ESS 312 Geochemistry

Practice problems on geochronology and isochron diagrams

(1) Complete the following table:

You may wish to consult the Table of nuclides, here: http://atom.kaeri.re.kr/index.html?
or here: http://www.nndc.bnl.gov/chart/

| Parent nuclide | Decay mode(s) | Daughter nuclide | Half-life | Decay const ($\lambda$) | Minerals rich in parent element (for geochronology) |
|---|---|---|---|---|---|
| $^{87}Rb$ | $\beta^-$ | $^{87}Sr$ | $1.42 \times 10^{11}$ yr | | K-feldspar, muscovite, biotite |
| $^{187}Re$ | | | | | |
| $^{234}U$ | | | | | |
| $^{40}K$ | $^{40}Ca$ | | | | |

(2) Carbon-14 ($t_{1/2} = 5730$ years) is produced by cosmic ray reactions in the upper atmosphere, and quickly reacts to form $^{14}CO_2$, which mixes with isotopically normal $CO_2$ throughout the atmosphere, biosphere and upper oceans. All living organisms (including you) ultimately derive carbon from atmospheric $CO_2$, and while alive, maintain an isotopic ratio close to:

$$(^{14}C/^{12}C)_{initial} = 1.2 \times 10^{-12}\ .$$

After death, $^{14}C$ is no longer exchanged and the $^{14}C/^{12}C$ ratio begins to decrease by radioactive decay. C-14 dating is based on measuring the present-day ($^{14}C/^{12}C$) ratio in fossil carbon, and comparing it to the initial ratio to determine the time elapsed since death of the organism.

(i) Write an expression for the $^{14}C$ age, in terms of the present and initial $^{14}C/^{12}C$ ratios, and the $^{14}C$ decay constant $\lambda$.

(ii) While digging potatoes in your back yard, you unearth a mammoth tusk. A sample of protein extracted from the tusk has a $^{14}C/^{12}C$ ratio of $4.21 \times 10^{-14}$. How long ago did this mammoth live? Note: $\lambda = 1.21 \times 10^{-4}$ yr$^{-1}$.

(iii) What assumptions do you have to make when calculating this $^{14}C$ age? What precautions would you need to take when preparing and handling the sample in the lab?

(2) Use EXCEL (or MATLAB, or Mathematica, or Maple, or even graph paper) to plot the following isochron data, and determine the age of the rocks from which they were taken.

(i) Granodiorite intrusion from the Shaw Granitic Complex, underlying Proterozoic rocks of the Mt Bruce Supergroup. (Note - this includes the Hamersley Ranges Banded Iron Formation sequence, ancient sedimentary rocks which mark the growth of oxygen in Earth's atmosphere).

| Mineral | Present-day $^{87}Rb/^{86}Sr$ | Present-day $^{87}Sr/^{86}Sr$ |
|---|---|---|
| apatite | 0.02 | 0.7014 |
| plagioclase | 1.70 | 0.7732 |
| k-feldspar | 5.50 | 0.9356 |
| biotite | 9.00 | 1.0853 |

(ii) Garnet-bearing granulite gneiss from the Furua Complex in Tanzania. Metamorphism of this rock is associated with the Pan-African Orogeny, a complex sequence of thermal and tectonic events preceding formation of the supercontinent Gondwana.

| Mineral | Present-day $^{147}Sm/^{144}Nd$ | Present-day $^{143}Nd/^{144}Nd$ |
|---|---|---|
| apatite | 0.211 | 0.51347 |
| plagioclase | 0.552 | 0.51509 |
| amphibole | 0.710 | 0.51583 |
| garnet | 3.224 | 0.52770 |

(iii) Jingchuan Ni-Cu-Pt deposit, China.

| | Present-day $^{187}Re/^{188}Os$ | Present-day $^{187}Os/^{188}Os$ |
|---|---|---|
| Whole-rock | 6.11 | 0.2533 |
| molybdenite | 34.4 | 0.6711 |

You will need the following decay constants:

$\lambda\ ^{87}Rb = 1.42 \times 10^{-11}\ yr^{-1}$

$\lambda\ ^{147}Sm = 6.54 \times 10^{-12}\ yr^{-1}$

$\lambda\ ^{187}Re = 1.67 \times 10^{-11}\ yr^{-1}$.