GEOL 103 Writing Assignment 4: Radiometric Dating

Name __________ KEY __________ Lab section: Monday or Tuesday (circle one)
To be counted, must be turned in by Monday, Oct. 28.

What we need to know to apply radiometric dating:

$^{40}$K has the simplest decay scheme, and is the only one we’ll examine in detail.

1. The **half-life** of a radioactive parent isotope = time required for half of the **remaining parent** to decay to a **stable** (non-radioactive) daughter isotope.
2. **Half-lives are constant** - not affected by anything we know of.
3. $^{40}$K decays to $^{40}$Ar with half-life = 1300 million years.
4. $^{40}$K and $^{40}$Ar **can be measured** in a mass spectrometer.
5. $^{40}$K is decaying to $^{40}$Ar **all the time**, but $^{40}$Ar is a gas and can escape **if** a mineral is above the "blocking temperature". Below the blocking temperature, $^{40}$Ar is **trapped** in the mineral.
6. If a mineral is **heated above the blocking temperature**, $^{40}$Ar is lost.
7. **Different isotopes** (of U, K, Rb, Sr, etc) used in dating have different blocking temperatures.

![Fig. 9.15](image)

Problems:
General algorithm to solve these problems, where $P =$ # of parent atoms, $D =$ # of daughter atoms

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P_{\text{orig}} = P_{\text{now}} + D_{\text{now}}
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Proportion of $P_{\text{orig}}$ remaining = \( \frac{P_{\text{now}}}{P_{\text{now}} + D_{\text{now}}} = \frac{P_{\text{now}}}{P_{\text{orig}}} \)

\( P_{\text{now}}/P_{\text{orig}} \) can be related to the graph above to determine the number of half-lives that have passed since the rock went below the blocking temperature for that isotopic system. E.g, if $P_{\text{now}}/P_{\text{orig}} = 0.125 = 1/8$, then 3 half-lives have passed.

If 3 half-lives have passed, therefore \((3 \text{ half-lives}) \times (X \text{ million years/half-life}) = \text{age of rock in years}\).

1A) How old is a rock if the mineral biotite from the rock has 100,000 $^{40}$K atoms and 100,000 $^{40}$Ar atoms? 1/2 of the original parent has decayed, thus one half-life has passed, and the rock is 1.3 billion = 1300 million years old.

1B) What if it had instead 125 $^{40}$K atoms and 875 $^{40}$Ar atoms?
All of the daughter was once parent, so $125/(125+875) = 125/1000 = 0.125$ gives 12.5% of the parent remaining. Thus 3 half-lives have passed, and the rock is $3(1.3 \text{ billion}) = 3.9 \text{ billion years old} = 3900 \text{ million years old}$.
2) If one metamorphic rock (that was a granite before metamorphism) gives a K/Ar date of 280 million years and a U/Pb date of 1 billion years, what is each date telling us? How old is the rock, and how are we defining “the rock?” The K/Ar date likely gives the age at which the metamorphic rock, which had been a granite and then reheated by metamorphism, cooled below the blocking temperature for K/Ar, so the 280 million year age is the age of metamorphism. The rock apparently did NOT go above the blocking temperature for U/Pb. The U/Pb date likely gives the age at which the granite, cooled below the blocking temperature for U/Pb, so the 1 billion year age is the age of the granite.

The rock is 280 million years old if we are referring to the metamorphic rock; 1 billion if referring to the granite.

3) Isotopic analysis of a granitic intrusion indicates that 25% of the original $^{40}$K is present. Analysis of a nearby basaltic intrusion indicates that 50% of the original amount of $^{40}$K is present. What is the absolute age of the granitic intrusion (in years)? 2.6 billion years old. What is the absolute age of the basaltic intrusion (in years)? 1.3 billion years old. The basaltic intrusion cuts through the granitic intrusion. Does this makes sense with the dates above? Why? Yes, the basaltic intrusion cross-cuts the granitic intrusion, telling us that the basaltic intrusion is younger.

4A). Pebbles of an igneous rock are incorporated within a conglomerate. The pebbles yield a radiometric age of 300 million years. What can you say about age of the conglomerate based on this data? The conglomerate is younger than the pebbles, so it’s younger than 300 million years.

4B) The same conglomerate is intruded by a dike that yields a radiometric age of 200 million years. What can you now say about the possible age range of the conglomerate? The conglomerate is younger than the pebbles, and also older than the 200 million year-old dike which cross-cuts it, thus the age is between 200 and 300 million years.

5) Would it be possible to use $^{14}$C age dating to estimate the age of a rock containing carbon from the time of the dinosaurs? Explain. (Dinosaurs became extinct at the end of the Mesozoic. See Fig 9.13) No. The end of the Mesozoic was 65 million years ago. Because the half-life of $^{14}$C is only 5730 years, all the $^{14}$C would have long since decayed away. $^{14}$C dating is no good past about 50,000 to 100,000 years.

6) How many half-lives are required to yield a mineral with 625 atoms of $^{238}$U and 19,375 atoms of $^{206}$Pb? (The half life for $^{238}$U to $^{206}$Pb decay is $0.71 \times 10^9$ years) $625/(625+19,375) = 625/(20,000) = 0.03125 = 1/32$. 3.125% of parent remains, and 5 half-lives have passed. The half life for $^{238}$U to $^{206}$Pb decay is $0.71 \times 10^9$ years, so 5 x 0.71 x $10^9$ years = $3.55 \times 10^9$ years.

7) Calculate the age of a rock containing the following atoms of radioactive parent element A:1,125,000 atoms. Stable daughter element B:34,875,000 atoms. The half-life of element A is 6.25 million years. What is the absolute age of the rock containing these parent and daughter elements? $1,125,000\,\text{atoms}/(1,125,000\,\text{atoms} + 34,875,000\,\text{atoms}) = 1,125,000\,\text{atoms}/36,000,000\,\text{atoms} = 0.03125 = 1/32$. 3.125% of parent remains, and 5 half-lives have passed. 5 x 6.25 million years = 31 million years.

8) A bone was recently recovered from a site in eastern Africa. Radiocarbon dating suggests that the bone contains 12.5% of the original amount of $^{14}$C. How old is the bone? (Half life of $^{14}$C = 5730 years) 12.5% of the original remaining indicates that 3 half-lives have passed. 3 half-lives x 5730 year/half-life = 17190 years old.