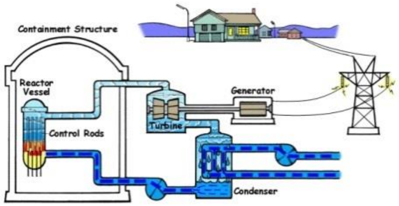
Thermal Power Stations II



Kafrelsheikh University
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Lecture (5) on

Nuclear Reactors Calculations

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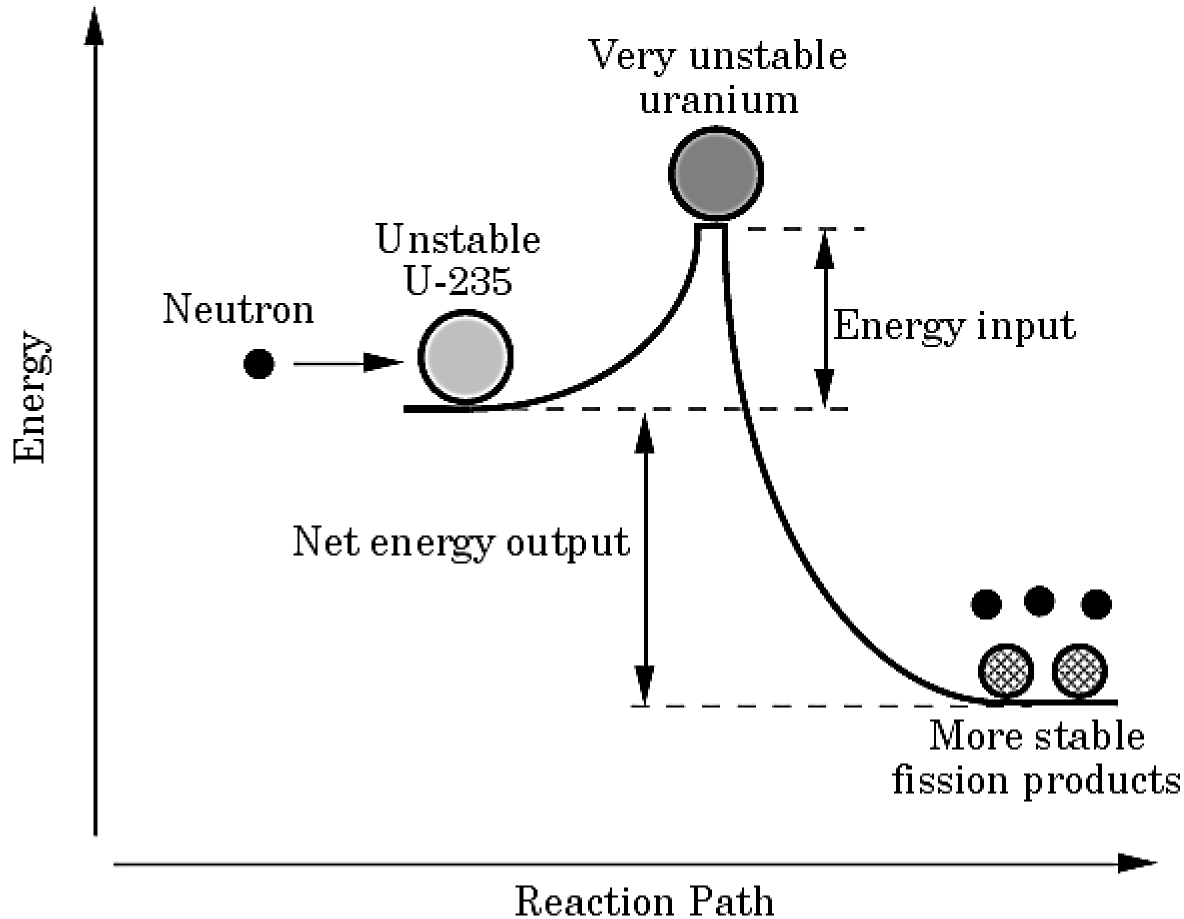
Nuclear Physics

- Nuclear power production is based on the energy released when an atomic nucleus such as uranium undergoes fission following the absorption of a neutron to form a compound nucleus.
- This compound nucleus is unstable and may break into two or three smaller atomic nuclei with the simultaneous emission of several neutrons together with the release of considerable amount of energy.
- These neutrons may themselves be absorbed by other nuclei, and if enough of these are uranium nuclei, it is possible for a chain reaction to develop. Chain reactions form the basis of the operation of a nuclear reactor.
- Natural uranium consists of 99.3% U_{238} and only 0.7% of lighter isotope U_{235}, but it is the latter that provides the most readily available fission energy in nuclear reactor.

Nuclear Physics

Schematic representation of a fission reaction



Nuclear Physics

Energy Mass Relationship

Einstein's theory of relativity shows that mass and energy are interchangeable. If mass is destroyed, energy is produced and mass can be produced by expenditure of energy. The energy mass relationship is:

$$E = mc^2$$

where E = energy in Joules

m = mass in kilogram

c = velocity of light (3×10^8 m/sec)

Nuclear energy is produced by the destruction of mass. If one gram of matter is destroyed, the energy produced is 9×10^{13} joules or 25000 MW hours. In nuclear engineering, energy is usually expressed in electron volts.

Nuclear Physics

Energy Mass Relationship

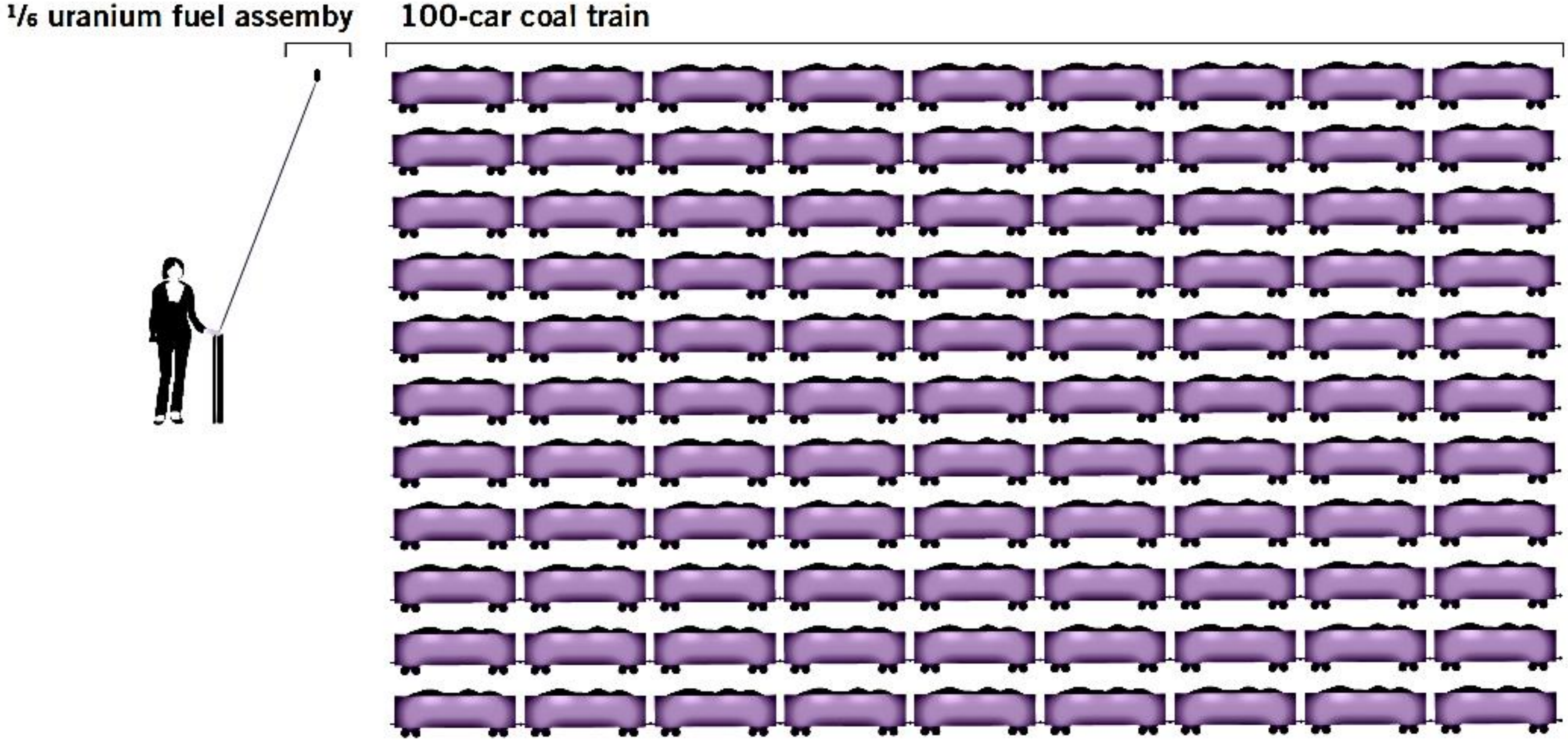
Fission of a single atom of uranium yields 200 MeV (= 3.2×10^{-11} J), whereas the oxidation of one carbon atom releases only 4 eV (= 6.4×10^{-19} J).

The molecular binding energy released when a carbon atom combines with an oxygen atom to form a CO_2 molecule is 6.4×10^{-19} Joules.

In physics, the electronvolt (eV) is defined as, the amount of energy gained (or lost) by the charge of a single electron moving across an electric potential difference of one volt.

Nuclear Physics

Amount of fuel needed to power a 1 GW power station (electricity required for about 700,000 US households) for 1 day



Nuclear Physics

Therefore, there must be the same number of atoms in 24.0000 g of this nuclide as in 12.0000 g of ^{12}C. This state of affairs is known as *Avogadro's law*, and the number of atoms or molecules in a mole is called *Avogadro's number*. This number is denoted by N_A and is equal to $N_A = 0.6022045 \times 10^{24}$

Using Avogadro's number, it is possible to compute the mass of a single atom or molecule. For example, since one gram mole of ^{12}C has a mass of 12 g and contains N_A atoms, it follows that the mass of one atom in ^{12}C is

$$m(^{12}C) = \frac{12}{0.6022045 \times 10^{24}} = 1.99268 \times 10^{-23} g$$

There is, however, a more natural unit in terms of which the masses of individual atoms are usually expressed. This is the *atomic mass unit*, abbreviated amu, which is defined as one twelfth the mass of the neutral ^{12}C atom, that is

$$1 \text{ amu} = \frac{1}{12} \times m(^{12}C).$$

Nuclear Physics

Inverting this equation gives

$$m(^{12}\mathrm{C}) = 12 \text{ amu}.$$

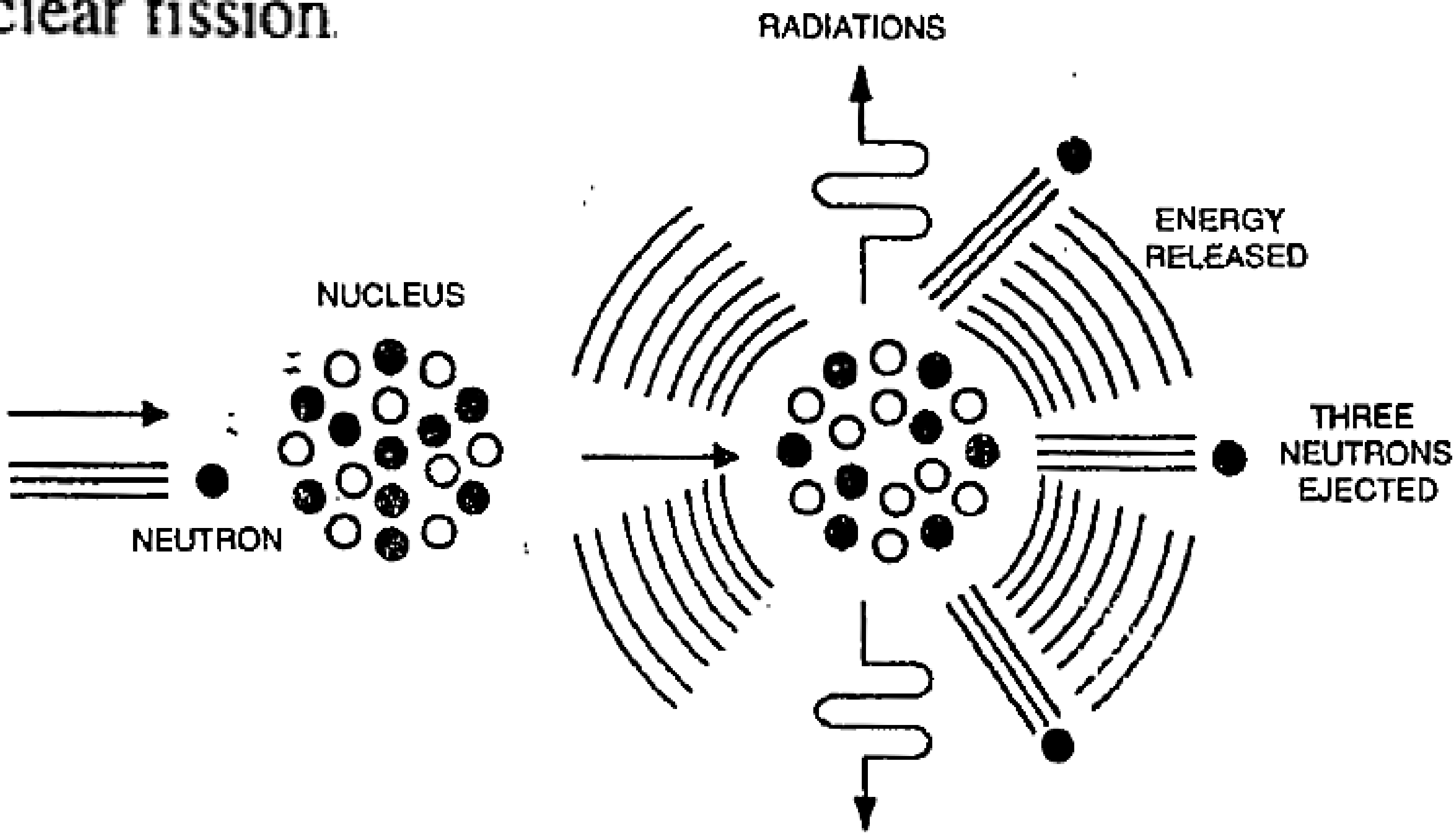
Introducing $m\,^{12}\mathrm{C}$ from the preceding paragraph gives

$$1 \text{ amu} = \tfrac{1}{12} \times 1.99268 \times 10^{-23}\,\mathrm{g} = 1/N_A \text{ g}$$

$$= 1.66057 \times 10^{-24} \text{ g}.$$

Nuclear Fission Energy

Nuclear fission.



Nuclear Fission Energy

Energy due to Fission The fission of a heavy atom can be caused by bombarding it with a thermal neutron. If a U235 atom is bombarded by a neutron, the nucleus splits to give nuclei of other elements. one possible fission reaction of U235 is

$$\text{Uranium}^{235} + \text{Neutron} \longrightarrow \text{Lanthanum}^{148} + \text{Bromine}^{85} + 3 \text{ free Neutrons} \quad (1)$$

The mass equation of this reaction is

$$235.124 + 1.009 \longrightarrow 147.961 + 84.938 + 3.027 \quad (2)$$