Name:_____**Period:**_____
Ms. Randall
Unit 13: Nuclear Chemistry Workbook

The **bold, underlined** words are **important vocabulary words** that you should be able to define and use properly in explanations. This is a study guide for what you will be tested on throughout the year. The objectives are divided into categories of "**Knowledge**" (**what you have to *know***) and "**Application**" (**what you have to be able to *do***).

I. NUCLEAR CHEMISTRY		
	Knowledge	**Application**
1.	○ The stability of an isotope is based on the ratio of the neutrons and protons in the nucleus. ○ Usually when the ratio is not 1:1, the nucleus gets a little unstable and starts spitting out particles so that it will have a more stable 1:1 ratio. ○ Although most nuclei are stable, some are unstable and **spontaneously emit radiation**. We call these unstable isotopes ***radioactive* isotopes, radioisotopes, or nuclides**.	
2.	○ **Spontaneous decay** (natural emission of radiation) by a nuclide (radioactive isotope) involves the release of particles and/or energy from the nucleus. ○ Each radioactive isotope has a specific **decay mode** (the kind of particle or energy it gives off from its unstable nucleus) *(Tables N and O!)* ▯ **alpha decay**: release of **alpha particles** ▯ **beta decay**: release of **beta particles** ▯ **positron emission**: release of **positrons** ▯ **gamma radiation** : release of **gamma rays** ○ These emissions differ in mass, charge, **ionizing power**, and **penetrating power**.	○ Determine decay mode and write nuclear equations showing alpha decay, beta decay, positron emission, and gamma radiation *(*Remember to put radioactive emissions on the RIGHT side of the arrow – if something is released, it goes on the right)* ○ Compare and contrast the 4 different types of radiation in terms of mass, charge, ionizing power, and penetrating power.
3.	○ Each radioactive isotope has a specific **half-life** (rate of decay). The half-life is the time it takes for *half* of the radioisotope to decay/transmute into something more stable). *(Table N)*	○ Calculate the initial amount, the fraction remaining, time elapsed, or the half-life of a radioactive isotope, given the other variables
4.	○ Nuclear reactions are represented by equations that include symbols for elements and radioactive emissions (with mass number in upper left and charge/atomic number in lower left) ○ These reactions show **conservation of mass and charge**	○ Complete nuclear equations and predict missing particles in nuclear equations ○ Write nuclear equations given word problems

5.	○ A change in the nucleus of an atom that changes it from one element to another is called **transmutation**. This can occur naturally or can be done artificially by bombarding the nucleus with high-energy particles.	○ Distinguish between **natural transmutation** (one reactant) and **artificial transmutation** (two reactants) given nuclear equations
6.	○ Types of nuclear reactions include **fission** and **fusion**. Fission and fusion can be natural or artificial transmutations.	○ Compare and contrast fission and fusion reactions. ○ Distinguish between fission and fusion reactions given nuclear equations
7.	○ Nuclear changes convert matter into energy ($E = mc^2$) ○ Energy released during nuclear reactions is much greater than the energy released during chemical reactions.	○ Compare and contrast chemical reactions and nuclear reactions ○ Describe benefits of using nuclear fission
8.	○ There are risks and problems associated with radioactivity and the use of radioactive isotopes, including: biological exposure, long-term storage and disposal problems, and nuclear accidents which release radioactive materials into the environment.	○ Describe the risks and problems associated with using radioactive isotopes
9.	○ In addition to using nuclear fission for nuclear power, radioactive isotopes have other beneficial uses in medicine and industrial chemistry, including: □ radioactive dating *(ages of once-living things can be found from the ratio of C-14 to C-12 in the remains; ages of rocks can be found from the ratio of U-238 to Pb-206)* □ tracing chemical and biological processes *(radioactive tracers can be injected into the body and then x-rayed. The radioactive substance will show up on the x-ray and if there are problems, they can be detected easily)* □ detecting and treating of disease *(**Sr-90:** diagnosing and treating bone cancer; **I-131**: diagnosing and treating thyroid disorders; **Co-60**: cancer treatment* □ radiation can be used to kill bacteria in foods *(used with spices, meats, produce)*	

Goal setting: Based upon your learning style results and the information above list at least two techniques you plan to use to stu during this unit.

1.
2.

What grade would you like to achieve on this unit based on your efforts? _____%

Lesson 1: Radioactivity **Date:_____**

Objective: To determine rates of decay or remaining element based on half-lifes of unstable elements

Check your understanding

1) In a nuclear reaction, the particle may be spontaneously released from the nucleus of an atom resulting in the transmutation of the atom into another element.

   a) According to the Selected Radioisotopes table, what is the half-life of C-14?

   b) What mass of 10.0 g sample of C-14 remains after 11,460 years have evolved?

2) A radioactive element has a half-life of 2 days. What is the fraction of the original sample will remain after six days?

Practice: Use Table N to help complete the following questions

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Time Elapsed

1. How long will it take for 30. g of ^{222}Rn to decay to 7.5 g?

2. How long will it take a sample of Fr-220 to decay to 1/4 of its original amount?

3. The fossilized remains of a plant were found at a construction site. The fossilized remains contain $1/16^{th}$ the amount of carbon-14 that is present in a living plant. Determine the approximate age of these fossilized remains.

Amount Remaining

4. How many grams of ^{16}N will be left from a 16.0 g sample after 21.6 s?

5. After 9.8×10^{10} years, how many grams will be left from a 256 g sample of Th-232?

6. What is the amount of a 500. gram sample of iron-53 that will remain unchanged after 34.04 minutes?

Fraction Remaining

7. What fraction of a 100 g sample of K-42 will remain after 24.8 hours?

8. What fraction of a radioactive I-131 sample would remain unchanged after 32.28 days?

9. A woolly mammoth fossil is determined to be 17,200 years old. What is the fraction of carbon-14 remaining in the bones of this mammoth?

Number of Half-Lives

10. How many half-life periods will it take for 50 g of ^{99}Tc to decay to 6.25 g?

11. How many half-lives will pass by the time a 60.0g sample of Co-60 decays to 7.5 g?

Original Mass

12. If 2 grams of an original sample of gold-198 remained after 13.45 days, what was the mass of the original sample?

13. If 16.5 g of uranium-235 remain after 2.84×10^9 years, how much of the radioactive isotope was in the original sample?

Half-Life

14. An original sample of the radioisotope fluorine-21 had a mass of 80.0 milligrams. Only 20.0 milligrams of this original sample remain unchanged after 8.32 seconds. What is the half-life of fluorine-21?

15. What is the half-life of a radioisotope if $1/16^{th}$ of it remains undecayed after 26.4 days?

Lesson 2: Transmutation **Date:_____**

Objective: To compare and contrast the reactants and products of nuclear decay reactions.

Check your understanding:

1. The three types of radioactive emissions are called alpha, beta and gamma radiation. Complete the table below with the correct information about each type.

	Charge	**Atomic Symbol**	**Can Be Stopped By**
Alpha			
***Beta**			
Gamma			

3. Which of the three radioactive emissions (alpha, beta, gamma) best fit the following statements? Write the correct symbol/s on the lines.

These emissions are charged. _____
This emission is the most massive (heaviest). _____
This emission is the most charged. _____
This emission is most dangerous outside of the body. _____
This emission is stopped by thin paper or a few centimeters of air. _____
This emission can travel through paper, but is stopped by aluminum. _____
This emission can travel through fairly thick lead. _____

4. Which type of radiation – alpha, beta, or gamma?

a. Results in the greatest change in atomic number? Why?
_____

b. Results in the least change in atomic number? Why?
_____
c. Produces the greatest change in mass number? Why?
_____

d. Produces the least change in mass number? Why?
_____

5. Complete the following nuclear reactions:

$^{226}_{88}Ra \rightarrow \square + {}^{0}_{-1}e$

$^{209}_{84}Po \rightarrow {}^{205}_{82}Pb + \square$

Practice:

Writing Nuclear Equations – Use Table N!

When elements undergo radioactive decay, they change from one element to another. This happens by losing high energy alpha or beta particles, or by emitting positrons. The process of an atom becoming a different atom is called **transmutation**. Nuclear equations are written to track the changes that occur during transmutation. When writing nuclear equations, it is important to make sure that mass and charge are conserved.

Remember: CONSERVATION OF mass AND charge
- ✓ that the masses on each side of the arrow are equal
- ✓ that the charges on each side of the arrow are equal
- the ***nuclear*** charge of an atom IS the atomic number (# of protons), so use it to find the new element that is formed

1. Write the complete nuclear equation for the spontaneous decay of the following nuclides:

a. ^{198}Au

b. iodine-131

c. ^{42}K

d. strontium-90

What is the decay mode for the nuclides above? _____

2. Write the complete nuclear equation for the spontaneous decay of the following nuclides:

f. ^{220}Fr

g. thorium-232

h. ^{239}Pu

i. radon-222

What is the decay mode for the nuclides above? _____

3. Write the complete nuclear equation for the spontaneous decay of the following nuclides:

k. ^{37}Ca

l. iron-53

m. ^{37}K

n. neon-19

What is the decay mode for the nuclides above? _____

Lesson 3: Energy and Nuclear Reactions Date:_____

Objective: To compare and contrast the reactants and products of fusion and fission nuclear reactions

Check your understanding:

1. Which nuclear equation represents a natural transmutation?

   (1) ${}^{9}_{4}\mathrm{Be} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{6}_{3}\mathrm{Li} + {}^{4}_{2}\mathrm{He}$

   (2) ${}^{27}_{13}\mathrm{Al} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{30}_{15}\mathrm{P} + {}^{1}_{0}\mathrm{n}$

   (3) ${}^{14}_{7}\mathrm{N} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{17}_{8}\mathrm{O} + {}^{1}_{1}\mathrm{H}$

   (4) ${}^{235}_{92}\mathrm{U} \rightarrow {}^{231}_{90}\mathrm{Th} + {}^{4}_{2}\mathrm{He}$

2. Which balanced equation represents nuclear fusion?

   (1) ${}^{1}_{0}\mathrm{n} + {}^{235}_{92}\mathrm{U} \rightarrow {}^{142}_{56}\mathrm{Ba} + {}^{91}_{36}\mathrm{Kr} + 3{}^{1}_{0}\mathrm{n}$

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

   (3) ${}^{6}_{3}\mathrm{Li} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{3}_{1}\mathrm{H} + {}^{4}_{2}\mathrm{He}$

   (4) ${}^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n}$

3. Which reaction converts an atom of one element to an atom of another element?

   (1) combustion (3) saponification

   (2) polymerization (4) transmutation

4. Which equation represents a fusion reaction?

   (1) $\mathrm{H_2O(g)} \rightarrow \mathrm{H_2O}(\ell)$

   (2) $\mathrm{C(s) + O_2(g)} \rightarrow \mathrm{CO_2(g)}$

   (3) ${}^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n}$

   (4) ${}^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{142}_{56}\mathrm{Ba} + {}^{91}_{36}\mathrm{Kr} + 3{}^{1}_{0}\mathrm{n}$

Practice:

1. Which reaction represents natural nuclear decay?
   (1) $H^+ + OH^- \rightarrow H_2O$
   (2) $KClO_3 \rightarrow K^+ + ClO_3^-$
   (3) $^{235}_{92}U \rightarrow {}^{4}_{2}He + {}^{231}_{90}Th$
   (4) $^{14}_{7}N + {}^{4}_{2}He \rightarrow {}^{17}_{8}O + {}^{1}_{1}H$

2. Which equation represents a spontaneous nuclear decay?
   (1) $C + O_2 \rightarrow CO_2$
   (2) $H_2CO_3 \rightarrow CO_2 + H_2O$
   (3) $^{27}_{13}Al + {}^{4}_{2}He \rightarrow {}^{30}_{15}P + {}^{1}_{0}n$
   (4) $^{90}_{38}Sr \rightarrow {}^{0}_{-1}e + {}^{90}_{39}Y$

3. In a nuclear fusion reaction, the mass of the products is
   (1) less than the mass of the reactants because some of the mass has been converted to energy
   (2) less than the mass of the reactants because some of the energy has been converted to mass
   (3) more than the mass of the reactants because some of the mass has been converted to energy
   (4) more than the mass of the reactants because some of the energy has been converted to mass

4. Nuclear fusion differs from nuclear fission because nuclear fusion reactions

   (1) form heavier isotopes from lighter isotopes
   (2) form lighter isotopes from heavier isotopes
   (3) convert mass to energy
   (4) convert energy to mass

5. One benefit of nuclear fission reactions is

   (1) nuclear reactor meltdowns
   (2) storage of waste materials
   (3) biological exposure
   (4) production of energy

6. The change that is undergone by an atom of an element made radioactive by bombardment with high-energy protons is called

   (1) natural transmutation
   (2) artificial transmutation
   (3) natural decay
   (4) radioactive decay

7 A nuclear fission reaction and a nuclear fusion reaction are similar because both reactions

   (1) form heavy nuclides from light nuclides
   (2) form light nuclides from heavy nuclides
   (3) release a large amount of energy
   (4) absorb a large amount of energy

8. A nuclear reaction in which two light nuclei combine to form a more massive nucleus is called
   (1) addition (3) fusion
   (2) fission (4) substitution

9. A serious risk factor associated with the operation of a nuclear power plant is the production of
   (1) acid rain
   (2) helium gas
   (3) greenhouse gases, such as CO_2
   (4) radioisotopes with long half-lives

10. What is a problem commonly associated with nuclear power facilities?
    (1) A small quantity of energy is produced.
    (2) Reaction products contribute to acid rain.
    (3) It is impossible to control nuclear fission.
    (4) It is difficult to dispose of wastes.

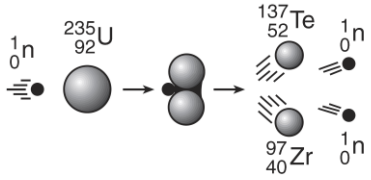
11. Which change takes place in a nuclear fusion reaction?
    (1) Matter is converted to energy.
    (2) Energy is converted to matter.
    (3) Ionic bonds are converted to covalent bonds.
    (4) Covalent bonds are converted to ionic bonds.

12. Types of nuclear reactions include fission, fusion, and
    (1) single replacement
    (2) neutralization
    (3) oxidation-reduction
    (4) transmutation

13. Atoms of one element are converted to atoms of another element through

(1) fermentation (3) polymerization
(2) oxidation (4) transmutation

14. Given the diagram representing a reaction:



Which phrase best describes this type of reaction and the overall energy change that occurs?
(1) nuclear, and energy is released
(2) nuclear, and energy is absorbed
(3) chemical, and energy is released
(4) chemical, and energy is absorbed

Use of Radioisotopes Practice

1. Which radioactive isotope is used in treating cancer?

(1) carbon-14 (3) lead-206
(2) cobalt-60 (4) uranium-238

2. Which nuclide is used to investigate human thyroid gland disorders?

(1) carbon-14 (3) cobalt-60
(2) potassium-37 (4) iodine-131

3. Which nuclide is paired with a specific use of that nuclide?

(1) carbon-14, treatment of cancer
(2) cobalt-60, dating of rock formations
(3) iodine-131, treatment of thyroid disorders
(4) uranium-238, dating of once-living organisms

4. The decay of which radioisotope can be used to estimate the age of the fossilized remains of an insect?

(1) Rn-222 (3) Co-60
(2) I-131 (4) C-14

5. According to Table N, which radioactive isotope is best for determining the actual age of Earth?

(1) ^{238} U (3) ^{60} Co
(2) ^{90} Sr (4) ^{14} C

6. Which isotope is most commonly used in the radioactive dating of the remains of organic materials?

(1) ^{14}C (3) ^{32}P
(2) ^{16}N (4) ^{37}K

Unit Study Guide

Law, Theories, BIG ideas	**Equations, Calculations, Reference Tables**
Laws:	Equation: (When to use & units)
Theories:	Calculations (When to use)
BIG ideas:	Reference Table (Hints & tricks)

Helpful tips, sayings, shortcuts

Things I always forget…

Unit Review: Nuclear Chemistry

Place a checkmark next to each item that you can do! If a sample problem is given, complete it as evidence.

_____1. I can still do everything from Unit 1.	
_____2. I can still do everything from Unit 2.	
_____3. I can still do everything from Unit 3.	
_____4. I can still do everything from Unit 4.	
_____5. I can still do everything from Unit 5.	
_____6. I can still do everything from Unit 6.	
_____7. I can still do everything from Unit 7.	
_____8. I can still do everything from Unit 8.	
_____9. I can still do everything from Unit 9.	
_____10. I can still do everything from Unit 10.	
_____11. I can still do everything from Unit 11.	
_____12. I can still do everything from Unit 11.	
_____13. I can compare types of radiation in terms of symbol, mass number, charge, penetrating power, shielding required, and biological hazard.	
____14. I can identify the three types of nuclear reactions.	The three types of nuclear reactions are: a. b. c.

Type	Symbol	Mass #	Charge	Penetrating Power
alpha				
beta				
gamma				
neutron				
positron				

_____15. I can define transmutation, fission, and fusion.	**<u>Definitions:</u>** transmutation fission fusion
_____16. I can state two synonyms for spontaneous decay.	Two synonyms for spontaneous decay are:_____ and _____.
_____17. I can show how mass number and electrical charge must be conserved in any nuclear reaction.	Complete the following nuclear equation: $^{42}_{19}\mathrm{K} \rightarrow {}^{42}_{20}\mathrm{Ca} +$ _____
_____18. I can explain what makes a nucleus stable or unstable.	The stability of the nucleus is dependent on the _____ to _____ ratio.
_____19. I can explain the difference between natural transmutation and artificial transmutation.	The difference between natural transmutation and artificial transmutation is that in natural transmutation an_____ _____breaks apart on its own and in artificial transmutation a _____ _____ is made _____ by hitting it with a high energy particle (such as a proton, neutron, or gamma radiation).
_____20. I can identify a natural decay reaction from a list of reactions.	Which equation represents a natural decay? **A)** $^{9}_{4}\mathrm{Be} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{6}_{3}\mathrm{Li} + {}^{4}_{2}\mathrm{He}$ **B)** $^{27}_{13}\mathrm{Al} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{30}_{15}\mathrm{P} + {}^{1}_{0}\mathrm{n}$ **C)** $^{14}_{7}\mathrm{N} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{17}_{8}\mathrm{O} + {}^{1}_{1}\mathrm{H}$ **D)** $^{235}_{92}\mathrm{U} \rightarrow {}^{231}_{90}\mathrm{Th} + {}^{4}_{2}\mathrm{He}$
_____21. I can identify an artificial transmutation reaction from a list of reactions.	Which equation represents artificial transmutation? **A)** $^{16}_{7}\mathrm{N} \rightarrow {}^{16}_{8}\mathrm{O} + {}^{0}_{-1}\mathrm{e}$ **B)** $^{14}_{7}\mathrm{N} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{17}_{8}\mathrm{O} + {}^{1}_{1}\mathrm{H}$ **C)** $^{37}_{19}\mathrm{K} \rightarrow {}^{37}_{18}\mathrm{Ar} + {}^{0}_{+1}\mathrm{e}$ **D)** $^{42}_{19}\mathrm{K} \rightarrow {}^{42}_{20}\mathrm{Ca} + {}^{0}_{+1}\mathrm{e}$

_____22. I can identify a fission reaction from a list of reactions.	Which equation represents fission? A) $^{1}_{0}\mathrm{n} + {}^{235}_{92}\mathrm{U} \rightarrow {}^{142}_{56}\mathrm{Ba} + {}^{91}_{36}\mathrm{Kr} + 3\,{}^{1}_{0}\mathrm{n}$ B) $^{226}_{88}\mathrm{Ra} \rightarrow {}^{222}_{86}\mathrm{Rn} + {}^{4}_{2}\mathrm{He}$ C) $^{6}_{3}\mathrm{Li} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{3}_{1}\mathrm{H} + {}^{4}_{2}\mathrm{He}$ D) $^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n}$
_____23. I can identify a fusion reaction from a list of reactions.	Which equation represents fusion? A) $^{1}_{0}\mathrm{n} + {}^{235}_{92}\mathrm{U} \rightarrow {}^{142}_{56}\mathrm{Ba} + {}^{91}_{36}\mathrm{Kr} + 3\,{}^{1}_{0}\mathrm{n}$ B) $^{226}_{88}\mathrm{Ra} \rightarrow {}^{222}_{86}\mathrm{Rn} + {}^{4}_{2}\mathrm{He}$ C) $^{6}_{3}\mathrm{Li} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{3}_{1}\mathrm{H} + {}^{4}_{2}\mathrm{He}$ D) $^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n}$

_____24. Given a list of reactions, I can differentiate a "nuclear" reaction from a "chemical" reaction.	Which of the following equations represent NUCLEAR reactions? A) $\mathrm{H_2O(g)} \rightarrow \mathrm{H_2O}(\ell)$ B) $\mathrm{C(s) + O_2(g) \rightarrow CO_2(g)}$ C) $^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n}$ D) $^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{142}_{56}\mathrm{Ba} + {}^{91}_{36}\mathrm{Kr} + 3\,{}^{1}_{0}\mathrm{n}$
_____25. I can define half-life.	**<u>Definition:</u>** half-life
_____26. Given the length of the half-life and the amount of time that has passed, I can determine the amount of radioactive sample.	Based on Reference Table N, what fraction of a radioactive sample of Au-198 will remain unchanged after 10.78 days? What was the original mass of a radioactive sample of K-37 if the sample decayed to 25.0 g after 4.92 seconds? The half-life of K-37 is 1.23 seconds)
_____27. Given the length of the half-life and the amount of radioactive sample, I can determine the amount of time that has passed.	A 100.0 g sample of Co-60 decays until only 12.5 g of it remains. Given that the half-life of Co-60 is 5.271 years, how long did the decay take?
_____28. Given the amount of time that has passed and the amount of radioactive sample, I can determine the length of the half-life.	What is the half-life of a radioisotope if 25.0 g of an original 200.0 g sample remains unchanged after 11.46 days?

_____29. Using Table N, I can determine the length of half-life and/or decay mode for a specific radioactive isotope.	Compared to K-37, the isotope K-42 has A) shorter half-life and the same decay mode B) shorter half-life and a different decay mode C) longer half-life and the same decay mode D) longer half-life and a different decay mode

_____30. I can state 5 beneficial uses for radioactive isotopes.	Five beneficial uses for radioactive isotopes are: a. b. c. d. e.
_____31. I can state the scientific use of 4 specific radioactive isotopes.	C-14 is used for _____ I-131 is used for_____ U-238 is used for _____ Co-60 is used for_____
_____32. I can state three risks associated with radioactivity and radioactive isotopes.	Three risks associated with radioactivity and radioactive isotopes are: a. b. c.