NGSS Regents Chemistry

PRACTICE PACKET
Unit 12: Nuclear Chemistry

Figure 1

Slow neutron

$^{141}_{56}$ Ba

$^{235}_{92}$ U

$^{92}_{36}$ Kr

(one possible pair of fission fragments)
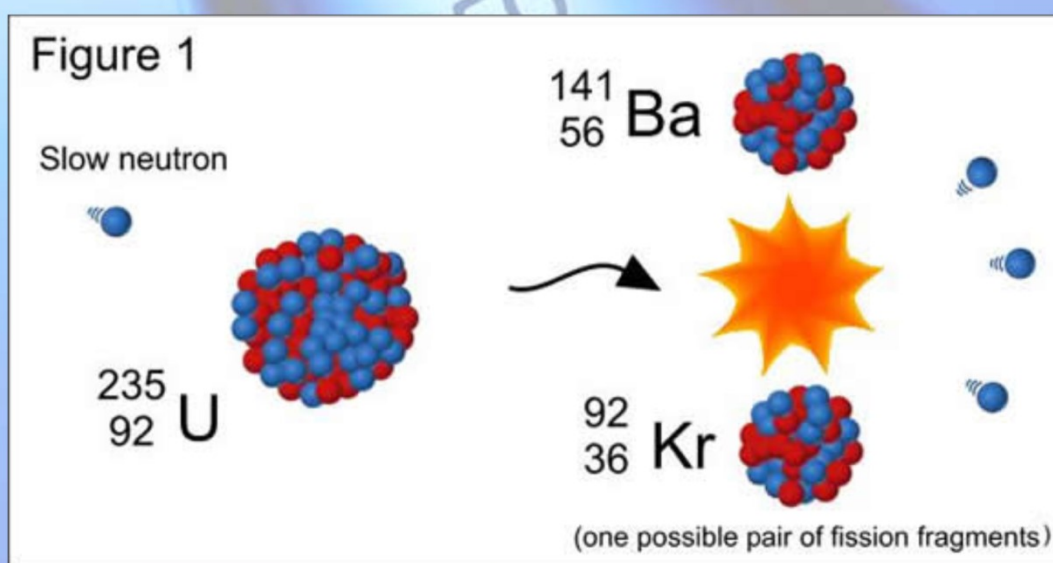
Give the correct number of protons, atomic notation, and predict the stability of each isotope.

Element Name	# of protons	# of neutrons	Atomic notation	Stability
Curium	96	151	$^{247}_{96}Cm$	unstable
Carbon	6	6	$^{12}_{6}C$	stable
Tin	50	67	$^{117}_{50}Sn$	stable
Silver	47	64	$^{111}_{47}Ag$	stable
Oxygen	8	8	$^{16}_{8}O$	stable
Francium	87	136	$^{223}_{87}Fr$	unstable
Platinum	78	117	$^{195}_{78}Pt$	stable
Hydrogen	1	3	$^{4}_{1}H$	stable
Krypton	36	48	$^{84}_{36}Kr$	Unstable
Thallium	81	123	$^{204}_{81}Tl$	Stable
Barium	56	81	$^{137}_{56}Ba$	stable
Barium	56	84	$^{140}_{56}Ba$	unstable
Hydrogen	1	1	$^{2}_{1}H$	stable
Hydrogen	1	2	$^{3}_{1}H$	stable
Astatine	85	125	$^{210}_{85}At$	unstable

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Regents Chemistry   **Natural Transmutation**

1. Which list of particles is in order of increasing mass?

    A) alpha particle → electron → proton
    B) proton → alpha particle → electron
    C) proton → electron → alpha particle
    D) electron → proton → alpha particle

2. Atoms of I-131 spontaneously decay when the

    A) stable nuclei emit alpha particles
    B) unstable nuclei emit alpha particles
    C) stable nuclei emit beta particles
    D) unstable nuclei emit beta particles

3. Positrons and beta particles have

    A) the same charge and the same mass
    B) different charges and different masses
    C) the same charge and different masses
    D) different charges and the same mass

4. When an atom of the unstable isotope Na-24 decays, it becomes an atom of Mg-24 because the Na-24 atom spontaneously releases

    A) a positron   B) a beta particle
    C) an alpha particle   D) a neutron

5. Which radioisotope has an atom that emits a particle with a mass number of 0 and a charge of +1?

    A) ^{3}H   B) ^{239}Pu   C) ^{16}N   D) ^{19}Ne

6. Radiation is spontaneously emitted from hydrogen-3 nuclei, but radiation is *not* spontaneously emitted from hydrogen-1 nuclei or hydrogen-2 nuclei. Which hydrogen nuclei are stable?

    A) nuclei from H-1, H-2, and H-3
    B) nuclei of H-1 and H-3 only
    C) nuclei of H-1 and H-2, only
    D) nuclei of H-2 and H-3 only

7. A mixture of emanations from radioactive atoms is passed through electrically charged plates, as shown in the diagram below.
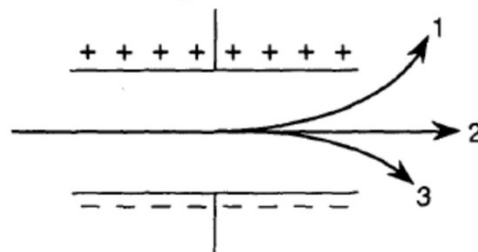
The nuclear emanations 1, 2, and 3 are called, respectively,

    A) beta, gamma, and alpha
    B) gamma, beta, and alpha
    C) gamma, alpha, and beta
    D) alpha, beta, and gamma

8. Which nuclear decay emission consists of energy, only?

    A) beta particle   B) alpha particle
    C) gamma radiation   D) positron

9. Which nuclear emission has no charge and no mass?

    A) beta particle   B) gamma ray
    C) positron   D) alpha particle

10. Which statement best describes gamma radiation?

    A) It has a mass of 4 and a charge of +2.
    B) It has a mass of 1 and a charge of 1.
    C) It has a mass of 0 and a charge of −1.
    D) It has a mass of 0 and a charge of 0.

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

    A) neutron   B) gamma ray
    C) alpha particle   D) beta particle

12. Which balanced equation represents a spontaneous radioactive decay?

    A) $14C + Ca_3(PO_4)_2 \rightarrow 3CaC_2 + 2P + 8CO$
    B) $^{14}_{7}N + ^{1}_{0}n \rightarrow ^{14}_{6}C + ^{1}_{1}P$
    C) $^{14}_{6}C \rightarrow ^{14}_{7}N + ^{0}_{-1}e$
    D) $H_2CO_3 \rightarrow H_2O + CO_2$

Natural Transmutation

13. Which particle is emitted when an atom of ^{85}Kr spontaneously decays?

    A) an alpha particle B) a beta particle
    C) a neutron   D) a proton

14. Positrons are spontaneously emitted from the nuclei of

    A) nitrogen-16   B) radium-226
    C) potassium-37   D) thorium-232

15. Given the nuclear equation:

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

    What particle is represented by X?

    A) positron   B) neutron
    C) alpha   D) beta

16. Which nuclear emission has the greatest mass?

    A) β^- B) γ C) α D) β^+

17. Which nuclear emission has the greatest mass and the *least* penetrating power?

    A) a beta particle   B) a neutron
    C) a positron   D) an alpha particle

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

    A) a beta particle   B) a neutron
    C) an alpha particle D) a proton

19. Alpha particles are emitted during the radioactive decay of

    A) radon-222   B) neon-19
    C) calcium-37   D) carbon-14

20. Which nuclear emission has the greatest penetrating power?

    A) gamma radiation B) positron
    C) proton   D) beta particle

21. Compared to the mass and the penetrating power of an alpha particle, a beta particle has

    A) more mass and greater penetrating power
    B) more mass and less penetrating power
    C) less mass and less penetrating power
    D) less mass and greater penetrating power

22. When an alpha particle is emitted by an atom, the atomic number of the atom will

    A) increase by 4   B) increase by 2
    C) decrease by 4   D) decrease by 2

23. Which particle has the *least* mass?

    A) beta particle   B) neutron
    C) proton   D) alpha particle

24. Which particle is emitted from a hydrogen-3 nucleus when it undergoes radioactive decay?

    A) β^- B) γ C) α D) β^+

25. Which particle has the greatest mass?

    A) an alpha particle   B) a positron
    C) a neutron   D) a beta particle

26. Given the nuclear equation:

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

    The particle represented by X is

    A) $^{10}_{6}\text{C}$ B) $^{10}_{5}\text{Be}$
    C) $^{9}_{4}\text{Be}$ D) $^{9}_{4}\text{Li}$

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

    A) ^{220}Fr B) ^{198}Au
    C) ^{53}Fe D) ^{137}Cs

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

    A) alpha particle, gamma ray, beta particle
    B) gamma ray, beta particle, alpha particle
    C) alpha particle, beta particle, gamma ray
    D) beta particle, alpha particle, gamma ray

29. An unstable nucleus loses the most mass if the nucleus emits

    A) a positron   B) a beta particle
    C) a gamma ray   D) an alpha particle

30. Which type of radiation is identical in mass and charge to a helium nucleus?

    A) positron   B) beta
    C) proton   D) alpha

Nuclear Decay Reactions

Type of Decay

1) $^{247}_{96}Cm \rightarrow {}^{243}_{94}Pu +$ $^{4}_{2}He$ or $^{4}_{2}\alpha$ Alpha

2) $^{243}_{94}Pu \rightarrow {}^{243}_{95}Am +$ $^{0}_{-1}e$ or $^{0}_{-1}\beta$ Beta

3) $^{243}_{95}Am \rightarrow {}^{239}_{93}Np +$ $^{4}_{2}He$ Alpha

4) $^{239}_{93}Np \rightarrow {}^{239}_{92}U +$ $^{0}_{+1}e$ or $^{0}_{+1}\beta$ Positron or Beta plus

5) $^{239}_{92}U \rightarrow {}^{235}_{90}Th +$ $^{4}_{2}He$ Alpha

6) $^{235}_{90}Th \rightarrow {}^{235}_{91}Pa +$ $^{0}_{-1}e$ Beta

7) $^{235}_{91}Pa \rightarrow {}^{235}_{90}Th +$ $^{0}_{+}e$ Positron

8) $^{235}_{90}Th \rightarrow {}^{231}_{88}Ra +$ $^{4}_{2}He$ Alpha

9) $^{231}_{88}Ra \rightarrow {}^{231}_{87}Fr +$ $^{0}_{+1}e$ Positron

10) $^{231}_{87}Fr \rightarrow {}^{227}_{85}At +$ $^{4}_{2}He$ Alpha

11) ^{227} ^{227}

$$_{85}At \rightarrow \ _{84}Po + \ _{1}^{0}e \qquad \text{Positron}$$

12) $$_{84}^{227}Po \rightarrow \ _{82}^{223}Pb + \ _{2}^{4}He \qquad \text{Alpha}$$

Write **nuclear equations** for each of the following:

1) Alpha decay of $_{91}^{231}Pa$ $_{91}^{231}Pa \rightarrow \ _{2}^{4}He + \ _{89}^{227}Ac$	2) Alpha decay of $_{62}^{146}Sm$ $_{62}^{146}Sm \rightarrow \ _{2}^{4}He + \ _{60}^{142}Nd$
3) Beta decay of $_{87}^{223}Fr$ $_{87}^{223}Fr \rightarrow \ _{-1}^{0}e + \ _{88}^{223}Ra$	4) Beta decay of At-198 $_{85}^{198}At \rightarrow \ _{-1}^{0}e + \ _{86}^{198}Rn$
5) Alpha decay of $_{62}^{149}Sm$ $_{62}^{149}Sm \rightarrow \ _{2}^{4}He + \ _{60}^{145}Nd$	6) Alpha decay of Gd-150 $_{64}^{150}Gd \rightarrow \ _{2}^{4}He + \ _{62}^{146}Sm$
7) Beta decay of $_{61}^{165}Pm$ $_{61}^{165}Pm \rightarrow \ _{-1}^{0}e + \ _{62}^{165}Sm$	8) Beta decay of Xe-152 $_{54}^{152}Xe \rightarrow \ _{-1}^{0}e + \ _{55}^{152}Cs$
9) Alpha decay of $_{101}^{249}Md$ $_{101}^{249}Md \rightarrow \ _{2}^{4}He + \ _{99}^{245}Es$	10) Beta decay of Cs-120 $_{55}^{120}Cs \rightarrow \ _{-1}^{0}e + \ _{56}^{120}Ba$

Regents Chemistry   **Artificial Transmutation**

1. In which type of reaction do two lighter nuclei combine to form one heavier nucleus?

   A) nuclear fusion   B) nuclear fission
   C) reduction   D) combustion

2. Which substance has *chemical* properties similar to those of radioactive ^{235}U?

   A) ^{233}U B) ^{235}Pa C) ^{206}Pb D) ^{233}Pa

3. Given the diagram representing a reaction:
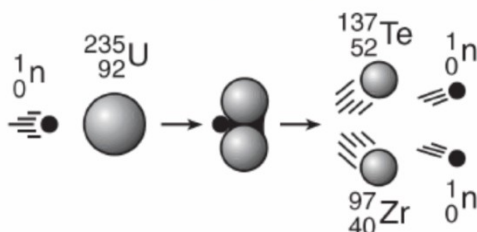
   Which phrase best describes this type of reaction and the overall energy change that occurs?

   A) nuclear, and energy is absorbed
   B) chemical, and energy is absorbed
   C) nuclear, and energy is released
   D) chemical, and energy is released

4. Which term identifies a type of nuclear reaction?

   A) transmutation   B) reduction
   C) deposition   D) neutralization

5. Given the balanced equation representing a nuclear reaction:

   $^{235}_{92}U + ^{1}_{0}n \rightarrow ^{142}_{56}Ba + ^{91}_{36}Kr + 3X + energy$
   Which particle is represented by X?

   A) $^{4}_{2}H$ B) $^{1}_{0}n$ C) $^{1}_{1}H$ D) $^{0}_{-1}e$

6. For a given mass of reactants, the energy released is greatest for a reaction involving

   A) slow oxidation   B) rapid oxidation
   C) fission   D) fusion

7. What is one benefit associated with a nuclear fission reaction?

   A) A large amount of energy is produced.
   B) The products are not radioactive.
   C) Stable isotopes are used as reactants.
   D) There is no chance of biological exposure.

8. Which statement best describes what happens in a fission reaction?

   A) Energy is released and less stable elements are formed.
   B) Energy is absorbed and more stable elements are formed.
   C) Light nuclei form into heavier nuclei.
   D) Heavy nuclei split into lighter nuclei.

9. The fusion of hydrogen nuclei with the release of energy can be initiated by a fission reaction because the fission reaction provides a

   A) high temperature and high pressure
   B) good supply of neutrons
   C) good supply of hydrogen nuclei
   D) high temperature and low pressure

10. Which change takes place in a nuclear fusion reaction?

    A) Ionic bonds are converted to covalent bonds.
    B) Matter is converted to energy.
    C) Energy is converted to matter.
    D) Covalent bonds are converted to ionic bonds.

11. In which reaction is mass converted to energy by the process of fission?

    A) $^{226}_{88}Ra \rightarrow ^{222}_{86}Ra + ^{4}_{2}He$
    B) $^{2}_{1}H + ^{2}_{1}H \rightarrow ^{4}_{2}He$
    C) $^{14}_{7}N + ^{1}_{0}n \rightarrow ^{14}_{6}C + ^{1}_{1}H$
    D) $^{235}_{92}U + ^{1}_{0}n \rightarrow ^{87}_{35}Br + ^{146}_{57}La + 3^{1}_{0}n$

12. Compared to an ordinary chemical reaction, a fission reaction will

    A) absorb smaller amounts of energy
    B) release smaller amounts of energy
    C) absorb larger amounts of energy
    D) release larger amounts of energy

Artificial Transmutation

13. Given the balanced equation representing a nuclear reaction:

    $^2_1H + ^3_1H \rightarrow ^4_2He + ^1_0n$

    Which phrase identifies and describes this reaction?

    A) fission, mass converted to energy
    B) fusion, energy converted to mass
    C) fission, energy converted to mass
    D) fusion, mass converted to energy

14. Which balanced equation represents a fusion reaction?

    A) $^2_1H + ^3_1H \rightarrow ^4_2He + ^1_0n$
    B) $^{235}_{92}U + ^1_0n \rightarrow ^{93}_{36}Kr + ^{140}_{56}Ba + 3^1_0n$
    C) $^{226}_{88}Ra \rightarrow ^{222}_{86}Rn + ^4_2He$
    D) $^{14}_7N + ^4_2He \rightarrow ^{17}_8O + ^1_1H$

15. Given the nuclear reaction:

    $^{235}_{92}U + ^1_0n \rightarrow ^{138}_{56}Ba + ^{95}_{36}Kr + 3^1_0n + energy$

    This equation can best be described as

    A) fission   B) endothermic
    C) natural decay   D) fusion

16. High energy is a requirement for fusion reactions to occur because the nuclei involved

    A) repel each other because they have like charges
    B) attract each other because they have like charges
    C) repel each other because they have unlike charges
    D) attract each other because they have unlike charges

17. When a nucleus with a high mass undergoes fission, the resulting nuclei are more stable than the original nucleus because they have a

    A) lower number of electrons
    B) lower binding energy per nucleon
    C) higher binding energy per nucleon
    D) higher number of electrons

18. An uncontrolled chain reaction takes place during the

    A) operation of a fission nuclear reactor
    B) production of energy by the Earth's Sun
    C) explosion of an atomic bomb
    D) fusion of light nuclei into heavier nuclei

19. Which balanced equation represents nuclear fusion?

    A) $CaO + CO_2 \rightarrow CaCO_2$
    B) $^6_3Li + ^1_0n \rightarrow ^3_1H + ^4_2He$
    C) $^2_1H + ^2_1H \rightarrow ^4_2He$
    D) $2H_2 + O_2 \rightarrow 2H_2O$

20. Which statement best describes a primary occurrence in an uncontrolled fission reaction?

    A) Mass is created and energy is stored.
    B) Mass is converted to energy, which is released.
    C) Mass is created and energy is released.
    D) Mass is converted to energy, which is stored.

21. The greatest amount of energy released per gram of reactants occurs during a

    A) redox reaction
    B) fission reaction
    C) substitution reaction
    D) neutralization reaction

22. Which balanced equation represents nuclear fusion?

    A) $^2_1H + ^2_1H \rightarrow ^4_2He$
    B) $^{235}_{92}U \rightarrow ^{231}_{90}Th + ^4_2He$
    C) $^{235}_{92}U + ^1_0n \rightarrow ^{90}_{38}Sr + ^{143}_{54}Xe + 3^1_0n$
    D) $^3_1H \rightarrow ^3_2He + ^0_{-1}e$

23. Which pair of nuclei can undergo a fusion reaction?

    A) uranium-238 and lead-208
    B) hydrogen-2 and hydrogen-3
    C) zinc-64 and calcium-44
    D) potassium-40 and cadmium-113

Regents Chemistry   **Half-Life**

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

    A) $\frac{1}{5}$ B) $\frac{1}{32}$ C) $\frac{1}{8}$ D) $\frac{1}{16}$

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

    A) Fr-220   B) N-16   C) P-32   D) K-42

3. What fraction of a Sr-90 sample remains unchanged after 87.3 years?

    A) $\frac{1}{2}$

    B) $\frac{1}{4}$

    C) $\frac{1}{3}$

    D) $\frac{1}{8}$

Base your answers to questions **4** through **7** on on the graph below. The graph represents the decay of radioactive material X into a stable decay product.
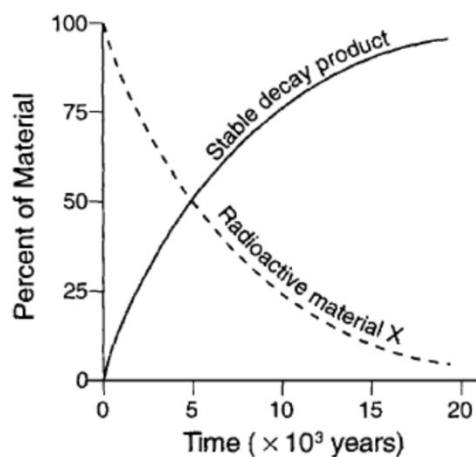

4. Each of the objects below has different amounts remaining of the original radioactive material X. Which object is most likely the oldest?

A)   B)   C)   D)

Rock   Shell   Bone   Wood

10% of the radioactive material remains   41% of the radioactive material remains   52% of the radioactive material remains   33% of the radioactive material remains

Half-Life

5. Which graph best represents the relative percentages of radioactive material X and its stable decay product after 15,000 years?(**The shaded region represents radioactive material while the non-shaded region represents stable decay products.**)

A)   B)   C)   D)
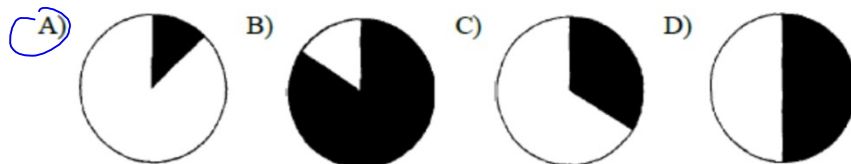
6. If radioactive material X were heated, the length of its half-life period would

   A) decrease   B) increase
   C) remain the same

7. What is the approximate half-life of radioactive material X?

   A) 5,000 yr   B) 100,000 yr   C) 10,000 yr   D) 50,000 yr

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

   A) 3.82 days and alpha decay   B) 1.91 days and beta decay
   C) 1.91 days and alpha decay   D) 3.82 days and beta decay

9. What is the half-life of a radioisotope if 25.0 grams of an original 200.-gram sample of the isotope remains unchanged after 11.46 days?

   A) 34.38 d   B) 11.46 d   C) 2.87 d   D) 3.82 d

10. 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?

   A) 8.3s   B) 2.08s   C) 1.04s   D) 4.16s

11. Which nuclide has a half-life that is *less* than one minute?

   A) strontium-90   B) phosphorus-32
   C) cesium-137   D) francium-220

12. In how many days will a 12-gram sample of $^{131}_{53}$I decay, leaving a total of 1.5 grams of the original isotope?

   A) 8.0   B) 16   C) 24   D) 20.

13. Exactly how much time must elapse before 16 grams of potassium-42 decays, leaving 2 grams of the original isotope?

   A) 8 × 12.4 hours   B) 2 × 12.4 hours
   C) 3 × 12.4 hours   D) 4 × 12.4 hours

14. An original sample of K-40 has a mass of 25.00 grams. After 3.9×10^9 years, 3.125 grams of the original sample remains unchanged. What is the half-life of K-40?

   A) 1.3×10^9 y   B) 3.9×10^9 y   C) 1.2×10^9 y   D) 2.6×10^9 y

HALF LIFE PROBLEMS - Use table N & T and show all work...

1) A sample of I-131 decays to 1.0 grams in 40 days. What was the mass of the original sample?

    32.0 g

2) What is the total number of hours required for Potassium-42 to undergo three half life periods?

    37.2 h

3) In 6.20 hours, a 100 gram sample of Ag-112 decays to 25.0 grams. What is the half life of Ag-112?

    3.1 h

4) A 2.5 g sample of an isotope of Strontium-90 was formed in a 1960 explosion of an atomic bomb at Johnson Island in the Pacific Test Site. Is what year will only 0.625 grams of the Strontium-90 remain?

    2018

5) An 80 g sample of a radioisotope decayed to 10 g after 24 days. What was the total number of grams of the original sample that remained unchanged after the first 8 days?

    40 g

6) What mass of a 32.0 g sample of ^{32}P will remain after 71.5 days of decay?

    1 g

7) After 60 days, 10.0 grams of radioactive isotope remains from an original 80.0 g sample. What is the half life of this element?

    20 d

8) 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. Given the following nuclear reaction:
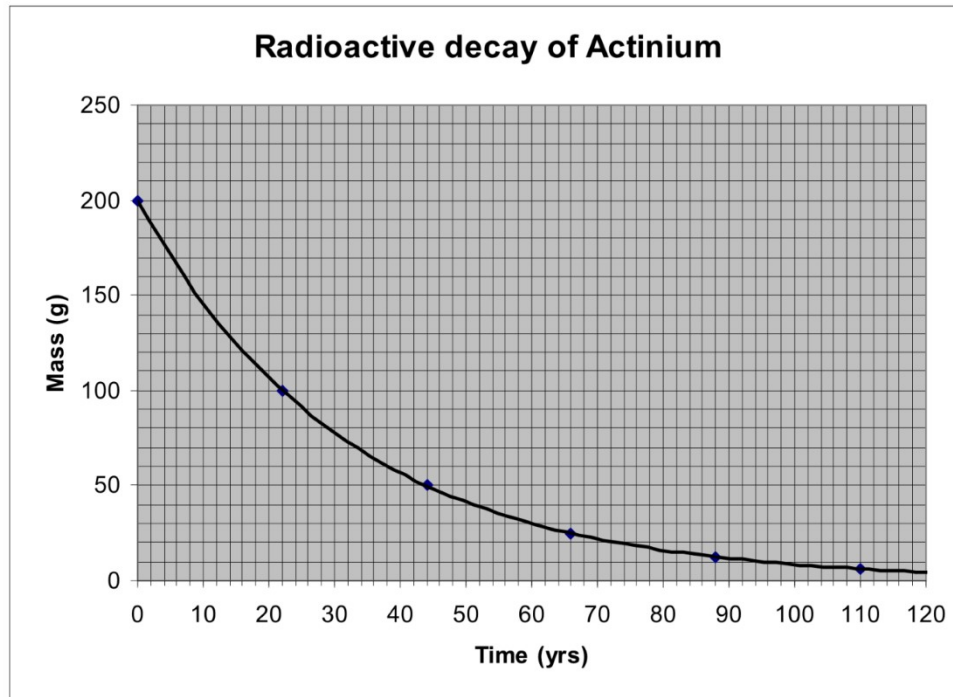
$$C\text{-}14 \rightarrow N\text{-}14 + X$$

a) What type of particle is represented by X? β^-

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

5,730 y

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

2.5 g

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

1/8

GRAPHING RADIOACTIVE DECAY

The graph for the decay of actinium below to answer questions 1-8.

Radioactive decay of Actinium

(Graph: Mass (g) on the y-axis from 0 to 250, Time (yrs) on the x-axis from 0 to 120, showing an exponential decay curve starting at 200 g with plotted points at approximately (0, 200), (22, 100), (44, 50), (66, 25), (88, 12), (110, 6).)

1) What was the original mass of the astatine sample? *200 g*

2) How many grams of astatine remain after 40 years? *57-58 g*

3) What is the half life of astatine? *22 l*

4) What mass of astatine remains after one half-life? *100 g*

5) What fraction of astatine remains after one half-life? *1/2 or 0.5*

6) How many half-lives must astatine go through until only 25% of the original sample mass remains? *2*

7) How many half-lives until only 6.25% remains? *4*

8) How many half-lives will it take for all of the original sample to decay?

   Impossible to tell