do not have to be typed/computered, although of course that is fine. While I don't technically "count off" for spelling, grammar, and punctuation, mistakes of that sort do annoy me, and intelligibility does matter. You should also use sentences and paragraphs that explain your answers, not just one word answers. You should make sure that in all case your units agree. That is, if you are using meters, seconds, and grams for your calculations, make sure you don't accidentally have any kilometers, years, or kilograms (or, heaven forbid, pounds) in your calculations or solutions. For these reasons and oh-so-many-others, please proofread your homeworks before you turn them in. **Homework is due in hardcopy in my hands due at the beginning of class on the designated due date**. I strongly suggest that you start looking over this homework assignment early – don't wait until the night before.

1) The bulk composition of the Earth is shown in Table 1. Compare this bulk composition to the cosmic abundance of elements at the formation of the Solar System. What elements are relatively enhanced in the Earth? What elements are relatively depleted in the Earth? Why do you think this is?

Jupiter's bulk composition is also shown in Table 1. Again, how does this bulk composition compare to the Solar System's composition (cosmic abundances) at its formation? Which elements are relatively enhanced and/or depleted, and why? How is Jupiter's bulk composition different from that of Earth's (in relative terms), and why? Hint: What do you know about Jupiter?

The composition of the Earth's lithosphere — the upper 10–30 km of the solid Earth — is also shown in the table. How does the bulk composition of the lithosphere compare to that of the bulk Earth, and to the Solar System's formation composition? What could explain these differences?

The composition of Earth's biosphere (all the living stuff) is also shown in the table. Again, how does this composition compare to Earth's lithosphere, the bulk Earth, and the pre-Solar System cosmic abundances, and why? What implications does this have for the search for life in the Universe?

2) This question will help you think about information and biomolecules. How many different nucleic acid bases are used in RNA? How many different combinations of these bases could you create if you had an RNA strand that was four bases long? How about if your strand was 8 bases long? or 80? You can see that the complexities of life can be stored in genes — you just need to make genes big enough and you can store arbitrarily large amounts of information in them. Information here simply means what kind of base you have in a given order, position, or sequence. How many pieces of information can be carried on a single human gene? Compare this to how many physical "characteristics" a human being has.

Now think about proteins. Proteins are made of amino acids, and life on this planet uses 20 different amino acids. How many different proteins could you make if you had a polymer that was 4 amino acids long? How about 8, and 80? So — you can see that, although protein polymer strands are made up of many fewer monomers than RNA polymers are (that is, protein chains have fewer units in them than RNA chains), there is still an enormous amount of complexity available for proteins. That explains (in part) why proteins are so flexible and valuable and have such a wide range of tasks in living systems.

3) Describe why, using terms like valence, ionic bond, covalent bond and also other things you have learned in the class so far, CH_4 (methane), NH_3 (ammonia), and CO_2 (carbon dioxide) were probably common molecules in the early Solar System but NH_4 (ammonium), SiO_2 (silicon dioxide, which is quartz), NaCl (sodium chloride, which is salt), and CO (carbon monoxide) might have been less common in the early Solar System.

4) The early Earth was a hot place. In addition to the many impacts of asteroids and comets and also in addition to volcanos, radioactive decay may have played a role in heating the early Earth. ^{26}Al is a radioactive isotope that decays to ^{26}Mg with a half-life of 720,000 years. Each atom of ^{26}Al that decays gives off 2.9×10^{-13} J (a Joule is the metric unit of energy).

When aluminum is created inside stars (and supernovas), the fraction of all aluminum that is ^{26}Al is around 5×10^{-5}. How much heat (energy) was created in the first 1.5 million years of the Earth's existence through radioactive decay of ^{26}Al? For the purposes of this problem, you may assume that the Earth's age started when it was fully formed, that is, no decay happened before the Earth reached its final mass of 6×10^{27} g. You also might want to know that there are 6×10^{27} atoms of Al in 27 grams of Al.

This amount of heat energy might not be that intuitive to you, so let's compare to something you do know about. *Power* is the amount of energy expended (or produced) over time. The metric unit of power is the Watt, and 1 W is equal to 1 Joule per second. How much power was produced from the ^{26}Al in the early Earth? How does this power compare to a common household appliance? How does it compare to the power output of the Sun, which is about 3×10^{26} W?

5) From the New York Times, Space.com, CNN, the BBC, or any other reputable news source, choose any recent astrobiologically relevant news article. Please do not choose an article that we have already talked about in the course so far. Write a one page summary, review, and discussion about this article. What are the main points of this article? Do you believe the conclusions? How does it relate to material that we have covered (and will cover) in the course?

Table 1: Approximate compositions (in percent by weight)

Element	Bulk Earth	Earth's lithosphere	Earth's biosphere	Bulk Jupiter
H	0.003	0.14	$<$1	86
He	$\sim$0	$\sim$0	0	14
C	$<$1	$\sim$10	$\sim$60	$<$1
N	$<$1	$\sim$8	$\sim$1	$<$1
O	30	46.6	$\sim$20	$<$1
Mg	14.9	2.1	0	0
Al	1.59	7.6	0	0
Si	14.9	27.7	0	0
S	1.9	$<$1	$<$1	$<$1
Fe	35	5.3	0	0
Other	5	$<$1	$<$1	$<$1