I. Objectives

1. Describe the basic differences between elements, minerals and rocks
2. Match the names and chemical formulas of some of the most common minerals
3. Apply the radioactive half-life equation to solve simple decay problems
4. Explain, in broad terms, why elements and atmospheric gases are found in their given abundances relative to cosmic levels.
5. Explain the process of environmental fractionation.

II. Introduction

This information will be helpful in answering the discussion questions.

Table 1: Some Properties of Earth's Closest Neighbors			
Property	Mars	Earth	Venus
Mass (10^{24} kg)	0.642	5.98	4.87
Gravity (m/s^2)	3.71	9.81	8.87
Distance to Sun (AU)	1.529	1.0	0.723
Average surface temperature (^{o}C)	-50	15	470
Surface pressure (bars)	0.007	1.0	90
Major atmospheric composition	CO_2	N_2, O_2	CO_2

III. Theory

You should be familiar with the basic radioactive decay equation:

$$N = N_o e^{-\lambda t} \quad (1)$$

where N is the current amount, N_o is the initial amount, λ is the decay constant and t is time. This equation can be simplified by taking the natural log of both sides, which shows that when the ratio is plotted on a log scale, the decay constant is the negative slope of the line:

$$\ln \frac{N}{N_o} = -\lambda t \quad (2)$$

For the special case where we are dealing with the half-life, this equation reduces to:

$$\frac{0.693}{\lambda} = -\frac{1}{\lambda}\ln\frac{1}{2} = t_{1/2} \;\Rightarrow\; \frac{0.693}{t_{1/2}} = \lambda \quad (3)$$

IV. Calculations

1. An isotope of cesium (^{137}Cs) has a half-life of 30 years. If 1.0 g of ^{137}Cs is all that is left after a period of 90 years, how many grams of ^{137}Cs did you start with?

$$\lambda = \frac{0.693}{30} = 0.0231\ yr^{-1}$$

$$N = N_o e^{-\lambda t} \quad \rightarrow \quad N_o = Ne^{\lambda t} = 1.0e^{0.0231(90)} = 8.0\ g$$

2. An isotope of carbon (^{14}C) is produced from ^{14}N in the atmosphere. It has a half-life of 5730 years. As living plants and animals respire, ^{14}C is incorporated in cells at the same ratio as it is found in the atmosphere. Once the organism dies, the ^{14}C starts to decay, altering the ration of carbon isotopes in the remaining material. What remaining fraction of the ^{14}C in a wood sample thought to date from the last ice age maximum, (11,640 yrs BP) would you expect to find?

$$\lambda = \frac{0.693}{5730} = 0.00012\ yr^{-1}$$

$$N = N_o e^{-\lambda t} \quad \rightarrow \quad \frac{N}{N_o} = e^{-0.00012(11640)} = .25 \text{ or } 25\%$$

3. Radioactive decay can also be used to date the age of the Earth. By measuring the ratio of ^{207}Pb (an isotope of lead) to ^{235}U (uranium) in rocks and comparing this ratio to values found in meteorites, it is possible to date the very oldest rocks on Earth because ^{207}Pb has a half-life of 704 million years. If the $^{207}Pb/^{235}U$ ratio from a sample of rock implies that 20% of the ^{207}Pb has decayed, how old is the rock? Note that the fraction of the original remaining is 80%.

$$\lambda = \frac{0.693}{7.04x10^8} = 9.844\ x\ 10^{-10}\ yr^{-1}$$

$$N = N_0 e^{-\lambda t} \quad \rightarrow \quad \frac{N}{N_o} = 0.8 = e^{-9.844x10^{-10}(t)}$$

$$t = \frac{\ln(0.8)}{-9.844x10^{-10}} = 227\ million\ years$$

V. Prelab Definitions

1. mafic

2. felsic

3. cation

4. anion

5. element

6. mineral

7. rock

8. isotope

9. radioactive decay

10. environmental fractionation

11. primordial

12. astronomical unit

13. bar (unit)

VI. Lab Procedure

1. Matching – draw a line connecting the mineral with its formula. Use one of the websites above if you need help.

Table 2: Mineral Names and Formulas	
Mineral name	Formula
Copper	$CaSO_4$
Gold	Cu
Silver	$NaCl$
Quartz	Au
Magnetite	$FeSO_4$
Galena	Ag
Pyrite	Fe_3O_4
Gypsum	$CaMg(CO_3)_2$
Halite	$CaCO_3$
Calcite	SiO_2
Dolomite	$Ca_3(PO_4)_2$
Apatite	$PbSO_4$

VII. Discussion and Problems

2. The evolution of Earth proceeded along a fortuitous pathway and gradually approached the conditions we are familiar with today. Based on today's lab lecture and the data in Table 1, outline the critical early developments in Earth's atmosphere that helped make Earth so receptive to life.

3. Compare some of the early stages with those of Venus and Mars, and explain why those planets followed a much less favorable evolutionary trajectory.

4. The half-life of isotope X is 3 years. How many years would it take for a 4.0 mg sample of X to decay to a remnant that weighs 0.50 mg?

$$\lambda =$$

$$N = N_o e^{-\lambda t}$$

5. The half-life of ^{14}C is 5730 years. If a sample has lost 40% of its ^{14}C (60% remains), how old is it?

$$\lambda =$$

$$\frac{N}{N_o} = e^{-\lambda t}$$

Lab courtesy of Dr. Jim Washburne