UG part II

Subsidiary

Nuclear chemistry

Saathi

Date ___/___/___

Part (II) (Subs) Radioactivity

Topic 3 → Nuclear stability

Nuclear stability means that the nucleus of an element is stable and thus it does not decay spontaneously emitting any kind of radioactivity.

A nucleus is stable if it cannot be transformed into another configuration.

- All nuclei are composed of two basic particles, neutrons and protons. Neutrons and protons are almost that same size but differ in their electrical charge.
- Neutrons have no electrical charge and contribute only mass to the nucleus. Each proton has a positive charge equal in strength to the negative charge carried by an electron.

- The number of protons in a nucleus is the atomic number (Z) and establishes the chemical identity of the atom. Each atomic number corresponds to a different chemical element. ; there are now approximately 108 known chemical elements that correspond to nuclei containing from 1 to 106 protons.

Nuclear stability refers to the tendency of a nucleus of atom to decay, which means to change in something else. If the isotope of an element (called a nuclide) is unstable, the nuclide has the tendency of emitting some kind of radiation and is called radioactive. Radioactivity is associated with unstable nuclide.

Stable nucleus → non-radioactive

Unstable nucleus → radioactive

Date ___/___/___

Saathi

- less stable means more radioactive and more stable means less radioactive.

Q What makes a nuclei stable?

Ans "Nature seeks the lowest energy state"
In the lowest energy state things are more stable less likely to change. Unstable atoms will try and become stable by getting to a lower energy state. So, the lowest energy state makes a nuclei stable.

- The most important factor which decides the stability is <u>Neutron to proton ratio</u>.

- Neutron to proton ratio is close to 1 for atoms of elements with low atomic number which is of less than about 20 protons.

- The n/p ratio steadily increases as the atomic number increases past element calcium (20) to about element polonium (84). Every element beyond an atomic number of 84 is unstable.

- The strong nuclear force exerts an attractive force among nucleons. The more proton packed together the more neutrons are needed to bind the nucleus together. Atomic nuclei with atomic number up to 20 have almost equal number of protons and neutrons
- Nuclei with higher atomic numbers have more neutrons to protons.

Date ___ / ___ / ______

- The number of neutrons needed to create a stable nuclei increases more than the number of protons

- The one of the simplest ways of predicting the nuclear stability is based on whether a nucleus contains an odd/even number of protons and neutrons.

Protons	Neutrons	Number of Stable Nuclides	Stability
odd	odd	4	least stable
odd	Even	50	more stable
Even	odd	57	even more stable
Even	Even	168	most stable.

Stability

- Nuclides containing odd numbers of both protons and neutrons are the least stable and this means more radioactive.
- Nuclides containing even numbers of both protons and neutrons are most stable and this means less radioactive.
- Nuclides contain odd numbers of protons and even numbers of neutrons are less stable than nuclides containing even numbers of protons and odd numbers of neutrons.

- In general, nuclear stability is greater for nuclides containing even numbers of protons

Nuclear Stability

It is noted that nuclei with certain number of protons or neutrons appear to be very stable. These numbers, called **magic number**. For protons the magic numbers are 2, 8, 20, 28, 50 and 82. Neutrons have these same magic numbers, as well as the magic number 126. For protons, calculations show that 114, 164 and 184 should also be a magic numbers. When both the number of protons and the number of neutrons are magic numbers the nucleus is very stable.

(1) Elements of even atomic number are more stable and more abundant than neighbouring elements of odd atomic number. This is known as **Harkin's Rule** (The rule applies almost universally but ^1_1H is a notable exception).

(2) Elements of even atomic number are richer in isotopes and never have less than three stable isotopes. Elements with odd atomic numbers often have only one stable isotope and never have more than two isotopes.

(3) There is a greater tendency for the number of neutrons and the number of protons in the nucleus to be even.

(4) Many radioactive nuclei decay by emitting alpha particles, or ^4_2He nuclei. There appears to be special stability in the ^4_2He nucleus. It contains 2 protons and 2 neutrons; that is, it contains a magic number of protons (2) and a magic number of neutrons (also 2).

(5) Another piece of evidence is seen in the final products obtained in natural radioactive decay. For example, uranium 238 decays to thorium – 234, which in turn decays to protactinium – 234, and so forth. Each product is radioactive and decay to another nucleus until the final product, $^{206}_{82}Pb$, is reached. This nucleus is stable. Note that it contains 82 protons, which is a magic number.

Table 7.2 : Number of Stable Isotopes with Even and Odd Number of Protons and Neutrons

Number of Stable Isotopes	164	55	50	5
Number of Protons	Even	Even	Odd	Odd
Number of Neutrons	Even	Odd	Even	Odd

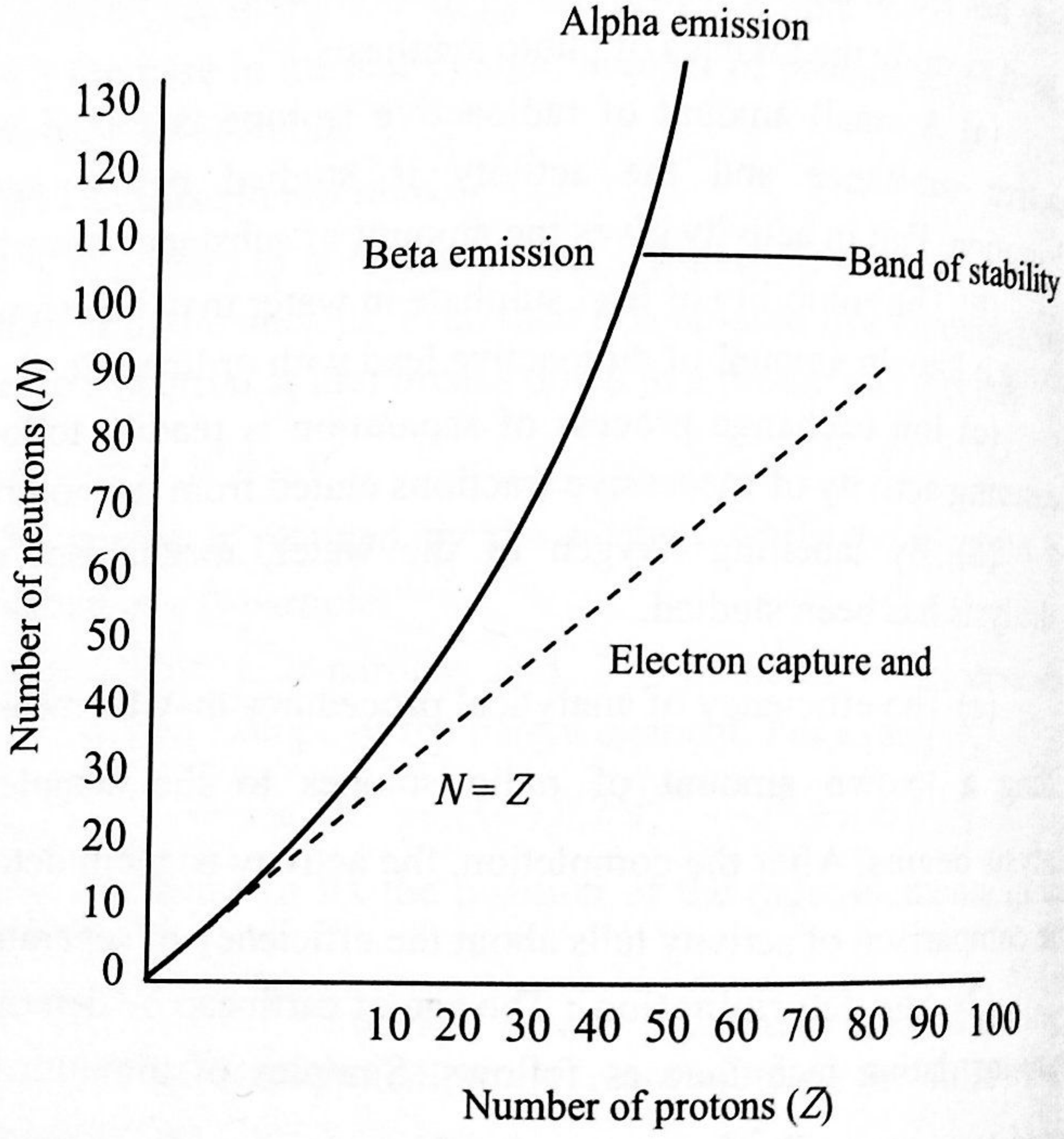
Finally, when we plot each stable nuclide on a graph with the number of protons (Z) on the horizontal axis and the number of neutrons (N) on the vertical axis, these nuclides fall in an area, or band which is known as band of stability. The band of stability is the region in which stable nuclides lie in a plot of number of protons against number of neutrons. Figure shows the band of stability.

(6) For elements of low atomic number (upto $Z = 20$) the most stable nuclei exist when the nucleus contains an equal number of protons P and neutrons N. This means that the ratio $N/P = 1$.

(7) Elements with higher atomic numbers are more stable if they have slight excess of neutrons as this increases the attractive

force and also reduces repulsion between protons. Thus the N/P ratio progressively increases upto about 1.5.

(8) When the number of protons becomes very large, the proton-proton repulsions become so great that stable nuclides are impossible. Thus, no stable nuclides are known with atomic numbers greater than 83. On the other hand all elements with Z equal to 83 or less have one or more stable nuclides, with the exception of technetium ($Z = 43$).



Band of stability : The stable nuclides are in a band. Nuclides to the left of the band of stability usually decay by beta emission, whereas those to the right usually decay by positron emission or electron capture. Nuclides of $Z >$ 83 often decay by alpha emission.

Fig. 7.2