Nuclear Chemistry

Level – 1

1. C

   Solution – Radio-activity was discovered by Henry Becquerel.

2. D

   Solution – The rate of disintegration is dependent on the number of radioactive atoms present in the element only. So, in vacuum, rate of disintegration is not affected.

3. A

   Solution - Gamma rays are the highest energy photons which have shortest wavelength and highest frequency, rising from nuclear events during radioactive decay.

4. A

   Solution – Chadwick observed that when the nucleus of uranium atom was bombarded with fast moving neutrons, it becomes so very unstable that it is immediately broken into two nuclei of nearly equal mass besides other frequency.

5. A

   Solution – Gamma rays causes a nucleus to lose energy which means it becomes more stable. Neutrons are not directly ionising as they have 0 charge but they are as penetrating as gamma rays.

6. C

   Solution – Gamma radiation emission leaves both atomic number and mass number unchanged.

7. C

   Solution – A radioisotope of argon ^{35}Ar, lies below the band of stability, one would predict that it decays via positron emission.

8. D

Solution – Positron emission results from the transformation of one nuclear proton into neutron. The isotope thus produced possess same mass number.

9. C

Solution – When a radioactive nucleus emits α-particle mass number decreases and the atomic number decreases.

10. A

Solution – The half-life of radioactive element is 50 days.

$T_{1/2} = 50$

It reduces to ¼ i.e. ½ to ½

50 x 2 = 100

The time required are 100 days

11. C

Solution – There are 55 electrons, 55 protons and 78 neutrons in an atom of $^{133}_{55}Cs$.

12. A

Solution – bombardment of uranium-235 with a neutron generates tellurium-135 3 neutrons and zirconium-98.

Nuclear reaction: $^{235}U + n° \rightarrow {}^{135}Te + {}^{98}Zr + 3n°$.

Atomic number of uranium is 92, atomic number of zirconium (Zr) is 40 and atomic number of tellurium (Te) is 52, 92 = 40 + 52.

Uranium has atomic mass 235, zirconium has 98 and tellurium has 135:

235 + 1 = 135 + 98 +3, 236 = 236.

13. C

Solution – When the mass number and atomic number of an element undergoes beta decay the mass number does not change and atomic number increase by 1.

14. A

Solution - Alpha particles have low penetrating power largely because they are immensely more massive than beta, gamma, or neutron radiation.

15. B

Solution – Deuterium is a hydrogen isotope consisting of one proton, one neutron and one electron. Tritium is a hydrogen isotope consisting of one proton, two neutrons and one electron.

Level – 2

1. C

Solution - Nuclear isomers, which have the same number of protons and neutrons but differ in energy content and radioactivity, are also distinct nuclides.

2. D

Solution – The radioactive element X which has decays by electron beta emission with half of 4 days to a stable nuclide of elements Z. In this case the element X has an atomic number equal to n, then element X has an atomic number equal to n-1.

3. A

Solution - Positron emission: It is a type of decay process, in which a proton gets converted to neutron and an electron neutrino. This is also known as β^+-decay. In this the mass number remains same.

4. B

Solution – $_{92}U^{235} + {}_0n^1 \longrightarrow {}_{36}Kr^{94} + 3\ {}_0n^1 + {}_zX^A$

Using conservation of charge and mass

$235 + 1 = 94 + 3 + A$

$236 = 97 + A$

$A = 236 - 97$

$A = 139$

$92 + 0 = 36 + 0 + Z$

$92 = 36 + Z$

$Z = 92 - 36$

$Z = 56$

5. B

Solution – Proton is 1837 (approx 1800) times heavier than an electron. Penetration power $\propto$ 1/mass

6. D

Solution - ${}_0n^1 \longrightarrow {}_{+1}p^1 + {}_{-1}e^0$

7. B

Solution – No. of half lives = initial qty/ final qty

90/30 = 3

$(½)^3$ = 0.125 (amt remaining after 3 half lives)

600 atoms x 0.125 = 75 atoms

600 – 75 = 525 atoms.

8. A

Solution – No. of half lives = initial qty/ final qty

40/20 = 2 half lives

$(½)^2$ = 0.25 (amt remaining after 2 half lives)

100g x 0.25 = 25 g

9. D

Solution - Radon-222 itself alpha decays to polonium-218 with a half-life of approximately 3.82 days, making it the most stable isotope of radon.

10. A

Solution – Large energy release in an atomic bomb explosive is mainly due to products having a lesser mass than initial substance as there is mass decay that takes place.

11. A

Solution – ${}^{226}_{88}Ra \longrightarrow {}_{82}{}^{206}Pb$

No. of α particles A = 226 – 206 = 20/4 = 5α

Z = 88 -82 = 6/2 = 3

Now if 5α is emitted then Z should be reduced by

88 – (5 x 2) = 88 – 10 = 78 but you get 82Pb

82 – 78 = 4

12.A

Solution – No. of half-lives = initial qty/ final qty

$3.25 \times 10^5 / 3.25 \times 10^4 = 10$ half lives

$(½)^{10} = 9.76 \times 10^{-4}$ (amt remaining after 10 half lives)

$10.40\ \mu m \times 9.76 \times 10^{-4} = 0.0102\ \mu m$

13. B

Solution – $_{92}U^{235} + {}_0n^1 \longrightarrow {}_{36}Kr^{94} + 3\ {}_0n^1 + {}_zX^A$

Using conservation of charge and mass

235 + 1 = 94 + 3 + A

236 = 97 + A

A = 236 – 97

A = 139

92 + 0 = 36 + 0 + Z

92 = 36 + Z

Z = 92 – 36

Z = 56

14.D

Solution – Gamma rays is almost completed absorbed by 5 cm lead but not by 5mm aluminium. Beta rays is completely absorbed by 5mm aluminium but not by thin card. Alpha rays is absorbed by thin card.

Subjective question

1. Decay is the process by which an unstable atomic nucleus loses energy by radiation. A material containing unstable nuclei is considered radioactive. Three of the most common types of decay are alpha

decay, beta decay, and gamma decay, all of which involve emitting one or more particles or photons. Radioactive decay is the process in which the nuclei of radioactive atoms emit charged particles and energy, which are called by the general term radiation. Radioactive atoms have unstable nuclei, and when the nuclei emit radiation, they become more stable.

2. Radioactive decay is the set of various processes by which unstable atomic nuclei emit subatomic particles i.e. radiation. This is a random process, which means that it is impossible to predict when a particular radioactive nucleus will decay. It is also spontaneous which means the time of a decay in any way.
3. There are three primary types of radiation -
    - Alpha - these are fast moving helium atoms.
    - Beta - these are fast moving electrons.
    - Gamma - these are photons, just like light, except of much higher energy, typically from several keV to several MeV.
4. An isotope of a chemical element is an atom that has a different number of neutrons (that is, a greater or lesser atomic mass) than the standard for that element. The atomic number is the number of protons in an atom's nucleus. A Radioisotope is also an isotope by nature. The difference is that radioisotopes are very unstable and contain high levels of nuclear energy and emit this energy in the form of nuclear radiation.
5. An unstable form of a chemical element that releases radiation as it breaks down and becomes more stable. Radionuclides may occur in nature or be made in a laboratory. In medicine, they are used in imaging tests and in treatment. Also called radioisotope.
6. Alpha particles, also called alpha rays or alpha radiation, consist of two protons and two neutrons bound together into a particle identical to a helium-4 nucleus. Alpha particles are written or denoted by ‘α’
7. Penetration Power means the ability of an orbital to attract an electron. The Penetration effect of s orbital is the maximum because of

the closeness to the nucleus than are the p, d and f orbitals. There are three types radioactive particle; alpha, beta and gamma. Beta particles are more penetrating than alpha particles, but can be stopped by a thin sheet of aluminium. Of the three basic types of emissions gamma particles are the most penetrating.

8. ${}_{92}^{234}X + \beta^- + \alpha = Y + \gamma + 2\beta^+$

   ${}_{92}^{234}X + {}_{-1}^{0}\beta^- + {}_{2}^{4}\alpha = {}_{b}^{a}Y + {}_{0}^{0}\gamma + 2{}_{+1}^{0}\beta$

   $234 + 0 + 4 = 238 \qquad a + 0 + 2(0) = 238$

   $92 - 1 + 2 = 93 \qquad b + 0 + 2(1) = 93$

   $b = 91$

   ${}_{91}^{238}Y$ = no. of protons – 91, mass no. - 238

9. The following reaction are artificial radioactive decay because it's a positron and such nuclear reactions are induced.

   ${}_{12}^{24}Mg + \beta^+ \longrightarrow {}_{13}^{24}Al$

10. When an atom emits an alpha particle in alpha decay, the atom's mass number decreases by four due to the loss of the four nucleons in the alpha particle. The atomic number of the atom goes down by exactly two, as a result of the loss of two protons, the atom becomes a new element.

11. Beta particles are a type of ionizing radiation and for radiation protection purposes are regarded as being more ionising than gamma rays, but less ionising than alpha particles. Beta particles are emitted by neutron rich unstable nuclei. Beta particles are high energy electrons. These electrons are not electrons from the electron shells around the nucleus, but are generated when a neutron in the nucleus splits to form a proton and an accompanying electron.

12. There are three types of radiation: alpha particles, beta particles and gamma rays. Alpha particles can be absorbed by a thin sheet of paper or by a few centimetres of air. Beta particles can be blocked by a sheet of aluminium, but gamma rays can pass through paper, air and aluminium.

13. No. of half live = initial qty/ final qty

$(½)^{3.5}$ = 0.088 (amt remaining after 3.5 half lives)

4 x 0.088 = 0.35 g

$t_{1/2}$ = 5730 days

4g = 5730 days

2g = 5730 days

1g = 5730 days

0.5g = 5730 days

0.25g = 5730 days

} 4 half lives

5730 x 4 = 22920 years.

14. The nucleus of an atom is held together by the strong nuclear force that binds together protons and neutrons. Although the strong nuclear force is the strongest of the four fundamental forces, it acts only over very short - typically nuclear - distances. It binds together the protons and neutrons in the nucleus. The stability of an atom depends on the ratio of its protons to its neutrons, as well as on whether it contains neutrons or protons that would represent closed and filled quantum shells. Too many neutrons or protons upset this balance disrupting the binding energy from the strong nuclear forces making the nucleus unstable.
15. An unstable nucleus tries to achieve a balanced state by given off a neutron or proton and this is done via radioactive decay. The nucleus of this kind of atom is said to be stable. In some atoms the binding energy is not strong enough to hold the nucleus together, and the nuclei of these atoms are said to be unstable. Unstable atoms will lose neutrons and protons as they attempt to become stable.
16. Nuclear fusion is a reaction in which two or more nuclei combine forming a new element with a higher atomic number. The energy realised in fusion is related to $E = mc^2$.Few radioactive particles are produced by fusion reaction but are trigged by fission reaction. Nuclear fission is the splitting a large atom into two or more small ones. Fission produces many highly radioactive particles.

17. Chain reaction, self-sustaining reaction that, once started, continues without further outside influence. A pile of wood burning after it has been kindled is an example of a chemical chain reaction.

$$H_2 + Br_2 \longrightarrow 2\ HBr$$

18. The 4n series is one of three classical radioactive series beginning with naturally occurring thorium-232.As a result, the 4n series is known as the thorium series.

1 Thorium series (4_n series) beings with $_{90}TH^{232}$ and ends at $_{82}Pb^{208}$.

2.Neptunium series (4_n +1 series) begins with $_{94}Pu^{241}$ and ends at $_{83}Bi^{209}$.

3. Uranium series (4_n +2 series) begins with $_{92}U^{238}$ and ends at $_{82}Pb^{206}$.

4. Actinium series (4_n +3 series) begins with $_{92}U^{235}$ and ends at $_{82}Pb^{207}$.