Department of Chemistry
University of Texas at Austin

Name:_______________

Nuclear Chemistry Unit Activity – Rate of Decay KEY

The purpose of this activity is to develop the concept of radioactive decay by simulating a radioactive decay in class. The faster an isotope decays, the less stable the isotope! You will need a coin, your I-clicker and a writing utensil.

You are a radioactive isotope: Po-210. You will undergo alpha decay and become Pb-206, a stable isotope. You will know if you emitted an alpha particle during a certain time interval, if upon the flip of a coin, you observe tails. If you flip and you end up with heads, you do not undergo decay during the designated time interval. When advised please stand and flip your coin.

Heads – you HAVE NOT undergone decay, remain STANDING.
Tails – you HAVE undergone decay, please SIT, and do not stand or flip again.

At the appointed time you will stand. Then, you will listen carefully to the instructions from your instructor to begin filling in the data table.

1. Write a balanced nuclear equation for the alpha decay of Po-210.

$^{210}Po \rightarrow {}^{4}He + {}^{206}Pb$

Clicker Question:
A) Standing (Po-210) B) Sitting (Pb-206)

Collect your data (via clicker questions, have TA at doc-cam fill in standers)

Event (time)	Standers (Po-210)	Sitters (Pb-206)	Change
0	365	0	0
1	167	198	198
2	95	270	72
3	52	313	43
4	25	338	27
5	14	347	11
6	9	352	5
7	4	361	5
8	2	363	2
9	1	364	1
10	1	364	0
11	1	364	0
12	0	365	

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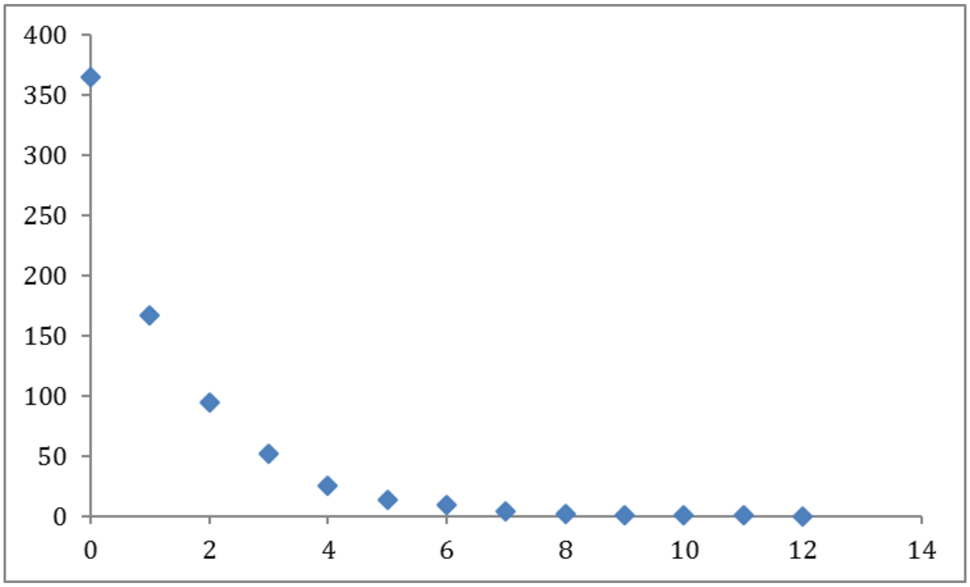
3. Plot your data on the graph below:



Elapsed Time (138.4 days per unit)

4. Is your graph linear?

No.

5. Is the slope constant?

No.

6. Was the elapsed time between events the same?

Yes.

7. Looking at the graph you just created, is the amount of Po that decays the same with each event?

No.

8. When is most of the Po lost? Why?

Clicker question

The first event. As about half of the Po is lost at each event, the first event, when you have the most to begin with is also when you have the most to lose. For example, if you have 12 apples and lose half of them, you would lose six entire apples. However, if you only started with two apples and you lose half, you would lose just one apple! The more stuff you have to begin with, the more stuff you have to lose if you cut your amount in half.

9. Complete filling in the table. Calculate and record the amount of Pb-206 present at each time period. Calculate and record the change in the amount of Po-210. (at each event #, record the amount of Po-210 left at that event minus the amount from the previous event. Report the absolute value.)

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10. Is there a relationship between the number of Po that decay during the given time period and the number of Po that you started with for that decay time period?

Clicker question

Yes. There cannot be more Po lost than we started with. Also, if only one time period has passed, then half of the Po has decayed. If two time periods have passed, one fourth of the original Po is left, meaning the three-fourths has decayed. It seems like we keep cutting the amount in half after each time period.

ΔPo = - ΔPb

(whole class check in)

11. Is there a relationship between the change in the number of Po and the change in the number of Pb for the given time period?

Clicker question

Yes. As the change in the number of Po goes down, the amount of Pb increases by the same rate.

Mini-lecture on rates

12. What is the "rate" of alpha particle emission compared to the rate of production of Pb? Compared to the rate of decay of Po?

The "rate" of alpha particle emission is the same as the rate of production of Pb. That is, for every one alpha particle released, there is a Pb produced--at the same time, at the same speed.

Likewise, at the same rate the alpha particles are emitted and Pb is produced, Po is decaying.

13. Write a mathematical expression to show the relationship defined in question 11.

-change in Po over time = change in Pb over time

we can write it like this:

$$-\frac{\Delta Po}{\Delta t} = \frac{\Delta Pb}{\Delta t}$$

14. Using that mathematical expression of rate of change of Po-210 with change in time, express a proportionality relationship with the starting amount of Po-210.

$$-\frac{\Delta Po}{\Delta t} \alpha [Po_{initial}]$$

14. Can we express the proportionality expression in 13 as an equality? How?

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$$-\frac{\Delta Po}{\Delta t} = k[Po_{initial}]$$

Where k is a rate constant.

(whole class check in)

The half-life of a nuclear decay has been defined as the time it takes for the nuclear decay of ½ the initial amount of radioactive isotope.
Half life, $t_{1/2}$, for Po-210 is 138.4 days.

15. Imagine we started with 96 student isotopes. How many ½ lives would have to pass to get to 6 student isotopes left?

Clicker question

4 events

1st: 96/2 = 48

2nd: 48/2 = 24

3rd: 24/2 = 12

4th: 12/6 = 6

16. If you had 960 student isotopes, how many ½ lives would have to pass to get 60 student isotopes left?

4 events

1st: 960/2 = 480

2nd: 480/2 = 240

3rd: 240/2 = 120

4th: 120/2 = 60

17. P-32 has a half-life of 14 days. After 3 months what would be the residual radioactivity of 1 millicurie of ATP labeled with P-32?

Clicker question

3 months is about 6 half-lives (each month is comprised of about two half-life periods).

1 millicurie = 1000 microcuries - we will do this analysis in microcuries!

1st: 1000/2 = 500 microcuries

2nd: 500/2 = 250 microcuries

3rd: 250/2 = 125 microcuries
4th: 125/2 = 62.5 microcuries
5th: 62.5/2 = 31.25 microcuries
6th: 31.25/2 = 15.625 microcuries

OR $\frac{1000\mu Ci}{2^6} = 15.625\mu Ci$

18. The graph of the number of Po atoms remaining with time was a characteristic decay. Will all radioactive decay graphs look similar? If so, in what way?
YES. With any decay, the most material will lost at the beginning, followed by less and less material. The amount of remaining material is being cut in half after each half-life. Thus the rate of decay will slow the longer the decay process continues.