1.(1) Nucleon: a generic term used to identify a nuclear particle ie either a proton or a neutron.

(2) The atomic number of a nucleus is the number of protons in that nucleus.

(3) Mass number (A) of a nucleus is the total number of nucleons in that nucleus (= protons + neutrons)

2. (1) Pb^{214}_{82}

Atomic no. Z = 82

Mass no. A = 214

(2) Pb^{215}_{82}

Identical to Pb^{214}_{82} in all respects except that it has one more neutron in its nucleus.

Pb^{215} has the same chemical properties as Pb^{214}, but different physical props. (eg density).

3.

Symbol	# proton	# neutron	# nucleon
Fe^{56}_{26}	26	30	56
Ba^{141}_{56}	56	85	141
O^{16}_{8}	8	8	16
Np^{239}_{93}	93	146	239
Li^{6}_{3}	3	3	6

4(1) An element is defined by the no. of protons in its nucleus. (Atomic no.).

An isotope of an element is a specific combination of that no. of protons with same no. of neutrons.

∴ different isotopes of the same element have the same no. of protons but a different no. of neutrons

4(2) $O^{16}_{8} \rightarrow 8p, 8n$

$O^{17}_{8} \rightarrow 8p, 9n.$

(3) Too many neutrons or too few neutrons.

There are certain combinations of protons & neutrons that are stable.

If an isotope of an element has more neutrons than a stable combination (or less) it will decay radioactively.

5 Isotopes of an element are identical in their chemical behaviour.

∴ If radioactive isotopes of an element occur in nature they will follow the same ecological environmental / food chain path as their stable counterparts.

∴ they will remain together.

6. (1) There is a stronger nucleon force holding the nucleons together.

(2) It is a very strong force (the strongest known force)

It is of very short range ($\sim 10^{-15}$ m). It does not act over a distance greater than the diameter of several nucleons.

It is generally attractive but over extremely small distances it is repulsive

It is charge independent. The force between 2 nucleons is the same, no matter whether proton or neutron.

(3) If there are >83 protons the cummulative repulsive force of these protons overcomes the short range attractive force between nucleons. (Electrostatic force is long range)

7, mass $H^2_1 = 3.344 \times 10^{-27}$ kg

$m_p = 1.673 \times 10^{-27}$ kg

$m_n = 1.675 \times 10^{-27}$ kg

$\therefore m_p + m_n = 3.348 \times 10^{-27}$ kg.

∴ Mass defect $\Delta m = .004 \times 10^{-27}$

$= 4 \times 10^{-30}$ kg

$E = \Delta m c^2$

$= 4 \times 10^{-30} \times 9 \times 10^{16}$

$= 3.6 \times 10^{-13}$ J

$= \dfrac{3.6 \times 10^{-13}}{1.6 \times 10^{-19}}$

$\approx 2.25 \times 10^{6}$ eV

$\approx$ 2.25 MeV

8 mass $Fe^{56}_{26} = 9.2860 \times 10^{-26}$ kg

(1) mass of 26p $= 26 \times 1.673 \times 10^{-27}$

$= 4.3498 \times 10^{-26}$ kg

mass of 30n $= 30 \times 1.675 \times 10^{-27}$

$= 5.025 \times 10^{-26}$ kg

$\therefore 26m_p + 30m_n = 9.3748 \times 10^{-26}$ kg

$\therefore \Delta m = (9.3748 - 9.2860) \times 10^{-26}$

$= 8.88 \times 10^{-28}$ kg

(2) $E = \Delta m c^2$

$= 8.88 \times 10^{-28} \times 9 \times 10^{16}$

$= 7.992 \times 10^{-11}$ J

$= \dfrac{7.992 \times 10^{-11}}{1.6 \times 10^{-19}}$ eV

$= 4.995 \times 10^{8}$ eV

$\approx$ 500 MeV

9. H^2_1 : $\Delta m = 4 \times 10^{-30}$ kg (see Q 7)

H^3_1 : $2m_n + m_p = 5.023 \times 10^{-27}$ kg

$\therefore \Delta m = (5.023 - 5.0089) \times 10^{-27}$

$= 1.41 \times 10^{-29}$ kg

∴ BE of H^3_1 > BE of H^2_1 as mass defect is greater

10. Matter is converted into energy on formation of H^2_1. (it has a mass defect)

This energy is emitted as the gamma photon.

11. (1) BE of U^{238}_{92} = 1800 MeV

$= 1.80 \times 10^{9} \times 1.6 \times 10^{-19}$

$= 2.88 \times 10^{-10}$ J.

(2) $E = \Delta m . c^2$

$\therefore \Delta m = \dfrac{E}{c^2}$

$= \dfrac{2.88 \times 10^{-10}}{9 \times 10^{16}}$

$= 3.2 \times 10^{-27}$ kg.

12 (1) $He^4_2 + N^{14}_7 \longrightarrow O^{17}_8 + H^1_1$

(2) $H^2_1 + H^3_1 \longrightarrow He^4_2 + n^1_0$

(3) $Ra^{226}_{88} \longrightarrow Rn^{222}_{86} + He^4_2$

(4) $Po^{210}_{84} \longrightarrow Pb^{206}_{82} + He^4_2$

(5) $Al^{27}_{13} + He^4_2 \rightarrow P^{30}_{15} + n^1_0$

(6) $n^1_0 + N^{14}_7 \longrightarrow C^{14}_6 + H^1_1$

(7) $C^{12}_6 + H^1_1 \longrightarrow N^{13}_7 + \gamma^0_0$

13. (1) X^1_1 ∴ mass no. = 1, atomic no. = 1 } proton

(2) Y^9_4 ∴ mass no. = 5, atomic no. = 4

14. (1) $H^2_1 + H^3_1 \longrightarrow He^4_2 + n^1_0$

mass of reactants on LHS

$= (3.344 + 5.023) \times 10^{-27}$

$= 8.367 \times 10^{-27}$ kg

mass of products on RHS

$= (6.644 + 1.675) \times 10^{-27}$

$= 8.319 \times 10^{-27}$ kg

∴ Energy is released (mass decreases)

14 (1) $\Delta m = (8.367 - 8.319) \times 10^{-27}$ kg
$= 4.8 \times 10^{-29}$ kg

$\therefore E = \Delta m c^2$
$= 4.8 \times 10^{-29} \times 9 \times 10^{16}$
$= 4.32 \times 10^{-12}$ J
$= \frac{4.32 \times 10^{-12}}{1.6 \times 10^{-19}}$ eV
$= 2.7 \times 10^{7}$ eV
$= \underline{27 \text{ MeV}}$

15 Conservation of Mass Number (or Nucleon Number)
Conservation of Charge (ie Atomic No.)
Conservation of TOTAL Energy (ie of Mass-Energy)
Conservation of Momentum.

16. $Po^{210}_{84} \rightarrow Pb^{206}_{82} + He^{4}_{2}$

(1) Before decay total momentum $\vec{P}_T = 0$
$\therefore$ By conservation of mom. $\vec{P}_T = 0$ after the decay
$\therefore \vec{P}_{Pb} + \vec{P}_{\alpha} = 0$
$\therefore \vec{P}_{Pb} = -\vec{P}_{\alpha}$
$\therefore$ Pb nucleus & α particle must move in opposite directions.

(2) $\frac{v_{Pb}}{v_{\alpha}} = \frac{m_{\alpha}}{m_{Pb}} = \underline{\frac{1}{51.5}}$

(3) $\frac{K_{\alpha}}{K_{Pb}} = \frac{m_{Pb}}{m_{\alpha}} = \underline{51.5}$

17. All nuclei have a mass defect. In all nuclear reactions, either mass is converted to energy or energy is converted to matter. ($E = mc^2$).
$\therefore$ Mass is not conserved.

18. $n^{1}_{0} + N^{14}_{7} \rightarrow C^{14}_{6} + H^{1}_{1}$

(1) High energy neutrons just collide with the N^{14}_{7} nucleus transferring energy to it.
The neutron must be moving slowly so that it can be absorbed into the N^{14}_{7} nucleus.
The reaction above releases energy $\therefore$ does not need an input of energy to proceed.

(2) A 2 body collision.
Momentum is conserved.
Some energy transfer.

(3) Mass of reactants on LHS
$= 2.3252 \times 10^{-26} + 1.675 \times 10^{-27}$
$= \underline{2.4927 \times 10^{-26}}$ kg.

Mass of products in RHS
$= 2.3253 \times 10^{-26} + 1.673 \times 10^{-27}$
$= \underline{2.4926 \times 10^{-26}}$ kg.

$\therefore$ Mass lost $= 0.0001 \times 10^{-26}$ kg
$= \underline{1.0 \times 10^{-30}}$ kg

$\therefore$ Energy is released.

(4) $E = \Delta m c^2$
$= 1 \times 10^{-30} \times 9 \times 10^{16}$
$= 9 \times 10^{-14}$ J
$= \frac{9 \times 10^{-14}}{1.6 \times 10^{-19}}$ eV
$= 5.6 \times 10^{5}$ eV
$= \underline{0.56 \text{ MeV}}$

19. $H^{2}_{1} + C^{12}_{6} \rightarrow N^{13}_{7} + n^{1}_{0}$

(1) The cyclotron can accelerate the deuterons (H^{2}_{1}) to energies in excess of 0.28 MeV.
This K.E. of these particles is the energy input to cause this reaction to proceed.

(2) 0.28 MeV is just the energy need to create the extra mass of the products ($E = \Delta m c^2$)
But the deuteron is moving & momentum must be conserved.
$\therefore$ the products are moving & hence have kinetic energy.
$\therefore$ The extra 0.05 MeV of energy must be input to provide for the KE of the reactants.

(3) $E = 0.28$ MeV
$E = 2.8 \times 10^{5} \times 1.6 \times 10^{-19}$ J
$= 4.48 \times 10^{-14}$ J
But $E = \Delta m c^2$
$\therefore \Delta m = \frac{E}{c^2}$
$= \frac{4.48 \times 10^{-14}}{9 \times 10^{16}}$
$= \underline{5.0 \times 10^{-31}}$ kg.

20. $H^{1}_{1} + O^{16}_{8} \rightarrow N^{13}_{7} + He^{4}_{2}$

(1) Mass of reactants on LHS
$= 1.673 \times 10^{-27} + 2.65527 \times 10^{-26}$
$= \underline{2.82257 \times 10^{-26}}$ kg

Mass of products on RHS
$= 2.15900 \times 10^{-26} + 6.64462 \times 10^{-27}$
$= \underline{2.82346 \times 10^{-26}}$ kg.

$\therefore$ Energy is absorbed (mass products > mass reactants)

20(2) $\Delta m = 0.00089 \times 10^{-26}$ kg
$= 8.9 \times 10^{-30}$ kg

$\therefore E = \Delta m c^2$
$= 8.9 \times 10^{-30} \times 9 \times 10^{16}$
$= 8.0 \times 10^{-13}$ J
$= \frac{8.0 \times 10^{-13}}{1.6 \times 10^{-19}}$ eV
$= \underline{5.0 \text{ MeV}}.$

21. Carbon-14 C^{14}_{6} is produced in the upper atmosphere when neutrons collide with stable nitrogen-14 N^{14}_{7} atoms.
$n^{1}_{0} + N^{14}_{7} \rightarrow C^{14}_{6} + H^{1}_{1}$
The neutrons are released on collisions of protons (from "cosmic ray showers") with atmospheric gases.

22. Nitrogen-13 atoms are produced in hospitals by accelerating deuterons (H^{2}_{1}) in a cyclotron and using them to bombard stable carbon-12 atoms.
$H^{2}_{1} + C^{12}_{6} \rightarrow N^{13}_{7} + n^{1}_{0}$

or else/
accelerating protons in the cyclotron & using these to bombard stable oxygen-16 atoms:
$H^{1}_{1} + O^{16}_{8} \rightarrow N^{13}_{7} + He^{4}_{2}$