Homework 1 assigned: Tues, Sep. 30 due: Mon, Oct 13

Readings:

Earth System intro: KKC Chap 1 (all)
Nature of Science: Popper article "Knowledge without authority"
Stratospheric Ozone Depletion: KKC Chap 17 (all)

1. *Global warming:* Explain the difference between global warming and the greenhouse effect [6 pts].

2. *Global warming:* (a) By how much has Earth's atmospheric CO_2 concentration increased since the year 1800? [3pts] (b) What two types of measurements give scientists high confidence in this conclusion? [4pts] (c) What are thought to be the primary causes of this increase? [3pts]

3. *Temperature records:* (a) How far back in time (approximately) do direct measurements of the Earth's surface temperature extend? [3pts] (b) Give three reasons why is it difficult to determine accurately the long-term temperature trend for the globe? [9pts – 3 pts for each valid reason]

4. *Time scales:* Three global-scale environmental problems are: global warming, stratospheric ozone depletion, and loss of biodiversity. Characterize the timescale for recovery associated with each problem. Briefly explain your answers. [9 pts]

5. *Definitions from text and lectures:* Define the following terms in the context of this course: "anthropogenic", "fossil fuels", "stratosphere", "catalyst", "dynamic equilibrium" [2 pts each]

6. *Popper article:* Consider the following assertion of empirical knowledge:
Data from thermometers indicates that global average surface temperature in 1998 was the highest for any year since such data have been available.
Discuss how one would pursue "questions of origin" vs "questions of validity" in regard to this assertion. Use this discussion to distinguish what Popper means by these two phrases. [6 pts]

7. *Popper article and lectures:* Our society must make decisions with regard to environmental issues, and these decisions always depend, in part, on questions of scientific truth. A typical situation is that the scientific community, through official committees, will issue an assessment of current knowledge in order to inform the public discussion. Frequently, the scientific knowledge presented in these assessments is publicly attacked by so-called "skeptics", and these "skeptics" sometimes get "equal time" in media presentations. Explain how these attacks could be good for science but bad for societal decision-making. [6 pts]

8. *Ozone column depth and graph-reading:* Answers are found on graphs in Chap 17 and Chap 1. Be sure to give the units where appropriate. (For example, 300 Dobson Units or 300 DU, not just the number 300.) (a) What was the minimum ozone column depth observed over Melbourne, Australia from Dec, 1987 to Jan, 1988? (b) State a month of

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the year when ozone column depth over the equator is less than the amount given in a? (c) Ozone column depth shows a strong annual cycle at high latitudes. At 70° N, what month has the highest values of ozone column depth and what month has the lowest? (d) The ozone hole was first detected by ground-based measurements of ozone column depth over Halley Bay Antarctica. In terms of the October mean, what were typical values in the 1960's and how low had values fallen by the 1990's? [2 pts for each part]

9. *Chemical cycling through the atmosphere:* Referring to "The Chlorine Cycle" and "Ozone Hole" sections of Chap 17, answer the following. (a) Why have the concentrations of carbon tetrachloride and methyl chloroform responded so much more quickly to emission controls than have the concentrations of freon-11 and freon-12? [3 pts] (b) Explain how CFC emissions at the Earth's surface lead to enhanced chlorine concentrations in the stratosphere? Your explanation should mention "photolysis" and include the fact that CFCs are chemically inert. [6 pts] (c) State the two forms of "reactive chlorine". [2 pts] (d) State the two main forms of "unreactive chlorine" in the stratosphere. [2 pts] (e) Why is HCl (hydrochloric acid) removed very efficiently from the atmosphere? [3 pts]

10. *Chemical reactions of ozone formation and destruction:* The oxygen-only ozone cycle (or Chapman cycle) in the stratosphere can be represented by four reactions, shown below (but not in the usual order).

(1) $O_3 + O \rightarrow O_2 + O_2$
(2) $2O_2 + 2O \rightarrow 2O_3$
(3) $O_2 + UV \rightarrow O + O$
(4) $O_3 + UV \rightarrow O_2 + O$

(a) Which two represent ozone-production? (b) Which two are fast reactions? (c) Which reaction is catalyzed by reactive chlorine? [2 pts each]

11. *UV radiation:* Give two reasons why the flux of UVB radiation to the surface (and thus the danger of sunburn) is higher in the tropics than at high latitudes. [4 pts]

12. *Ozone hole:* What is the relationship between polar stratospheric clouds and heterogeneous reactions? [3 pts]

Extra Credit: Chap 17, Critical-Thinking Problems: 1a, b [4 pts], 2a, b [6 pts]