Name ______________________ Class ________ Date ________

Unit 10 Nuclear Chemistry

Activity 10-1

Natural Radioactivity

Radioactivity

1. What are isotopes? atoms of the same element (same atomic number) having a different number of neutrons and, thus, different atomic mass and mass number

2. What is a radioisotope? an isotope that undergoes spontaneous nuclear breakdown accompanied by the release of some form of radiation; a radioactive isotope

3. Choose words from the word list to complete the following paragraphs relating to radioactivity. The list groups words that have contrasting or related meanings.

Word List

alpha/beta/gamma	number(s)
breakdown	particles
energy	protons/electrons/neutrons
isotope(s)	stable/unstable
nucleus	transmutation(s)

Radioactivity is the spontaneous ___breakdown___ of the ___nucleus___ of an atom. This breakdown is accompanied by the emission of ___particles___ and/or radiant ___energy___. This breakdown changes the makeup of the ___nucleus___. When the number of ___protons___ in the nucleus changes, one element has been changed to another element. If only the number of ___neutrons___ changes, one isotope of an element has been changed to another ___isotope___ of the same element. The first kind of change—one element to another—is called ___transmutation___.

Some naturally occurring ___isotopes___ are radioactive. All known ___isotopes___ of elements with atomic ___number___ greater than 83 are unstable. These isotopes undergo transmutation such that they are eventually converted to ___isotopes___ with atomic ___numbers___ less than 83. One well-studied series of ___transmutations___ is that of uranium-238. This unstable radioisotope, $^{238}_{92}U$, undergoes transmutation to $^{206}_{82}Pb$, a ___stable___ isotope. The breakdown products formed during ___transmutations___ are called nuclear emissions. These include ___alpha___ decay, ___beta___ decay, and ___gamma___ radiation.

Nuclear emissions

Nuclei of radioisotopes emit energy and subatomic particles. These emissions, or emanations, differ from each other in mass, charge, penetrating power, and ionizing power.

4. Complete the following table to show the properties of some subatomic particles. You may refer to table H in the Appendix.

Name	Symbol used in equations	Other symbol	Mass number	Charge
electron	$^{0}_{-1}e$	β^- or e^-	0	−
positron	$^{0}_{+1}e$	β^+	0	+
proton	$^{1}_{1}H$	p	1	+
alpha particle	$^{4}_{2}He$	α	4	2+
neutron	$^{1}_{0}n$	n	1	0

5. Choose words from the word list below to fill in the blanks in the following paragraphs relating to the properties of nuclear emissions. Words with contrasting meanings have been paired in the list.

Word List

deflected/undeflected	positive/negative
electric	positively/negatively
emissions	zero
particles/rays	

Some ____emissions____ are deflected as they pass through an ____electric____ field. Emissions such as positrons, protons, and alpha particles that are ____positively____ charged are deflected toward the ____negative____ electrode. Beta particles, which are ____negatively____ charged, are deflected toward the ____positive____ electrode. Neutrons and gamma radiation pass ____undeflected____ through an electric field since they possess no charge.

Gamma radiation is in the form of ____rays____, not ____particles____. Gamma radiation is not included in the list of emissions above because gamma rays have a mass of nearly ____zero____ and a charge of ____zero____.

Nuclear equations

6. Complete the following statements:

In balanced nuclear equations, the sum of the superscripts on the left is ____equal to____ (*greater than/equal to/less than*) the sum of the ____superscripts____ (*subscripts/superscripts*) on the right. This illustrates the principle of conservation of ____mass____ (*mass/charge*). Similarly the sum of the subscripts on the left is ____equal to____ (*greater than/equal to/less than*) the sum of the ____subscripts____ (*subscripts/superscripts*) on the righ . This illustrates the principle of conservation of ____charge____ (*mass/charge*).

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Nuclear equations show transmutations of one kind of nucleus into another. Complete and balance the equations for the following nuclear transmutations.

7. ${}^{14}_{6}C \rightarrow {}^{14}_{7}N + $ ${}^{0}_{-1}e$

8. ${}^{218}_{84}Po \rightarrow {}^{4}_{2}He + $ ${}^{214}_{82}Pb$

9. ${}^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + $ ${}^{4}_{2}He$

10. ${}^{22}_{11}Na \rightarrow {}^{22}_{10}Ne + $ ${}^{0}_{1}e$

11. ${}^{234}_{90}Th \rightarrow {}^{0}_{-1}e + $ ${}^{234}_{91}Pa$

12. ${}^{140}_{59}Pr \rightarrow {}^{140}_{58}Ce + $ ${}^{0}_{1}e$

13. ${}^{24}_{11}Na$ $\rightarrow {}^{24}_{12}Mg + {}^{0}_{-1}e$

14. ${}^{230}_{88}Th \rightarrow {}^{4}_{2}He + $ ${}^{226}_{86}Rn$

15. ${}^{234}_{91}Pa \rightarrow {}^{234}_{92}U + $ ${}^{0}_{-1}e$

16. ${}^{9}_{5}B \rightarrow {}^{1}_{1}H + $ ${}^{8}_{4}Be$

17. ${}^{8}_{2}He \rightarrow {}^{7}_{2}He + $ ${}^{1}_{0}n$

18. ${}^{16}_{6}C \rightarrow {}^{1}_{0}n + $ ${}^{15}_{6}C$

19. ${}^{13}_{8}O \rightarrow {}^{12}_{7}N + $ ${}^{1}_{1}H$

20. ${}^{3}_{1}H \rightarrow {}^{3}_{2}He + $ ${}^{0}_{-1}e$

Half-life

21. What is the definition of half-life for a radioisotope? the time required for one-half of the nuclei of a given sample of that radioisotope to decay (or disintegrate)

22. Write the balanced equation for the transmutation of ${}^{131}I$ as described in Table F in the Appendix. ${}^{131}_{53}I \rightarrow {}^{0}_{-1}e + {}^{131}_{54}Xe$

23. a. From a starting mass of 100 g of ${}^{131}I$, what mass will remain after 8 days? 50.0 g
After 16 days? 25.0 g After 24 days? 12.5 g

b. Which of the following will be the remaining mass of ${}^{131}I$ after 4 days? (See the graph on page 330.) Circle your answer.

greater than 75 g   75 g   (less than 75 g)

Explain your answer. rate of decay depends on the original number of atoms; rate of decay is faster during the first part of half-life period

24. Write the balanced equation for the transmutation of ${}^{220}Fr$ as described in Table F in the Appendix. ${}^{220}_{87}Fr \rightarrow {}^{4}_{2}He + {}^{216}_{85}At$

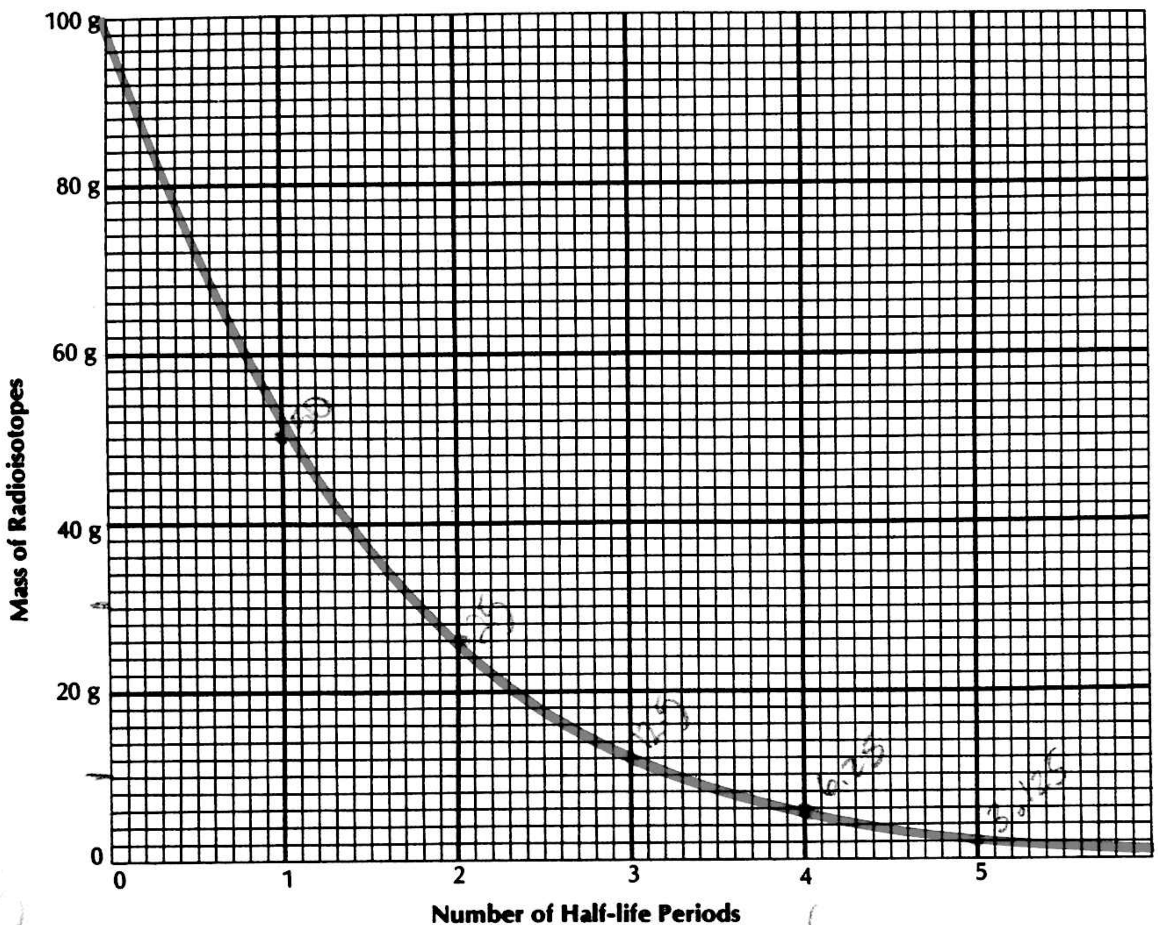
25. Starting with a sample of 4.0×10^{-7} mole of Fr atoms, how many Fr atoms will remain ($= 2.4 \times 10^{17}$ atoms)
After 27.4 sec? 1.20×10^{17} After 54.8 sec? 6.0×10^{16} After 82.2 sec? 3.0×10^{16}

In the space below, show your calculations.

$4.0 \times 10^{-7} \text{ mole} \times \frac{6.02 \times 10^{23} \text{ atoms}}{1 \text{ mol}} = 2.41 \times 10^{17} \text{ atoms}$ $\frac{2.41 \times 10^{17}}{2} = 1.20 \times 10^{17}$ $\frac{2.41 \times 10^{17}}{4} = 6.0 \times 10^{16}$

$\frac{2.41 \times 10^{17}}{8} = 3.0 \times 10^{16}$

26. Using the following grid, make a graph to show the quantity of radioisotope remaining unchanged after the passage of successive half-life periods. The original mass of the radioisotope is 100 grams.



For each of the following, write the equation for the nuclear transformation, the number of half-life periods that has elapsed, and the quantity of radioisotope remaining unchanged after the given period of time. Refer to Table F in the Appendix for information you need.

27. Radioisotope: $^{42}_{19}K$. Original quantity: 100 grams. Time elapsed: 62 hours.

Equation $^{42}_{19}K \rightarrow {}^{0}_{-1}e + {}^{42}_{20}Ca$

Number of half-life periods 5

Mass of radioisotope remaining unchanged 3.125 grams

28. Radioisotope: $^{226}_{88}Ra$. Original quantity: 8.0×10^{19} atoms. Time elapsed: 16 000 years.

Equation $^{226}_{88}Ra \rightarrow {}^{4}_{2}He + {}^{222}_{86}Rn$

Number of half-life periods 10

Number of atoms of radioisotope remaining unchanged 7.8×10^{16} atoms