## Solutions

### Question 1

**a.** The number of nucleons in the nucleus

**b.** The number of protons in the nucleus or, equivalently, the number of electrons in the electron cloud of a neutral atom.

---

### Question 2

$^{9}_{4}Be$ gives 4 protons and (9 – 4) = 5 neutrons

$\therefore$ **D (ANS)**

---

### Question 3

**a.** $^{226}_{88}Ra$

88 protons,
(226 – 88) = 138 neutrons
226 nucleons

**b.** $^{35}_{17}Cl$

17 protons,
(35 – 17) = 18 neutrons
35 nucleons

**c.** $^{184}_{74}Ta$

74 protons,
(184 – 74) = 110 neutrons
184 nucleons

---

### Question 4

Isotopes have the same number of protons but different numbers of neutrons.

$\therefore$ **D (ANS)**

### Question 5

An **ion** is an atom or molecule in which the total number of electrons is not equal to the total number of protons, giving the atom or molecule a net positive or negative electrical charge.

$\therefore$ **C (ANS)**

---

### Question 6

Isotopes have the same number of protons but different numbers of neutrons.

$\therefore$ **A and B (ANS)**

---

### Question 7

Alpha particle radiation consists of two neutrons and two protons, a helium nucleus, emitted from the nucleus of large atoms that are unstable.

---

### Question 8

Beta-particle radiation consists of fast moving electrons or positrons (anti-electron, positively charged). A proton is transformed into a neutron, or vice versa, inside an atomic nucleus. They emanate from the nucleus of radioactive nuclei that has too many neutrons for stability. This process allows the atom to move closer to the optimal ratio of protons and neutrons.

---

### Question 9

Changes of energy states within the nucleus result in the emission of gamma rays (high energy photons, outside the visible spectrum). Gamma rays are electromagnetic waves, similar in nature to light waves and x-rays. They have no charge and do not alter the mass number of the nucleus that emits them.

---

### Question 10

**a)** X-rays, infrared, microwaves and gamma rays
**b)** alpha particles
**c)** alpha particles
**d)** beta particles
**e)** alpha, beta, gamma, X-rays
**f)** gamma rays

---

### Question 11

$\beta$-decay involves the loss of an electron (or positron) from the nucleus. Therefore the atomic number will increase by one (hence the original element becomes a new element) and the mass number remains constant.

$\therefore$ **D (ANS)**

---

**Question 12**

Alpha decay is the emission of a helium nucleus, ${}^{4}_{2}He^{2+}$.

Therefore the mass number decreases by 4, and the atomic number decreases by 2.

$\therefore$ **A (ANS)**

---

**Question 13**

$\therefore$ **A (ANS)**

by definition

---

**Question 14**

Alpha particle radiation consists of two neutrons and two protons.

**C (ANS)**

---

**Question 15**

Gamma radiation is produced by the decay of atomic nuclei as they transition from a high energy state to a lower state, in order to become more stable.

**D (ANS)**

---

**Question 16**

**A (ANS)**

---

**Question 17**

Gamma rays travel at the speed of light, beta particles can go as fast as 90% of the speed of light, and Alpha particles can travel up to 10% of the speed of light.

$\therefore$ **A (ANS)**

---

**Question 18**

$\therefore$ **A (ANS)**

by definition

---

**Question 19**

(i) **C (ANS)**
(ii) **D (ANS)**

---

**Question 20**

(i) **F (ANS)**
(ii) **G (ANS)**

---

**Question 21**

You need to balance the 'equations' on both sides.

The first equation becomes

${}^{214}_{83}Bi \rightarrow {}^{210}_{81}Q + {}^{4}_{2}\alpha$

The second equation becomes

${}^{214}_{83}Bi \rightarrow {}^{214}_{84}R + {}^{0}_{-1}\beta$

$\therefore$ **B (ANS)**

---

**Question 22**

You need to balance the 'equations' on both sides.

The first equation becomes

${}^{214}_{83}Bi \rightarrow {}^{210}_{81}Q + {}^{4}_{2}\alpha$

The second equation becomes

${}^{214}_{83}Bi \rightarrow {}^{214}_{84}R + {}^{0}_{-1}\beta$

$\therefore$ **C (ANS)**

---

**Question 23**

4.2 MeV = $4.2 \times 10^{6} \times 1.6 \times 10^{-19}$
= $6.72 \times 10^{-13}$

$\therefore$ **B (ANS)**

---

**Question 24**

The equation is ${}^{212}_{84}Po \rightarrow X + {}^{4}_{2}He$

$\therefore X = {}^{208}_{82}Pb$

$\therefore$ **D (ANS)**

---

**Question 25**

The decay process is

$${}^{214}_{83}Bi \rightarrow {}^{Z}_{A}X + {}^{4}_{2}He + {}^{0}_{-1}e + 2\gamma$$

$\therefore$ **Z = 210, A = 82 (ANS)**

---

**Question 26 and 27**

The decay process is

$$^{237}_{93}Np \rightarrow ^{213}_{83}Bi + n(^{4}_{2}He) + m(^{0}_{-1}e)$$

Use the mass number to determine the number of alpha particles released.

$\therefore$ n = (237 - 213)/4

$\therefore$ n = 24/4

$\therefore$ n = 6

This would mean that the atomic number should be 93 – (6 × 2) = 81

Since it is 83, then m = 2.

**$\therefore$ 6 alpha particles and 2 beta particles (ANS)**

---

**Question 28**

The probability that any particular nucleus will decay in the next half life is always 0.5

**$\therefore$ C (ANS)**

---

**Question 29**

With a half-life of 10 days, after 20 days there will ¼ of the original sample undecayed.

**$\therefore$ 2.5 × $10^{-4}$ gm (ANS)**

---

**Question 30**

With a title of “decay constant”, you would expect it to remain the same.

The decay constant is the % that decay in a particular time frame.

**$\therefore$ 0.07 per day (ANS)**

---

**Question 31**

18 hours is 3 half-lives. Therefore you will initially need $2^3$ times the final amount.

**$\therefore$ 8 µg (ANS)**

---

**Question 32**

The fraction $\frac{2.0}{16}$ reduces to $\frac{1}{8} = \frac{1}{2^3}$

It will take 3 half-lives for the amount of radon to decrease to 2.0 mg.

$\therefore$ 3 × 3.8 = 11.4 days.

**$\therefore$ 11.4 days (ANS)**

---

**Question 33**

The activity will drop to 50% after the first half-life and to 25% after the second.

$\therefore$ 2 × 5 = 10

**$\therefore$ 10 years (ANS)**

**Question 34**

$\frac{1}{16} = \frac{1}{2^4}$, therefore 4 half-lives in 24 hours.

**$\therefore$ 6 hours (ANS)**

---

**Question 35**

The equation must always balance the mass number and the atomic number.

Therefore the first step in this process must be

$$^{98}_{42}Mo + ^{1}_{0}n \rightarrow ^{99}_{42}Mo$$

this will lead to

$$^{99}_{42}Mo \rightarrow ^{99m}_{43}Tc + \beta^- + \gamma$$

**$\therefore$ C (ANS)**

---

**Question 36 (1983, 76, 77)**

The equation becomes

$$^{56}_{25}Mn \rightarrow ^{56}_{26}D + ^{0}_{-1}e$$

Therefore D has 26 protons and 30 neutrons.

**$\therefore$ N = 30, Z = 26 (ANS)**

**Question 37**

10 hours is 4 half-lives, therefore there will be $\frac{1}{16}$ the number of $^{56}_{25}Mn$ but the same number of the stable $^{55}_{25}Mn$

$\therefore \frac{1}{16} \times 1.0 \times 10^{-10}$

**$\therefore$ 6.25 × $10^{-12}$ (ANS)**

---

**Question 38**

If $^{14}_{6}C$ decays by $\beta^-$ emission, then the atomic number will increase by 1, whilst the mass number remains constant.

$\therefore$ $^{14}_{7}N$

**$\therefore$ C (ANS)**

**Question 39**

If the ratio was greater by a ratio of 8, that is a factor of $2^3$. This implies that one sample is 3 half-lives older than the other.

$3 \times 5740 =$ **17,220 Years (ANS)**

---

**Question 40**

If we assume that all of the $^{206}Pb$ has come from the decay of $^{238}U$, and the rocks contain roughly equal numbers of atoms of $^{238}U$ and $^{206}Pb$, then one half life must have past.
One half life is $4.5 \times 10^9$ years.
$\therefore$ **$4.5 \times 10^9$ years (ANS)**

**Question 41**

Looking at the mass numbers
238-206/4
= 32/4
= 8
$\therefore$ **8 alpha particles (ANS)**

---