SCHOOL OF STUDIES IN PHYSICS JIWAJI UNIVERSITY GWALIOR

Topic: Energy release in Fission and Application of LDM to Fission

One of the most striking features of fission process is the amount of the energy released in fission, which is very large in comparison to other nuclear reaction. The amount of energy released can be estimated from binding energy curve. The binding energy per nucleon (B/A) is 8.5 MeV in range of mass number 50 to 150 and end products of fission process are in this range. The average B/A is 7.6 MeV in neighborhood of Uranium. Hence, after fission B/A is about 0.9 greater in daughter nuclei compared to parent nucleus. This excess energy of 0.9 MeV per nucleon is liberated in fission process. Therefore, amount of energy released during fission process should be roughly equal to product of number of nucleons multiplied by excess of binding energy per nucleon i.e., energy released is 236 * 0.9 = 214 MeV. Thus energy released is roughly 200 MeV.

The total energy released can also be calculated from nuclear masses of ^{236}U i.e., parent nucleus and nuclear masses of daughter nuclei. The fission has a maximum values for A = 139 and A = 95, if $^{95}_{42}Mo$ and $^{139}_{57}La$ are taken to be stable daughter nuclei. Their combined mass is [138.953 + 94.946] a.m.u. = 233.9 a.m.u. as given by semi-empirical mass formula. The corresponding mass number 234 and two neutrons are released in te process. When 2.018 a.m.u. mass is added to mass of fragments. The mass of product of reaction becomes 235.98. When ^{235}U is incident by slow moving neutron, the compound nucleus ^{236}U is formed having mass of 236.133 a.m.u.

Mass defect (Δm) = (236.133 – 235.98) a.m.u = 0.215 a.m.u.

Therefore, energy released = (Δm* 931) MeV = 0.215 * 931 MeV = 198 MeV.

Although there are atleast 30 different ways in which nucleus can be divided, but mass defect is approximately same for all cases. Thus we can say average energy released is 200 MeV.

The predicted value of energy can be compared with experimental value. The amount of energy released per fission is sum of K.E. of fragments, K.E. of emitted neutrons, K.E. of prompt rays and total energy of decay process in the fission decay chain. The energy released in fission ^{235}U by thermal neutrons.

Energies in ^{235}U thermal fission

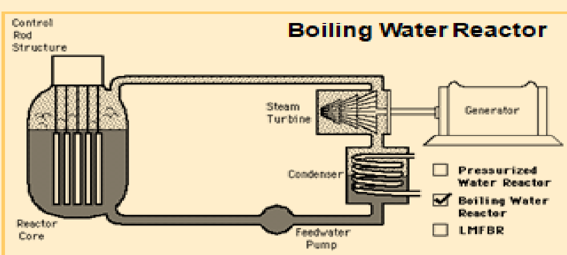
< prompt energy >	
fragment E_{kin}	169.0
neutron emission	4.8
g emission	7.0
	180.8
< delayed energy >	
β^- energy	6.4
delayed neutron emission	0.01
γ emission	6.2
$\bar{\nu}$ emission	10.0
	22.61
< total energy >	203.41

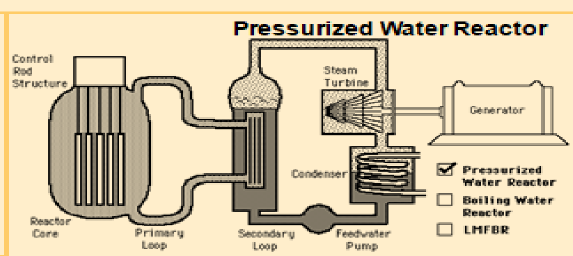
The total kinetic energy of the fragments increases with the mass and the charge of the fissioning nucleus as $Z^2/A^{1/3}$. In the contrary, it is independent of the excitation energy of the fissioning system due to the effect of the Coulomb repulsion of the fragments formed.

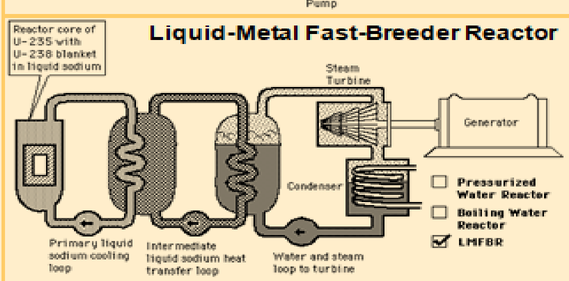
Total energy determined in this way is 200 MeV with uncertainty between 5-10 MeV. Thus we can say that a huge amount of energy about 200 MeV is liberated during the fission process.

Nuclear reactors

It takes 10^{11} fissions per second to produce one watt of electrical power. As a result, about one gram of fuel is consumed per day per megawatt of electrical energy produced. This means that one gram of waste products is produced per megawatt per day, which includes 0.5 grams of ^{239}Pu.







BWR: the most common
in case of a leak the water can become radioactive

PWR: the moderating and turbine waters are separated
more expensive

LMFBR: liquid sodium is used as moderator and heat transfer medium

Application of LDM to fission

The fission process can be explained on the basis of liquid drop model pictorially shown below. In a spherical liquid drop like nucleus, the shape depends upon the balance between surface tension force and the coulomb repulsive force. If energy is added to the drop resulting from the capture of slow neutron, this energy appears to initiate a series of rapid oscillations within drop. These oscillations trend to distort spherical shape. So drop may become ellipsoidal in shape. The surface tension force tend to retain the original shape of drop while excitation energy tends to distort it. If excitation energy is sufficiently large the drop may attain dumb-bell shape. The coulomb repulsion force may then push two lobes apart until dumb-bell splits into two dissimilar drops each of them become spherical. However, if excitation energy is small the ellipsoidal shape may retrace to spherical shape by liberating the excitation energy in form of ϒ-photon. This process is known as radiate capture.