Chemistry Review
Unit 10 – Nuclear Chemistry

Half-Life, Natural Radioactivity, Artificial Radioactivity, Nuclear Energy

Nuclear Chemistry

1. The stability of an isotope depends on the ratio of protons to neutrons in the nucleus.

- ✓ Most nuclei are stable, but some are unstable. These nuclei will spontaneously decay, emitting radiation.
- ✓ Stable isotopes have a 1:1 ratio of protons and neutrons. Most radioactive isotopes have twice as many neutrons as protons.
- ✓ All elements with an atomic number higher than 83 are radioactive.

2. Each isotope has a specific mode and rate of decay. (see Table N)

- ✓ The rate of decay is called half life.
- ✓ Half-life is a constant that can never be changed.
- ✓ Half life is the measure of the time it takes exactly one half of an amount of isotope to decay.
- ✓ The amount of substance will never decay to zero.

3. A change in the nucleus of an atom changes it to a new type of atom (i.e. a new element). This is called transmutation.

Transmutation can occur naturally or artificially.

- ✓ Artificial transmutation requires the bombardment of a nucleus by high energy particles.

4. Spontaneous decay can involve the release of different particles from the nucleus.

- ✓ The types of particles, as well as their masses and charges, can be found on Table O.

5. Nuclear reactions include natural and artificial decay, nuclear fission and nuclear fusion.

- ✓ Nuclear fission occurs when the nucleus of an atom is split. This can be caused artificially by "shooting" the nucleus with a neutron.
- ✓ Nuclear fusion combines two light nuclei to form heavier nuclei. Nuclear fusion is the process that powers the sun.
- ✓ Nuclear fusion requires very high temperatures, and is not yet ready for practical use. The main advantage it offers is that the products are not radioactive wastes (as with fission).

6. Nuclear reactions can be represented by equations that include symbols which represent atomic nuclei (with mass number and atomic number), subatomic particles (with mass and charge) and emitted particles.

7. Energy from nuclear reactions comes from the very small fraction of mass that is lost – the reaction converts matter into energy.

- ✓ Einstein's $E=mc^2$ describes the relationship between energy and matter.

8. The energy released from nuclear reactions is much greater than that released from chemical reactions.

9. The risks associated with using radioactive isotopes include biological exposure (which may cause radiation poisoning and cancer), long-term storage and disposal, and nuclear accidents.

10. Radioactive isotopes may be used in medicine (tracing chemical and biological processes), radioactive dating, industrial measurement, nuclear power, and detection and treatment of disease.

Unit 10 – Nuclear Chemistry

January 2008

26 Which reaction converts an atom of one element to an atom of another element?

(1) combustion
(2) polymerization
(3) saponification
(4) transmutation

27 Which nuclear emission has the greatest mass?

(1) alpha particle
(2) beta particle
(3) gamma ray
(4) positron

28 Which two radioisotopes have the same decay mode?

(1) ^{37}Ca and ^{53}Fe
(2) ^{220}Fr and ^{60}Co
(3) ^{37}K and ^{42}K
(4) ^{99}Tc and ^{19}Ne

49 Which fraction of an original 20.00-gram sample of nitrogen-16 remains unchanged after 36.0 seconds?

(1) $\frac{1}{5}$
(2) $\frac{1}{8}$
(3) $\frac{1}{16}$
(4) $\frac{1}{32}$

50 Which radioactive isotope is used in treating cancer?

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

August 2007

28 What is the decay mode of ^{37}K?

(1) β^-
(2) β^+
(3) γ
(4) α

29 Which nuclear emission has the greatest penetrating power?

(1) alpha particle
(2) beta particle
(3) gamma radiation
(4) positron

30 What is the mass number of an alpha particle?

(1) 1
(2) 2
(3) 0
(4) 4

29 Which list of nuclear emissions is arranged in order from the *least* penetrating power to the greatest penetrating power?

(1) alpha particle, beta particle, gamma ray
(2) alpha particle, gamma ray, beta particle
(3) gamma ray, beta particle, alpha particle
(4) beta particle, alpha particle, gamma ray

30 One benefit of nuclear fission reactions is

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

49 Which nuclear equation represents a natural transmutation?

(1) $^{9}_{4}Be + {}^{1}_{1}H \rightarrow {}^{6}_{3}Li + {}^{4}_{2}He$
(2) $^{27}_{13}Al + {}^{4}_{2}He \rightarrow {}^{30}_{15}P + {}^{1}_{0}n$
(3) $^{14}_{7}N + {}^{4}_{2}He \rightarrow {}^{17}_{8}O + {}^{1}_{1}H$
(4) $^{235}_{92}U \rightarrow {}^{231}_{90}Th + {}^{4}_{2}He$

50 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

June 2007

27 Which list of radioisotopes contains an alpha emitter, a beta emitter, and a positron emitter?

(1) C-14, N-16, P-32
(2) Cs-137, Fr-220, Tc-99
(3) Kr-85, Ne-19, Rn-222
(4) Pu-239, Th-232, U-238

28 Which nuclear decay emission consists of energy, only?

(1) alpha particle (3) gamma radiation
(2) beta particle (4) positron

29 Which balanced equation represents nuclear fusion?

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

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

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

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

30 The energy released by a nuclear reaction results primarily from the

(1) breaking of bonds between atoms
(2) formation of bonds between atoms
(3) conversion of mass into energy
(4) conversion of energy into mass

50 Which radioisotope is used in medicine to treat thyroid disorders?

(1) cobalt-60 (3) phosphorus-32
(2) iodine-131 (4) uranium-238

61 Complete the nuclear equation *in your answer booklet*. Include the symbol, atomic number, and mass number for the missing particle. [1]

61 ${}^{42}_{19}K \rightarrow {}^{0}_{-1}e +$ _____

Base your answers to questions 80 through 82 on the information below.

In living organisms, the ratio of the naturally occurring isotopes of carbon, C-12 to C-13 to C-14, is fairly consistent. When an organism such as a woolly mammoth died, it stopped taking in carbon, and the amount of C-14 present in the mammoth began to decrease. For example, one fossil of a woolly mammoth is found to have $\frac{1}{32}$ of the amount of C-14 found in a living organism.

80 Identify the type of nuclear reaction that caused the amount of C-14 in the woolly mammoth to *decrease* after the organism died. [1]

81 Determine the total time that has elapsed since this woolly mammoth died. [1]

82 State, in terms of subatomic particles, how an atom of C-13 is different from an atom of C-12. [1]

80 _____

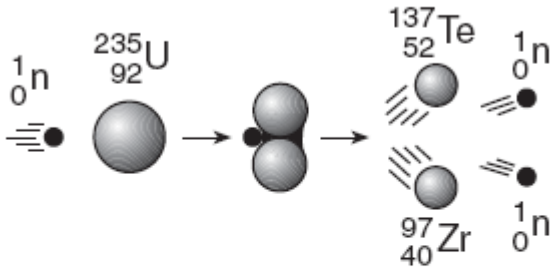
81 _____ y

82 _____

_____

January 2007

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

24 Which group of nuclear emissions is listed in order of increasing charge?

(1) alpha particle, beta particle, gamma radiation
(2) gamma radiation, alpha particle, beta particle
(3) positron, alpha particle, neutron
(4) neutron, positron, alpha particle

49 If $\frac{1}{8}$ of an original sample of krypton-74 remains unchanged after 34.5 minutes, what is the half-life of krypton-74?

(1) 11.5 min
(2) 23.0 min
(3) 34.5 min
(4) 46.0 min

50 Given the nuclear equation:

$$^{253}_{99}Es + X \rightarrow {}^{1}_{0}n + {}^{256}_{101}Md$$

Which particle is represented by X?

(1) $^{4}_{2}He$
(2) $^{0}_{-1}e$
(3) $^{1}_{0}n$
(4) $^{0}_{+1}e$

August 2006

28 Which notation of a radioisotope is correctly paired with the notation of its emission particle?

(1) ^{37}Ca and $^{4}_{2}He$
(2) ^{235}U and $^{0}_{+1}e$
(3) ^{16}N and $^{1}_{1}p$
(4) ^{3}H and $^{0}_{-1}e$

29 Atoms of one element are converted to atoms of another element through

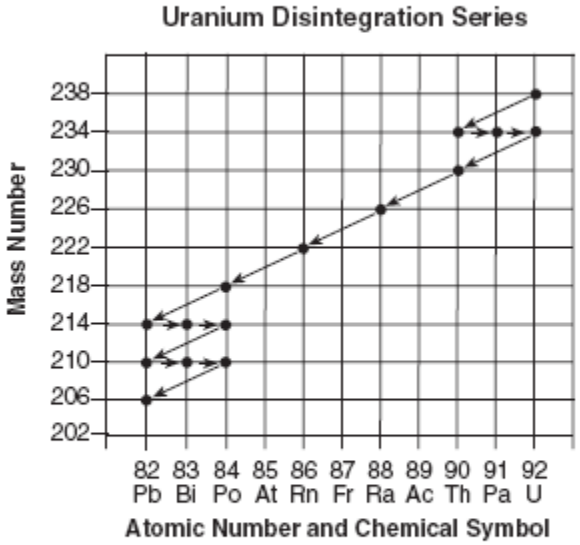
(1) fermentation
(2) oxidation
(3) polymerization
(4) transmutation

30 An atom of potassium-37 and an atom of potassium-42 differ in their total number of

(1) electrons
(2) neutrons
(3) protons
(4) positrons

Base your answers to questions 64 and 65 on the information below.

A U-238 atom decays to a Pb-206 atom through a series of steps. Each point on the graph below represents a nuclide and each arrow represents a nuclear decay mode.



64 Based on this graph, what particle is emitted during the nuclear decay of a Po-218 atom? [1]

65 Explain why the U-238 disintegration series ends with the nuclide Pb-206. [1]

64 _____

65 _____

_____

_____

Base your answers to questions 66 and 67 on the information below.

Some radioisotopes used as tracers make it possible for doctors to see the images of internal body parts and observe their functions. The table below lists information about three radioisotopes and the body part each radioisotope is used to study.

Medical Uses of Some Radioisotopes

Radioisotope	Half-life	Decay Mode	Body Part
^{24}Na	15 hours	beta	circulatory system
^{59}Fe	44.5 days	beta	red blood cells
^{131}I	8.1 days	beta	thyroid

66 Complete the equation *in your answer booklet* for the nuclear decay of the radioisotope used to study red blood cells. Include *both* the atomic number and the mass number for *each* missing particle. [1]

67 It could take up to 60. hours for a radioisotope to be delivered to the hospital from the laboratory where it is produced. What fraction of an original sample of ^{24}Na remains unchanged after 60. hours? [1]

66 $^{59}_{26}Fe \rightarrow$ _____ + _____

67 _____

June 2006

27 According to Reference Table *N*, which pair of isotopes spontaneously decays?

(1) C-12 and N-14
(2) C-12 and N-16
(3) C-14 and N-14
(4) C-14 and N-16

28 Which equation represents the radioactive decay of $^{226}_{88}Ra$?

(1) $^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + {}^{4}_{2}He$
(2) $^{226}_{88}Ra \rightarrow {}^{226}_{89}Ac + {}^{0}_{-1}e$
(3) $^{226}_{88}Ra \rightarrow {}^{226}_{87}Fr + {}^{0}_{+1}e$
(4) $^{226}_{88}Ra \rightarrow {}^{225}_{88}Ra + {}^{1}_{0}n$

29 Which type of reaction converts one element to another element?

(1) neutralization
(2) polymerization
(3) substitution
(4) transmutation

30 Which nuclear emission has the greatest mass?

(1) α
(2) γ
(3) β^-
(4) β^+

49 What is the half-life of sodium-25 if 1.00 gram of a 16.00-gram sample of sodium-25 remains unchanged after 237 seconds?

(1) 47.4 s
(2) 59.3 s
(3) 79.0 s
(4) 118 s

January 2006

24 Positrons are spontaneously emitted from the nuclei of

(1) potassium-37
(2) radium-226
(3) nitrogen-16
(4) thorium-232

25 The amount of energy released from a fission reaction is much greater than the energy released from a chemical reaction because in a fission reaction

(1) mass is converted into energy
(2) energy is converted into mass
(3) ionic bonds are broken
(4) covalent bonds are broken

27 Types of nuclear reactions include fission, fusion, and

(1) single replacement
(2) neutralization
(3) oxidation-reduction
(4) transmutation

49 Given the nuclear equation:

$$^{1}_{1}\mathrm{H} + X \rightarrow {}^{6}_{3}\mathrm{Li} + {}^{4}_{2}\mathrm{He}$$

The particle represented by X is

(1) $^{9}_{4}\mathrm{Li}$
(2) $^{9}_{4}\mathrm{Be}$
(3) $^{10}_{5}\mathrm{Be}$
(4) $^{10}_{6}\mathrm{C}$

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

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

56 Based on Reference Table *N*, what is the fraction of a sample of potassium-42 that will remain unchanged after 62.0 hours? [1]

56 _____

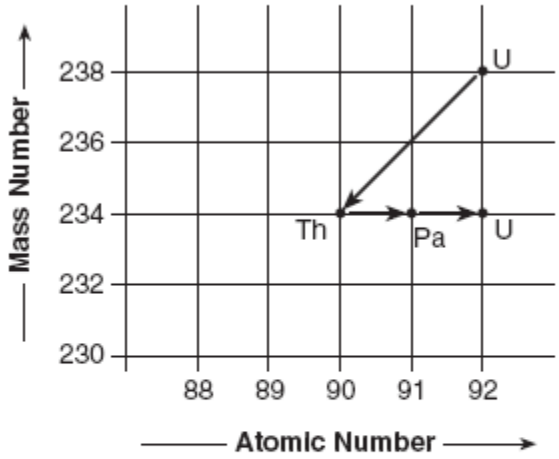
28 Which isotope will spontaneously decay and emit particles with a charge of +2?

(1) ^{53}Fe (3) ^{198}Au
(2) ^{137}Cs (4) ^{220}Fr

29 Radioactive cobalt-60 is used in radiation therapy treatment. Cobalt-60 undergoes beta decay. This type of nuclear reaction is called

(1) natural transmutation
(2) artificial transmutation
(3) nuclear fusion
(4) nuclear fission

50 The chart below shows the spontaneous nuclear decay of U-238 to Th-234 to Pa-234 to U-234.



What is the correct order of nuclear decay modes for the change from U-238 to U-234?

(1) β^- decay, γ decay, β^- decay
(2) β^- decay, β^- decay, α decay
(3) α decay, α decay, β^- decay
(4) α decay, β^- decay, β^- decay

Base your answers to questions 83 through 85 on the information below.

The radioisotopes carbon-14 and nitrogen-16 are present in a living organism. Carbon-14 is commonly used to date a once-living organism.

83 Complete the nuclear equation *in your answer booklet* for the decay of C-14. Include *both* the atomic number and the mass number of the missing particle. [1]

84 Explain why N-16 is a poor choice for radioactive dating of a bone. [1]

85 A sample of wood is found to contain $\frac{1}{8}$ as much C-14 as is present in the wood of a living tree. What is the approximate age, in years, of this sample of wood? [1]

83 $^{14}_{6}C \rightarrow$ _____ $+ {}^{0}_{-1}e$

84 _____

_____

_____

85 _____ y

June 2005

24 What is the oxidation state of nitrogen in $NaNO_2$?

(1) +1
(2) +2
(3) +3
(4) +4

29 What is the half-life and decay mode of Rn-222?

(1) 1.91 days and alpha decay
(2) 1.91 days and beta decay
(3) 3.82 days and alpha decay
(4) 3.82 days and beta decay

30 Which equation represents a transmutation reaction?

(1) $^{239}_{92}U \rightarrow {}^{239}_{92}U + {}^{0}_{0}\gamma$
(2) $^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e$
(3) $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$
(4) $nC_2H_4 \xrightarrow{\text{catalyst}} (-C_2H_4-)_n$

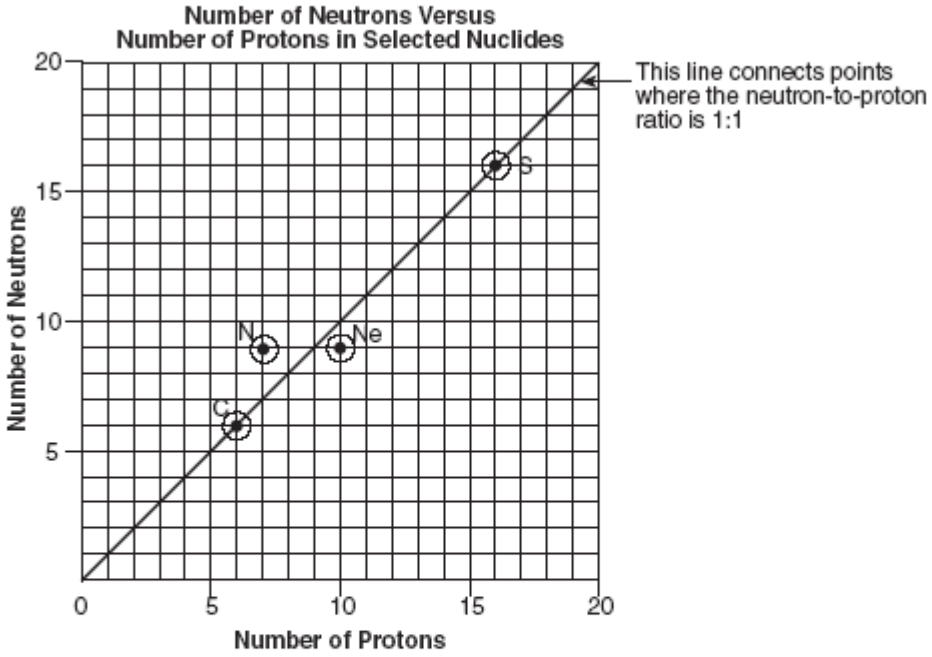
31 Which equation represents positron decay?

(1) $^{87}_{37}Rb \rightarrow {}^{0}_{-1}e + {}^{87}_{38}Sr$
(2) $^{227}_{92}U \rightarrow {}^{223}_{90}Th + {}^{4}_{2}He$
(3) $^{27}_{13}Al + {}^{4}_{2}He \rightarrow {}^{30}_{15}P + {}^{1}_{0}n$
(4) $^{11}_{6}C \rightarrow {}^{0}_{+1}e + {}^{11}_{5}B$

32 Which equation represents a fusion reaction?

(1) $H_2O(g) \rightarrow H_2O(\ell)$
(2) $C(s) + O_2(g) \rightarrow CO_2(g)$
(3) $^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + {}^{1}_{0}n$
(4) $^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{142}_{56}Ba + {}^{91}_{36}Kr + 3{}^{1}_{0}n$

Base your answers to questions 61 through 64 on the information below, which relates the numbers of neutrons and protons for specific nuclides of C, N, Ne, and S.



61 Using the point plotted on the graph for neon, complete the table *in your answer booklet*. [1]

62 Explain, in terms of atomic particles, why S-32 is a stable nuclide. [1]

63 Using the point plotted on the graph for nitrogen, what is the neutron-to-proton ratio of this nuclide? [1]

64 Based on Reference Table *N*, complete the decay equation for N-16 *in your answer booklet*. [1]

61

Element	Number of Protons	Number of Neutrons	Mass Number	Nuclide
C	6	6	12	C-12
N	7	9	16	N-16
Ne	10			
S	16	16	32	S-32

62 _____

_____

_____

63 _____

64 $^{16}_{7}N \rightarrow$ _____ + _____

January 2005

28 Which reaction is an example of natural transmutation?

(1) $^{239}_{94}\text{Pu} \rightarrow {}^{235}_{92}\text{U} + {}^{4}_{2}\text{He}$

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

(3) $^{238}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow {}^{239}_{94}\text{Pu} + 2\,{}^{0}_{-1}\text{e}$

(4) $^{239}_{94}\text{Pu} + {}^{1}_{0}\text{n} \rightarrow {}^{147}_{56}\text{Ba} + {}^{90}_{38}\text{Sr} + 3{}^{1}_{0}\text{n}$

29 Which statement best describes gamma radiation?

(1) It has a mass of 1 and a charge of 1.
(2) It has a mass of 0 and a charge of –1.
(3) It has a mass of 0 and a charge of 0.
(4) It has a mass of 4 and a charge of +2.

30 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.

49 Based on Reference Table *N*, what fraction of a radioactive ^{90}Sr sample would remain unchanged after 56.2 years?

(1) $\frac{1}{2}$ (3) $\frac{1}{8}$

(2) $\frac{1}{4}$ (4) $\frac{1}{16}$

50 Given the nuclear equation:

$$^{19}_{10}\text{Ne} \rightarrow X + {}^{19}_{9}\text{F}$$

Which particle is represented by *X*?

(1) alpha (3) neutron
(2) beta (4) positron

Base your answers to questions 82 through 84 on the information below, the *Reference Tables for Physical Setting/Chemistry*, and your knowledge of chemistry.

Radioactivity and radioactive isotopes have the potential for both benefiting and harming living organisms. One use of radioactive isotopes is in radiation therapy as a treatment for cancer. Cesium-137 is sometimes used in radiation therapy.

A sample of cesium-137 was left in an abandoned clinic in Brazil in 1987. Cesium-137 gives off a blue glow because of its radioactivity. The people who discovered the sample were attracted by the blue glow and had no idea of any danger. Hundreds of people were treated for overexposure to radiation, and four people died.

82 Using Reference Table *N*, complete the equation provided *in your answer booklet* for the radioactive decay of $^{137}_{55}Cs$. Include *both* atomic number and mass number for *each* particle. [1]

83 If 12.5 grams of the original sample of cesium-137 remained after 90.69 years, what was the mass of the original sample? [1]

84 Suppose a 40-gram sample of iodine-131 and a 40-gram sample of cesium-137 were both abandoned in the clinic in 1987. Explain why the sample of iodine-131 would *not* pose as great a radiation risk to people today as the sample of cesium-137 would. [1]

82 $^{137}_{55}Cs \rightarrow$ _____ + _____

83 _____ g

84 _____

_____

_____

August 2004

31 Which radioisotope undergoes beta decay and has a half-life of less than 1 minute?

(1) Fr-220
(2) K-42
(3) N-16
(4) P-32

49 How many days are required for 200. grams of radon-222 to decay to 50.0 grams?

(1) 1.91 days
(2) 3.82 days
(3) 7.64 days
(4) 11.5 days

Base your answers to questions 82 through 85 on the reading passage below and on your knowledge of chemistry.

A Glow in the Dark, and Scientific Peril

The [Marie and Pierre] Curies set out to study radioactivity in 1898. Their first accomplishment was to show that radioactivity was a property of atoms themselves. Scientifically, that was the most important of their findings, because it helped other researchers refine their understanding of atomic structure.

More famous was their discovery of polonium and radium. Radium was the most radioactive substance the Curies had encountered. Its radioactivity is due to the large size of the atom, which makes the nucleus unstable and prone to decay, usually to radon and then lead, by emitting particles and energy as it seeks a more stable configuration.

Marie Curie struggled to purify radium for medical uses, including early radiation treatment for tumors. But radium's bluish glow caught people's fancy, and companies in the United States began mining it and selling it as a novelty: for glow-in-the-dark light pulls, for instance, and bogus cure-all patent medicines that actually killed people.

What makes radium so dangerous is that it forms chemical bonds in the same way as calcium, and the body can mistake it for calcium and absorb it into the bones. Then, it can bombard cells with radiation at close range, which may cause bone tumors or bone-marrow damage that can give rise to anemia or leukemia.

— Denise Grady, *The New York Times*, October 6, 1998

82 State one risk associated with the use of radium. [1]

83 Using Reference Table *N*, complete the equation provided *in your answer booklet* for the nuclear decay of $^{226}_{88}Ra$. Include *both* atomic number and mass number for *each* particle. [1]

84 Using information from the Periodic Table, explain why radium forms chemical bonds in the same way as calcium does. [1]

85 If a scientist purifies 1.0 gram of radium-226, how many years must pass before only 0.50 gram of the original radium-226 sample remains unchanged? [1]

82 _____

83 $^{226}_{88}Ra \rightarrow$ _____ + _____

84 _____

_____

_____

85 _____ y

June 2004

31 Which of these particles has the greatest mass?

(1) alpha
(2) beta
(3) neutron
(4) positron

32 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

33 Which of these types of radiation has the greatest penetrating power?

(1) alpha
(2) beta
(3) gamma
(4) positron

49 Based on Reference Table *N*, what fraction of a sample of gold-198 remains radioactive after 2.69 days?

(1) $\frac{1}{4}$
(2) $\frac{1}{2}$
(3) $\frac{3}{4}$
(4) $\frac{7}{8}$

64 Given the nuclear equation:

$$^{58}_{29}\text{Cu} \rightarrow ^{58}_{28}\text{Ni} + X$$

What nuclear particle is represented by *X*? [1] 64 _____

January 2004

28 Which equation represents a spontaneous nuclear decay?

(1) $C + O_2 \rightarrow CO_2$
(2) $H_2CO_3 \rightarrow CO_2 + H_2O$
(3) $^{27}_{13}\text{Al} + ^{4}_{2}\text{He} \rightarrow ^{30}_{15}\text{P} + ^{1}_{0}\text{n}$
(4) $^{90}_{38}\text{Sr} \rightarrow ^{0}_{-1}\text{e} + ^{90}_{39}\text{Y}$

29 The stability of an isotope is based on its

(1) number of neutrons, only
(2) number of protons, only
(3) ratio of neutrons to protons
(4) ratio of electrons to protons

46 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

47 After 32 days, 5 milligrams of an 80-milligram sample of a radioactive isotope remains unchanged. What is the half-life of this element?

(1) 8 days
(2) 2 days
(3) 16 days
(4) 4 days

Base your answers to questions 71 through 74 on the article below, the *Reference Tables for Physical Setting/Chemistry*, and your knowledge of chemistry.

Radioactivity at home

You may be surprised to learn that you do not need to visit a nuclear power plant or a hospital X-ray laboratory to find sources of radioactivity. They are all around us. In fact, it is likely that you'll find a few at home. Your front porch may incorporate cinder blocks or granite blocks. Both contain uranium. Walk through the front door, look up, and you'll see a smoke detector that owes its effectiveness to the constant source of alpha particle emissions from Americium-241. As long as the gases remain ionized within the shielded container, electricity flows, and all is calm. When smoke enters the chamber, it neutralizes the charges on these ions. In the absence of these ions, the circuit breaks and the alarm goes off.

Indicator lights on your appliances may use Krypton-85; electric blankets, promethium-147; and fluorescent lights, thorium-229. Even the food we eat is radioactive. The more potassium-rich the food source, the more potassium-40—a radioactive isotope that makes up about 0.01% of the natural supply of this mineral—is present. Thus, brazil nuts, peanuts, bananas, potatoes, and flour, all rich in potassium, are radiation sources.

—*Chem Matters*
April 2000

71 Write the equation for the alpha decay that occurs in a smoke detector containing Americium-241 (Am-241). [2]

72 How is the radioactive decay of Krypton-85 different from the radioactive decay of Americium-241? [1]

73 State one benefit or useful application of radioactivity *not* mentioned in this article. [1]

74 State one risk or danger associated with radioactivity. [1]

71 _____

72 _____

_____

73 _____

_____

74 _____

_____

August 2003

31 Which of these types of nuclear radiation has the greatest penetrating power?

(1) alpha
(2) beta
(3) neutron
(4) gamma

32 Alpha particles and beta particles differ in

(1) mass, only
(2) charge, only
(3) both mass and charge
(4) neither mass nor charge

33 Given the nuclear reaction:

$$^{60}_{27}\text{Co} \rightarrow {}^{0}_{-1}\text{e} + {}^{60}_{28}\text{Ni}$$

This reaction is an example of

(1) fission
(2) fusion
(3) artificial transmutation
(4) natural transmutation

50 According to Reference Table *N*, which radioactive isotope will retain only one-eighth $\left(\frac{1}{8}\right)$ its original radioactive atoms after approximately 43 days?

(1) gold-198
(2) iodine-131
(3) phosphorus-32
(4) radon-222

Base your answers to questions 70 through 74 on the article below, the *Reference Tables for Physical Setting/Chemistry*, and your knowledge of chemistry.

In the 1920s, paint used to inscribe the numbers on watch dials was composed of a luminescent (glow-in-the-dark) mixture. The powdered-paint base was a mixture of radium salts and zinc sulfide. As the paint was mixed, the powdered base became airborne and drifted throughout the workroom causing the contents of the workroom, including the painters' clothes and bodies, to glow in the dark.

The paint is luminescent because radiation from the radium salts strikes a scintillator. A scintillator is a material that emits visible light in response to ionizing radiation. In watch-dial paint, zinc sulfide acts as the scintillator.

Radium present in the radium salts decomposes spontaneously, emitting alpha particles. These particles can cause damage to the body when they enter human tissue. Alpha particles are especially harmful to the blood, liver, lungs, and spleen because they can alter genetic information in the cells. Radium can be deposited in the bones because it substitutes for calcium.

70 Write the notation for the alpha particles emitted by radium in the radium salts. [1]

71 How can particles emitted from radioactive nuclei damage human tissue? [1]

72 Why does radium substitute for calcium in bones? [1]

73 Explain why zinc sulfide is used in luminescent paint. [1]

74 Based on Reference Table *F*, describe the solubility of zinc sulfide in water. [1]

70 _____

71 _____

_____

72 _____

_____

73 _____

_____

74 _____

_____

June 2003

7 Alpha particles are emitted during the radioactive decay of

(1) carbon-14 (3) calcium-37
(2) neon-19 (4) radon-222

32 Which type of radioactive emission has a positive charge and weak penetrating power?

(1) alpha particle (3) gamma ray
(2) beta particle (4) neutron

34 What is the name of the process in which the nucleus of an atom of one element is changed into the nucleus of an atom of a different element?

(1) decomposition (3) substitution
(2) transmutation (4) reduction

39 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

49 In the reaction $^{239}_{93}Np \rightarrow {}^{239}_{94}Pu + X$, what does X represent?

(1) a neutron (3) an alpha particle
(2) a proton (4) a beta particle

Base your answers to questions 68 through 73 on the information below and on your knowledge of chemistry.

Nuclear Waste Storage Plan for Yucca Mountain

In 1978, the U.S. Department of Energy began a study of Yucca Mountain which is located 90 miles from Las Vegas, Nevada. The study was to determine if Yucca Mountain would be suitable for a long-term burial site for high-level radioactive waste. A three-dimensional (3-D) computer scale model of the site was used to simulate the Yucca Mountain area. The computer model study for Yucca Mountain included such variables as: the possibility of earthquakes, predicted water flow through the mountain, increased rainfall due to climate changes, radioactive leakage from the waste containers, and increased temperatures from the buried waste within the containers.

The containers that will be used to store the radioactive waste are designed to last 10,000 years. Within the 10,000-year time period, cesium and strontium, the most powerful radioactive emitters, would have decayed. Other isotopes found in the waste would decay more slowly, but are not powerful radioactive emitters.

In 1998, scientists discovered that the compressed volcanic ash making up Yucca Mountain was full of cracks. Because of the arid climate, scientists assumed that rainwater would move through the cracks at a slow rate. However, when radioactive chlorine-36 was found in rock samples at levels halfway through the mountain, it was clear that rainwater had moved quickly down through Yucca Mountain. It was only 50 years earlier when this chlorine-36 isotope had contaminated rainwater during atmospheric testing of the atom bomb.

Some opponents of the Yucca Mountain plan believe that the uncertainties related to the many variables of the computer model result in limited reliability of its predictions. However, advocates of the plan believe it is safer to replace the numerous existing radioactive burial sites around the United States with the one site at Yucca Mountain. Other opponents of the plan believe that transporting the radioactive waste to Yucca Mountain from the existing 131 burial sites creates too much danger to the United States. In 2002, after years of political debate, a final legislative vote approved the development of Yucca Mountain to replace the existing 131 burial sites.

68 State one uncertainty in the computer model that limits the reliability of this computer model. [1]

69 Scientists assume that a manufacturing defect would cause at least one of the waste containers stored in the Yucca Mountain repository to leak within the first 1,000 years. State one possible effect such a leak could have on the environment near Yucca Mountain. [1]

70 State one risk associated with leaving radioactive waste in the 131 sites around the country where it is presently stored. [1]

71 If a sample of cesium-137 is stored in a waste container in Yucca Mountain, how much time must elapse until only $\frac{1}{32}$ of the original sample remains unchanged? [1]

72 The information states "Within the 10,000-year time period, cesium and strontium, the most powerful radioactive emitters, would have decayed." Use information from Reference Table *N* to support this statement. [1]

73 Why is water flow a crucial factor in deciding whether Yucca Mountain is a suitable burial site? [1]

68 _____

_____

69 _____

_____

70 _____

_____

71 _____

72 _____

_____

73 _____

_____

January 2003

20 Which radioisotope is a beta emitter?

(1) ^{90}Sr (3) ^{37}K

(2) ^{220}Fr (4) ^{238}U

29 Which equation is an example of artificial transmutation?

(1) $^{9}_{4}Be + {}^{4}_{2}He \rightarrow {}^{12}_{6}C + {}^{1}_{0}n$

(2) $U + 3\ F_2 \rightarrow UF_6$

(3) $Mg(OH)_2 + 2\ HCl \rightarrow 2\ H_2O + MgCl_2$

(4) $Ca + 2\ H_2O \rightarrow Ca(OH)_2 + H_2$

31 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

33 Which statement explains why nuclear waste materials may pose a problem?

(1) They frequently have short half-lives and remain radioactive for brief periods of time.

(2) They frequently have short half-lives and remain radioactive for extended periods of time.

(3) They frequently have long half-lives and remain radioactive for brief periods of time.

(4) They frequently have long half-lives and remain radioactive for extended periods of time.

56 Given the nuclear equation:

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

a State the type of nuclear reaction represented by the equation. [1]

b The sum of the masses of the products is slightly less than the sum of the masses of the reactants. Explain this loss of mass. [1]

c This process releases greater energy than an ordinary chemical reaction does. Name another type of nuclear reaction that releases greater energy than an ordinary chemical reaction. [1]

56 *a* _____

b _____

_____

c _____