Nuclear Chemistry Questions with Solutions

Q-1: To sterilise surgical instruments, which of the following radioisotopes is used?
a) Iodine-131
b) Chromium-51
c) Iodine-123
d) Cobalt-60

Answer: d) Cobalt-60

Explanation: Cobalt-60 radioisotope is used to sterilise surgical instruments as well as to improve the safety and reliability of industrial fuel burners.

Q-2: Consider the following radioactive decay,
$^{238}_{92}U \rightarrow ^{206}_{82}Pb$
Find the total number of α-particles and β-particles.

Answer: Let us assume number of α-particles emitted are x and number of β-particles emitted are y.

$^{238}_{92}U \rightarrow ^{206}_{82}Pb + x\,^{4}_{2}He + y\,_{-1}^{0}\beta^{-}$

Total mass number on the reactant side= Total mass number on product side
238= 4x+206

On solving,x= 8

Total atomic number on reactant side= Total atomic number on product side
92=82+2x-y
92= 82+2(8)-y

On solving, y= 6
Therefore, x+y= 14

Q-3: The type of radiation with the greatest ability to penetrate matter is

a) Alpha
b) Visible light
c) Gamma
d) β^{-}

Answer: c) Gamma

Q-4: Which one of the following nuclides is most likely to decay by positron(β^+) emission is

a) ^{68}Cu
b) ^{63}Cu
c) ^{67}Cu
d) ^{59}Cu

Answer: d) ^{59}Cu

Explanation: Those nucleus which have low value of n/p ratio undergoes positron(β^+) emission.

Nuclides	Neutrons,n= Mass number-protons	Protons	n/p ratio
^{68}Cu	39	29	1.3448
^{63}Cu	34	29	1.1724
^{67}Cu	38	29	1.310
^{59}Cu	30	29	1.03

Thus, the table clearly shows that nucleus ^{59}Cu has the lowest n/p value and will therefore emit positron(β^+) .

Q-5: Write a balanced equation for the reaction of N^{14} with ***α***-particles. Use shorthand notation to express the reaction.

Answer: The nucleus of nitrogen atom is converted into the nucleus of oxygen atom by ***α***-particle($^{4}_{2}He$) and proton is also produced as a by-product. The reaction is shown below:

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

The above reaction can be expressed by short hand notation given below, in which the projectile and the liberating particle are expressed by their symbols in small brackets in between the parent and product nucleus.

Shorthand notation: $^{14}_{7}N\ (\alpha,p)^{17}_{8}O$

Q-6: Differentiate between nuclear and chemical reactions.

Answer:

Chemical Reactions	Nuclear Reactions
No new element is formed	New element is formed
Valence electrons of atoms participate in reaction.	Only the nucleus of atoms participates in reaction.
Balanced by the conservation of atoms	Balanced by the conservation of nuclear charge and mass number
Mass conservation is obeyed	Disobey mass conservation
Rate depends on external factors like temperature and the catalytic conditions	Rate is independent from any external condition

Q-7: Which of the following nuclear reactor components is used to slow down fast-moving neutrons without absorbing them?
a) Control rods
b) Coolant
c) Moderator
d) Fissile materials

Answer: c) Moderator

Explanation: The functions of various parts of the nuclear reactor are:

a) Control rods: These are the rods of material which can absorb neutrons and hence control the fission reaction.
b) Coolant: These are the materials which transform the energy produced in the fission reaction into heat energy.
c) Moderator: It is used to slow down the fast moving neutrons without absorbing them.
d) Fissile materials are the nuclides which directly result in chain reaction on bombardment with slow neutrons.

Q-8: When a radioactive nucleus decays, it emits one alpha particle and two beta particles; the daughter nucleus is _________ of the parent nucleus.

a) Isobar
b) Isotope
c) Isoelectronic

d) Isotones

Answer: b) Isotope

Explanation: Consider the case of a radioactive nucleus that decays and emits one alpha particle and two beta particles.

$^{238}_{92}U \rightarrow ^{234}_{92}U + ^{4}_{2}He + 2\ ^{0}_{-1}\beta^{-}$

We can clearly see that the parent nuclei $^{238}_{92}U$ and daughter nuclei $^{234}_{92}U$ have the same atomic number(protons), therefore they both are isotopes.

Q-9: A radioactive sample has an initial activity of 23 dis/min. After 1/2h, the activity is 11.5 dis/min. How many atoms of the radioactive nuclide were present originally?[$\lambda t_{1/2}$=0.69]

Answer: We know that,

$$\lambda = \frac{2.303}{t} log \frac{A_o}{A}$$

Where, A_o is the initial activity and A is the activity at time,t

Given: A_o = 23 dis/min, A= 11.5 dis/min, t= ½= 30 min

$$\lambda = \frac{2.303}{30} log \frac{23}{11.5} = 0.0231$$

Also, $A_O=\lambda N_o$
Where, N_o is the number of atoms present initially.

23= 0.0231×N_o
N_o= 10^3

Q-10: The radioactive element Ra(Z=88) emits three alpha particles in succession. Deduce in which group the resulting element will be found?

Answer: Group 14
Explanation: After emitting three alpha particles ($^{4}_{2}He$) in succession, the radioactive element Ra(Z=88) yields an element with the atomic number 82(Pb). Pb is a member of Periodic Table Group 14.

Q-11: A radioactive nuclide's half life is 20 years. If a sample of this nuclide has an activity of 6400 disintegrations per minute (dis/min) today, calculate its activity (dis/min) after 100 years.

Answer: We know that,
$A=A_oe^{-\lambda t}$
Where A is the activity at time, t
A_o is the activity initially
t= 100 years
λ is the decay constant
λ = $0.693/t_{1/2}$= 0.693/20= 0.03465 min^{-1}

Substituting, A_o= 6400 dis/min , t= 100 min and **λ** = 0.03465 min^{-1} in $A=A_oe^{-\lambda t}$, we get

$A=6400e^{-0.03465\times100}$
A= 200 dis/min

Q-12: What are magic numbers?

Answer: Nuclei with 2,8,20,50,82 or 126 protons or neutrons are exceptionally stable and have a larger number of stable isotopes than neighbouring nuclei in the periodic table. These numbers are called magic numbers. Nuclei with a magic number of protons as well as neutrons have notably high stabilities.

Q-13: Calculate the binding energy and binding energy per nucleon in kJ/mol of ${}_{15}^{30}P$

Mass of ${}_{1}^{1}H$= 1.0078 amu
Mass of neutron= 1.0087 amu
Mass of ${}_{15}^{30}P$ = 29.978 amu

Answer: Binding energy = Δm(amu)× 931.5 Mev
Number of neutrons in ${}_{15}^{30}P$= 15
Number of protons in ${}_{15}^{30}P$= 15
Mass defect (Δm) = mass of neutron + mass of proton- mass of nucleus
Δm = (15×1.0087+ 15×1.0078-29.978)amu = 0.2695 amu
Binding energy = 0.2695 × 931.5 = 251.04 Mev
Binding energy per nucleon= B.E/number of nucleons = 251.04/29.978 = 8.37 Mev

Q-14: Mention the following radioisotopes' applications: thorium-229, uranium-234, and iridium-192.

Answer:
Thorium-229: Helps fluorescent lights last longer
Uranium-234: Used in dental fixtures like crowns and dentures to provide a natural colour and brightness
Iridium-192: Used to test the integrity of pipeline welds, boilers and aircraft parts.

Q-15: The nuclide $^{198}_{79}Au$ has a half life of 64.8 hours. How much of a 0.0100 g sample remains at the end of 1 day.

Answer: Half life, $t_{1/2}$= 64.8 hours , t= 1day= 24 hours
We know that, $t_{1/2}$= 0.693/λ

Decay constant,λ= 0.693/64.8 = 0.0107 hr^{-1}

$A= A_o e^{-\lambda t}$
$= 0.01e^{-(0.0107\times24)}$
$=0.007735$ g

Practise Questions on Nuclear Chemistry

Q-1: In the following equation X is
$^{241}_{95}Am + {}_2^4\alpha \rightarrow {}_{97}^{243}Bk + X$

a) $2\ {}_0^1n$
b) ${}_0^1n$
c) $2\ {}_1^1H$
d) ${}_2^4He$

Answer: a) $2\ {}_0^1n$

Explanation: We know that nuclear reactions are balanced by the conservation of nuclear charge and mass number. So it is only possible if the reaction occurs as follows:

$^{241}_{95}Am + {}_2^4\alpha \rightarrow {}_{97}^{243}Bk + 2\ {}_0^1n$

Q-2: $^{215}_{84}Po$ undergoes a α-emission, yielding element X, followed by β-emission, yielding element Y.
a) Write the valence shell electron configuration of Y.
b) Indicate the groups of the periodic table to which X and Y belong.

Answer: On α-emission, the following reaction takes place:
$^{215}_{84}Po \rightarrow {}_{82}^{211}Pb + {}_2^4He$

Further, on beta emission the reaction takes place as:

${}_{82}^{211}Pb \rightarrow {}_{83}^{211}Bi + {}_{-1}^{0}\beta$

Thus, X= $_{82}^{211}Pb$ and Y=$_{83}^{211}Bi$

a) The valence shell electronic configuration of Y($_{83}^{211}Bi$)= [Xe] $4f^{14}\ 5d^{10}\ 6s^2\ 6p^3$
b) X belongs to Group-14 and Y belongs to Group-15

Q-3: In Boron neutron capture therapy, the initial boron isotope used and the particle generated after neutron capture respectively are:
a) ^{11}B and α- particle
b) ^{10}B and α- particle
c) ^{11}B and β- particle
d) ^{10}B and β- particle

Answer: b) ^{10}B and α- particle
Explanation: In boron neutron capture therapy, following reaction takes place:

$^{10}_{5}B + {}_{0}^{1}n \rightarrow {}_{3}^{7}Li + {}_{2}^{4}He$

Thus, the initial boron isotope used is $^{10}_{5}B$, and the particle produced after neutron capture is $_{2}^{4}He$ (α-particle).

Q-4: Radioactive decay is a process of the first order. Radioactive carbon decays with a half life of 5770 years in wood samples. What is the decay rate constant (in yr^{-1})? What fraction would remain after 11540 years?

Answer: The half life period for a first order reaction, $t_{1/2}$= 0.693/λ
Decay constant,λ= 0.693/5770
= $1.2\times10^{-4}\ yr^{-1}$

We know that, $A=A_oe^{-\lambda t}$
The fraction that would remain after 11540 years= A/A_o = $e^{-1.2\times10^{-4}\times11540}$ = 1/4

Q-5: Complete the following nuclear reactions.

a) $^{7}_{3}Li + {}^{1}_{1}H \rightarrow$
b) $^{235}_{92}U + {}_{0}^{1}n \rightarrow {}^{137}_{52}A + {}^{97}_{40}B$ + ________
c) $_{34}^{82}Se \rightarrow 2\ {}_{-1}^{0}e$ + _____
d) $_{13}^{27}Al$ + ____$\rightarrow$ $_{13}^{28}Al + \gamma$

Answer:
a) $^{7}_{3}Li + {}^{1}_{1}H \rightarrow 2\ {}_{2}^{4}He$
b) $^{235}_{92}U + {}_{0}^{1}n \rightarrow {}^{137}_{52}A + {}^{97}_{40}B + 2\ {}_{0}^{1}n$

c) ${}_{34}^{82}Se \rightarrow 2\ {}_{-1}^{0}e + {}_{36}^{82}Kr$

d) ${}_{3}^{27}Al + {}_{0}^{1}n \rightarrow {}_{13}^{28}Al + \gamma$