The Good, the Bad, the Ugly: Nuclear Chemistry

Name Moore - 2016

Date ____________

Essential Questions	Vocabulary	Objectives
1. *How can radiation be harmful and helpful?* 2. *Do the risks of nuclear energy outweigh the benefits*	*non-ionizing radiation, ionizing radiation, radioactive decay, alpha particle, beta particle gamma ray, nucleon, radioisotopes radioactive decay, transmutation, fission , fusion, chain reaction, half-life*	1. *Develop an argument for or against nuclear power based on the assigned special interest group using the principles of nuclear chemistry, scientific evidence, and research.*

Town Hall: Should Springfield have a Nuclear Power Plant?

To further put your knowledge to use at the end of this unit, you and your classmates will participate in a Springfield Town Council Meeting in which special interest groups will voice their position on amendment to build a nuclear power plant on the river and the town council will decide whether approve or deny the proposal. Some members of your class will moderate the "Nuclear Town Hall" and others will activity! Get into your roles! Use acting, costumes, banners, slogans, etc.

Background on Power Plant Proposal:
The Springfield Energy would like to build a two unit water pressurized nuclear power plant located on the Snake River. The reactor would be built on land currently owned by Springfield energy adjacent to the Springfield Reservoir. The cost of construction would be approximately $1.2 billion and would take seven years for completion. The current power plant is aging and will not meet the estimated demands within the next ten years. The proposed plant will be able to produce 1,258 megawatt hours or enough energy to power 750,000 homes in the greater Springfield area (Perry Nuclear Power Plant Preparedness, 2016). The reactor would add approximately 1000 construction jobs and upon completion employ 500 workers. The current plant employs only 300.

Roles of Town Council

Town Council
Pro Nuclear Citizens
Con Nuclear Citizens
Environmentalists
Nuclear Lobby
Conspiracy Theorists
Nuclear Power Plant Officials
Petroleum Lobby

Positions
Each special interest group will decide its position on the nuclear power plant. Group members should define their position and find evidence to support their decision and refute/support others opinions. Each group will have two minutes to present their case. Your group may choose among several possible approaches.

1. Analytical: This approach attempts to answer questions like why is nuclear power good or bad, how nuclear can benefit/harm society, is nuclear sustainable. This is research and data driven
2. Offensive/Defensive: Both the defensive and offensive follows the same approach. The benefits and downfalls of nuclear would be used against the opposing side. This is a more emotional stance that may not be able to be backed up by data.
3. Other: Perhaps some combination of approaches or your own style would work better for you.

Each group must come up with a minimum of five arguments to support its position. The group must prepare one question and one backup for each of the other groups, but will only question 3 groups. If any other group asks your question, the examiner must be ready with the backup question. Each special interest group must fill out forms stating the position of the group, the arguments it will present, and the questions for the other groups.

Roles
Each special interest group must elect a "spokesperson." This person will address the Town Council and present arguments to the other citizens of Springfield. Each group must also have an "examiner." This person will question the arguments of other groups.

Backchannel
During the debate a live backchannel discussion will be conducted via google classroom. The members of the group not acting as spokesperson or examiner will be expected to live "tweet" the town hall. A minimum of three, maximum of five posts need to be made. All posts need to be professional and relevant to the discussion.

Rebuttal
After all groups have made their presentations and answered questions, each group will have one minute for rebuttal. A rebuttal is your group's chance to clarify its position, defend its actions, explain why it is not at fault, or suggest another group to be at fault. The spokesperson will address the rebuttal or, alternatively, a third person may be assigned to this task.

The Final Decision
After all of the arguments and rebuttals, the town council members will adjourn to make a decision on the matter and suggest a course for further action. The town council should ensure that the course of action in their plan is within their authority to implement.

Works Cited

Perry Nuclear Power Plant Preparedness. (2016). Retrieved from Lake County Ohio: http://www.lakecountyohio.org/ema/Preparedness/Nuclear.aspx

Unit 3 Atomic Structure & Nuclear Chemistry

Syllabus:

Lesson	Description	Homework
3.1	Introduction to nuclear chemistry and basic transmutations. Introduce Nuclear Project and Assign Roles.	Watch flip video over half life.
3.2	Continue Nuclear: Fission, Fusion, and Half Life	
3.3	Nuclear Project Work Day	
3.4	Assign Dead Dudes Prepare for debate in groups Town Hall Meeting	Research Dead Dude's contribution to Atomic Theory
3.5	Quiz 3.1-3.2 Nuclear & Introduction to Thermochemistry	

Unit 3 Nuclear Vocabulary

- nucleon
- nuclide
- parent nuclide
- daughter nuclide
- radiation
- transmutation
- electromagnetic radiation
- alpha particle
- beta particle
- gamma radiation
- positron
- isotope
- deuteron
- fission
- fusion
- chain reaction
- bombardment
- half-life
- decay

Basic Atomic Structure Guided Notes

What is an Atom???

- Atoms are NOT indivisible! They CAN be broken down into smaller particles.

Subatomic Particle	Charge	Mass	Location
Proton p^+	+1	1	nucleus
Neutron n^0	0	1	nucleus
Electron e^-	−1	0	electron cloud.

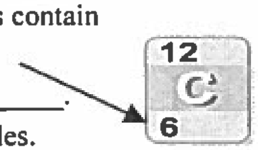
Protons, neutrons and electrons are _not_ evenly distributed in an atom.

Drawing of an Atom

- 1 amu (atomic mass unit) = $\frac{1}{12}$ of carbon-12
- The protons and neutrons exist in a _central_ core at the center of the atom. This is called the _nucleus_. The nucleus has a _positive_ charge because the protons have a positive charge and the _neutrons_ don't have a charge!
- The _electrons_ are spread out around the edge of the atom. They orbit the nucleus in layers called _energy levels_. Electrons have a _negative_ charge.
- The _atom_ of an element contain equal numbers of protons and electrons and so have no overall charge, so if you can find it on the Periodic Table, it means it has a charge of _Ø_!!!

Atomic Number (Z)

- The atoms of any particular element always contain the same number of _protons_. For example: hydrogen atoms always contain _1_ proton and carbon atoms always contain _12_ protons.
- The number of protons in an atom is known as the _atomic_ _number_.
- It is the _whole number_ of the two numbers shown in most periodic tables.



- If the number of protons changes, then the atom becomes a different _element_.
- Changes in the number of particles in the nucleus (protons or neutrons) are very _rare_. They only take place in _nuclear_ processes such as: radioactive decay, nuclear bombs or nuclear reactors.

Mass Number (A)

- Electrons have a mass of almost 0., which means that the mass of each atom results almost entirely from the number of protons and neutrons in the nucleus.
- The sum of the protons and neutrons in an atom's nucleus is the mass number. ~~It is the ____ of the two numbers shown in most periodic tables~~. (not shown on periodic table).

Mass Number= # Protons + # Neutrons

- That means in order to figure out the number of neutrons, you simply use the following:

Neutrons =Mass # - # Protons (Atomic #)

Electrons

- Atoms have no overall electrical charge and are neutral.
- This means atoms must have an equal number of protons and electrons
- The number of electrons is therefore the same as the atomic number.
- Atomic number is the number of protons rather than the number of electrons, because atoms can lose or gain electrons but do not normally lose or gain protons.

3.1& 3.2 Nuclear Chemistry and Nuclear Reactions

Nucleus of an atom is made up of protons and neutrons, together they collectively are called **nucleons.** The atom in a nuclear process is referred to as a **nuclide.** The starting atom is the **parent nuclide** and the resulting atoms are called **daughter nuclides.** During a nuclear 2 charge and mass are conserved. The nuclide can be represented a few different ways:

$^{228}_{88}Ra$ $or\ Radium - 228$ $or\ Ra - 228$

What causes radioactivity?

Stable nuclides all have something in common, looking at a plot of the number of protons to neutrons of a stable nuclide, "a beltlike graph is obtained" (Holt, 702). This graph is referred to as the band of stability. As the number of protons in a nuclide increases the repulsive, electrostatic, forces also begin to increase and therefore the number of neutrons required to increase the nuclear force to keep the nuclide stable increase. Elements with atomic numbers ≥ 84 are unstable because the electrostatic repulsive forces are greater than the nuclear force and are radioactive. Meaning the nucleus is not stable and it does not matter the ratio of protons to neutrons. Radioactive nuclides will undergo some form of nuclear decay or reaction to become stable.

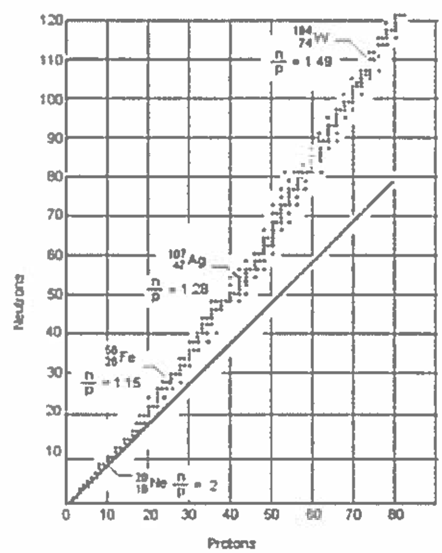


Figure 1: Band of Stability
http://chemed.chem.purdue.edu/genchem/topicreview/bp/ch23/modes.php

Types of Nuclear Particles:

Particle Name	Symbol	Charge	Mass	Penetrating Power	Shielding Required	Biological Hazard Body Damage
Alpha	${}^{4}_{2}He$	2	4	LOW	PAPER	HIGH IONIZING (biggest particle) · High in Low out
Beta	${}^{0}_{-1}\beta$	-1	0	MED	SKIN OR PLASTIC	MED IONIZING high damage out (little in)
Gamma	${}^{0}_{0}\gamma$	0	0	HIGH	LEAD SLOWS	LOW IONIZING (energy)
Positron	${}^{0}_{+1}\beta$	+1	0	MED	SKIN OR PLASTIC	MED IONIZING Low damage in HIGH out
Neutron	${}^{1}_{0}n^{0}$	0	1			
Proton	${}^{1}_{1}p^{+}$	1	1			
Deuteron	${}^{2}_{1}H$	1	2			

Types of nuclear reactions:

An unstable will nuclide will naturally (spontaneously) undergo a **transmutation,** meaning that the nucleus will undergo a decay or a series of decays until the daughter nuclide is stable. Sometimes a stable nuclide will undergo an induced decay after being bombarded by a particle. The addition of the particle causes the number of nucleons to fall outside of the band of stability resulting in a nuclear decay. Radioactive decay is defined as the spontaneous disintegration of a nucleus into a slightly lighter nucleus, accompanied by an emission of particles, electromagnetic radiation, or both (Holt, 705).

Alpha Decay:

$${}^{A}_{Z}X \rightarrow {}^{4}_{2}He + {}^{A-4}_{Z-2}Y$$

(α)

Beta Decay:

$${}^{A}_{Z}X \rightarrow {}^{0}_{-1}\beta + {}^{A}_{Z+1}Y$$

- neutron converted to a proton

$${}^{1}_{0}n^{0} \rightarrow {}^{0}_{-1}\beta + {}^{1}_{1}p^{+}$$

Electron Capture:

$${}^{A}_{Z}X + {}^{0}_{-1}e \rightarrow {}^{A}_{Z-1}Y$$

- proton converted to a neutron

$${}^{1}_{1}p + {}^{0}_{-1}e \rightarrow {}^{1}_{0}n^{0}$$

Positron Emission:

- proton converted to a neutron.

$$^{A}_{Z}X \rightarrow {}^{0}_{1}\beta^{+} + {}^{A}_{Z-1}Y$$

$$^{1}_{1}p^{+} \rightarrow {}^{0}_{+1}\beta^{+} + {}^{1}_{0}n^{0}$$

Fission: A larger parent nuclide splits into 2+ lighter daughters - usually with the production of neutrons to carry (sustain) the reaction.

$$^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{138}_{56}Ba + {}^{95}_{36}Kr + 3\,{}^{1}_{0}n^{0}$$

Fusion: 2+ lighter parent nuclides fuse into 1 heavier daughter nuclide (and maybe a neutron)

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

Where does gamma radiation and emission fit into all of this?

Gamma ($^{0}_{0}\gamma$) is just energy. Energy is given off in all nuclear reactions & depending on the frequency of the energy it could be gamma.

1. Complete the following nuclear equations in order to balance them. Identify the type of nuclear change represented by the equation.

Equation	Type of Nuclear Change
$^{235}_{92}U \rightarrow$ $^{4}_{2}He$ $+ {}^{231}_{90}Th$	alpha.
$^{240}_{95}Am + {}^{4}_{2}He \rightarrow$ $^{243}_{97}Bk$ $+ {}^{1}_{0}n$	Nuclear Fusion alpha bombardment.
$^{142}_{61}Pm +$ $^{0}_{-1}e$ $\rightarrow {}^{142}_{60}Nd$	electron capture
$^{1}_{0}n +$ $^{235}_{92}U$ $\rightarrow {}^{142}_{56}Ba + {}^{91}_{36}Kr + 3\,{}^{1}_{0}n$	Fission.
$^{6}_{3}Li +$ $^{1}_{0}n^{0}$ $\rightarrow {}^{4}_{2}He + {}^{3}_{1}H$	Fission

2. Write balanced nuclear equations for each process.

a). The alpha decay of radon-198.

$$^{198}_{86}Rn \rightarrow {}^{4}_{2}He\ (\alpha) + {}^{194}_{84}Po$$

b). The beta decay of uranium -237.

$$^{237}_{92}U \rightarrow ^{0}_{-1}\beta^- + ^{237}_{93}Np$$

c). Positron emission from silicon-26.

$$^{26}_{14}Si \rightarrow ^{0}_{+1}\beta^+ + ^{26}_{13}Al$$

d). Sodium-22 undergoes electron capture.

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

3. Write the overall nuclear equation for the decay of Po-210 if it undergoes 2 consecutive alpha decays followed by a beta decay followed by another alpha decay. (Note: it actually occurs stepwise, but this is a good lesson on how to put coefficients into nuclear equations.)

$$^{210}_{84}Po \rightarrow ^{4}_{2}He + ^{206}_{82}Pb \rightarrow ^{4}_{2}He + ^{202}_{80}Hg \rightarrow ^{0}_{-1}\beta^- + ^{202}_{81}Tl \rightarrow ^{4}_{2}He + ^{198}_{79}Au$$

or

$$^{210}_{84}Po \rightarrow 3\,^{4}_{2}He + ^{0}_{-1}\beta^- + ^{198}_{79}Au$$

4. Write a balanced nuclear equation for the conversion of carbon-13 to carbon-14.

$$^{1}_{0}n + ^{13}_{6}C \rightarrow ^{14}_{6}C$$

5. Write a balanced nuclear equation for the electron capture of thorium-235.

$$^{235}_{90}Th + ^{0}_{-1}e^- \rightarrow ^{235}_{89}Ac$$

6. Write a balanced nuclear equation for the beta decay of selenium-75.

$$^{75}_{34}Se \rightarrow ^{0}_{-1}\beta^- + ^{75}_{35}Br$$

7. Write a balanced nuclear equation for the positron emission of rubidium-81.

$$^{81}_{37}Rb \rightarrow ^{0}_{+1}\beta^+ + ^{81}_{36}Kr$$

8. Write the balanced nuclear equation for the alpha particle bombardment of einsteinium-238. One of the reaction products is a neutron.

$$^{238}_{99}Es + ^{4}_{2}He \rightarrow ^{1}_{0}n^0 + ^{241}_{101}Md$$

9. Write a balanced nuclear equation for the conversion of uranium-238 into californium-246 by bombardment with carbon-12.

$$^{238}_{92}U + ^{12}_{6}C \rightarrow ^{244}_{98}Cf + 4\,^{1}_{0}n$$

has to give off to achieve correct mass #

10. Write a balanced nuclear equation for the alpha particle bombardment of plutonium-239. The reaction products include a hydrogen atom and 2 neutrons.

$$^{239}_{94}Pu + ^{4}_{2}He \rightarrow ^{1}_{1}H + 2\,^{1}_{0}n + ^{240}_{95}Am$$

Nuclear Power v. Nuclear Bomb

Describe a chain reaction:

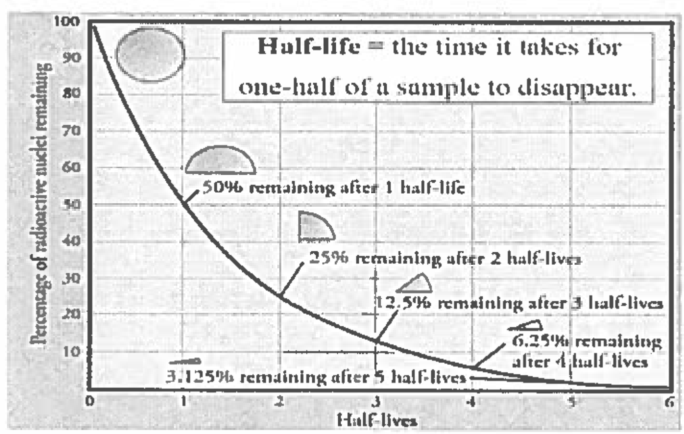
Nuclear process when the daughter nuclides can be used to cause the reaction to continue.

What is the difference between the reactions in nuclear power v. nuclear bomb?

Chain reaction in power plant is controlled - whereas in a bomb the reaction proceeds unchecked to cause an explosion due to the production of large amount of energy.

Half – Life

Many nuclides will undergo spontaneous decay, but the amount of time required is different for all nuclides. The amount of time for half of a radioactive sample to decay is referred to as the **half-life, $t_{1/2}$.** Radioactive decay is a logarithmic function. Why is half-life important and how is it used?



Half-life can be calculated using the following equation.

$$A = \frac{A_{\circ}}{2^n} \quad and \quad n = \frac{t}{t_{\frac{1}{2}}}$$

Where:

A - amount remaining

$A_{\circ}$ - initial amount

n - the number of half-life cycles

t - total time elapsed

$t_{1/2}$ – half-life

Half-Life Practice: Try #1 - #5 without using the equation:

1. Tritium (H-3) is a radioactive isotope of hydrogen with a half-life of 12.3 years. How long would it take for a 40.0 g sample to decay down to 1.25 g?

40.0 → 20.0 → 10.0 → 5.00 → 2.50 → 1.25

5 cycles

Ans: 61.5 yrs.

2. Fe-61 has a half-life of 6.00 min. Of a 100.0 mg sample, how much will remain after 18.0 min?

$\frac{18.0}{6.00}$ = 3 cycles.

100.0 → 50.0 → 25.0 mg → 12.5 mg

Ans: 12.5 mg.

3. After 20.0 days, a 120 kg sample of Bi-210 decays down to just 7.5 kg. What is its half-life?

120 → 60 → 30 → 15 → 7.5

20 / 4 cycles = 5 days.

Ans: 5 days.

4. What percent of a sample of a radioactive element whose halflife = 5.0 years will decay after 25 years?

$\frac{25}{5}$ = 5 cycles

100 → 50 → 25 → 12.5 → 6.25 → 3.125

Ans: 3.13%.

5. K-42 has a half-life of 12.0 hours. At present, a given ore sample contains 34.2 mg of K-42. How much did it contain yesterday at this same time?

136.8 ← 68.4 ← 34.2

Ans: 136.8 mg

For the remaining 6 problems, use the half-life equations to solve: (look up half-life on periodic table)

6. Tritium is hydrogen-3. Of a 24.0 mg sample, how much will remain after 9.25 years?

$A = \frac{A_o}{2^n}$

$n = \frac{t}{t_{1/2}}$

$A = \frac{24.0}{2^{\left(\frac{9.25}{12.3}\right)}}$

A = 14.1 mg

Ans: 14.1 mg

7. How long will it take for a 80.0 g sample of cobalt-60 to decay down to 13.0 g?

$2^n = \frac{A_o}{A}$

$n = \log\left(\frac{A_o}{A}\right) / \log 2$

$n = \frac{\log\left(\frac{80.0}{13.0}\right)}{\log 2}$

n = 2.62

$n = \frac{t}{t_{1/2}}$

t = 2.62 (5.27 yrs)

Ans: 13.8 yrs

8. After 34.8 min, a 43.5 g sample of Fr-215 has decayed down to 10.0 g. Whatis its half-life?

$2^n = \frac{A_o}{A}$

$n = \frac{\log\left(\frac{A_o}{A}\right)}{\log 2}$

$t / t_{1/2} = \frac{\log\left(\frac{A_o}{A}\right)}{\log 2}$

$\frac{34.8}{\left[\frac{\log\left(\frac{43.5}{10.0}\right)}{\log 2}\right]} = t_{1/2}$

Ans: 16.4 min.

9. An ore sample is found to contain 6.78 g of K-40. How much did it contain 6.0 billion years ago?

$A = \frac{A_0}{2^{t/t_{1/2}}}$ $t_{1/2} = 1.277 \times 10^9$ yrs.

$A_0 = A\left(2^{\wedge t/t_{1/2}}\right)$ $6.78\left(2^{\wedge \frac{6.0\times10^9}{1.277\times10^9}}\right)$

Ans: 176 g

10. How long will it take for one mole of Na-22 to decay down to just one atom? (hint- initial amount = 6.02 x 10^{23}) $t_{1/2} = 2.602$ yrs

$1 = \frac{6.022\times10^{23}}{2^{\wedge t/2.602}}$ $2.602 \cdot \frac{\log\left(\frac{6.022\times10^{23}}{1}\right)}{\log 2} = 206$

Ans: 206 yrs.

11. What percent of a tritium sample will decay in one day? (see #1)

t= 24 hrs | 1 day / 24 hrs | 1 yr / 365 days = 0.00274 yrs.

$A = \frac{100}{2^{\wedge \frac{0.00274}{12.3}}} = 99.985$ % remains

100 − 99.98 = decayed.

Ans: 0.0154 %

Ans (IRO+3): 0.0154 5 12.5 13.8 14.2 16.4 29.9 61.5 89.1 93.5 96.9 137 162 175 205 Units (IRO): min min years years years days mg mg mg g g % % ml 2n = mf (n=# of half-lives) T = (t1/2)(n)