UNIT-IV

NUCLEAR PHYSICS

APPLIED PHYSICS-II

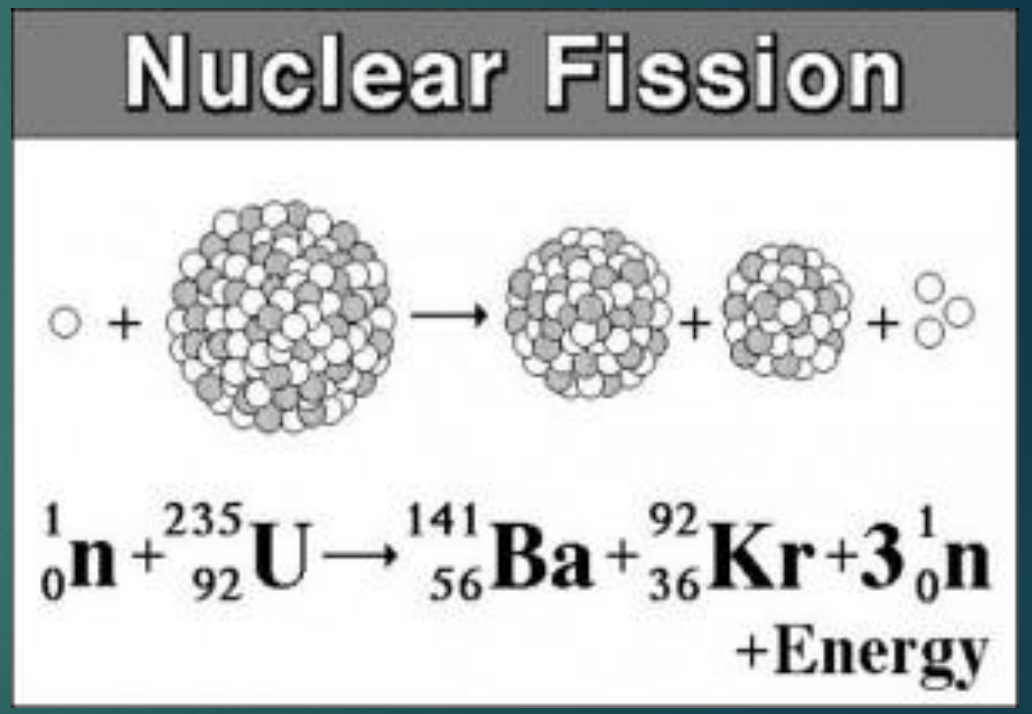
B.Sc. Home Science

SEMESTER-IV

NUCLEAR REACTOR

PRINCIPLE

- A nuclear reactor (formerly known as atomic pile) is based upon Controlled Nuclear Chain Reaction. It is a powerful device wherein the nuclear energy produced is utilized for constructive purposes.



CONSTRUCTION

Main components are:

1. **Nuclear Fuel:**

- Fissionable material
- Commonly used fuels are . ${}_{92}U^{233}$, ${}_{92}U^{235}$, ${}_{94}Pu^{239}$ etc.
- Generally, uranium oxide pellets inserted end to end into long hollow metal tubes (fuel rods)

Slow neutrons → Fuel → Fission → Energy released

2. Moderator:

- Function is to slow down the fast moving secondary neutrons produced during the fission
- Moderator material to be light and should not absorb neutrons
- E.g. .– heavy water, graphite, deuterium and paraffin etc.
- Moderators are rich in protons.

3. Control Rods:

- Ability to capture slow neutrons
- Rods of boron or cadmium (control rods) inserted in the holes of reactor core, up to a desirable length, to control the chain reaction from becoming violent
- Can be adjusted from outside the reactor

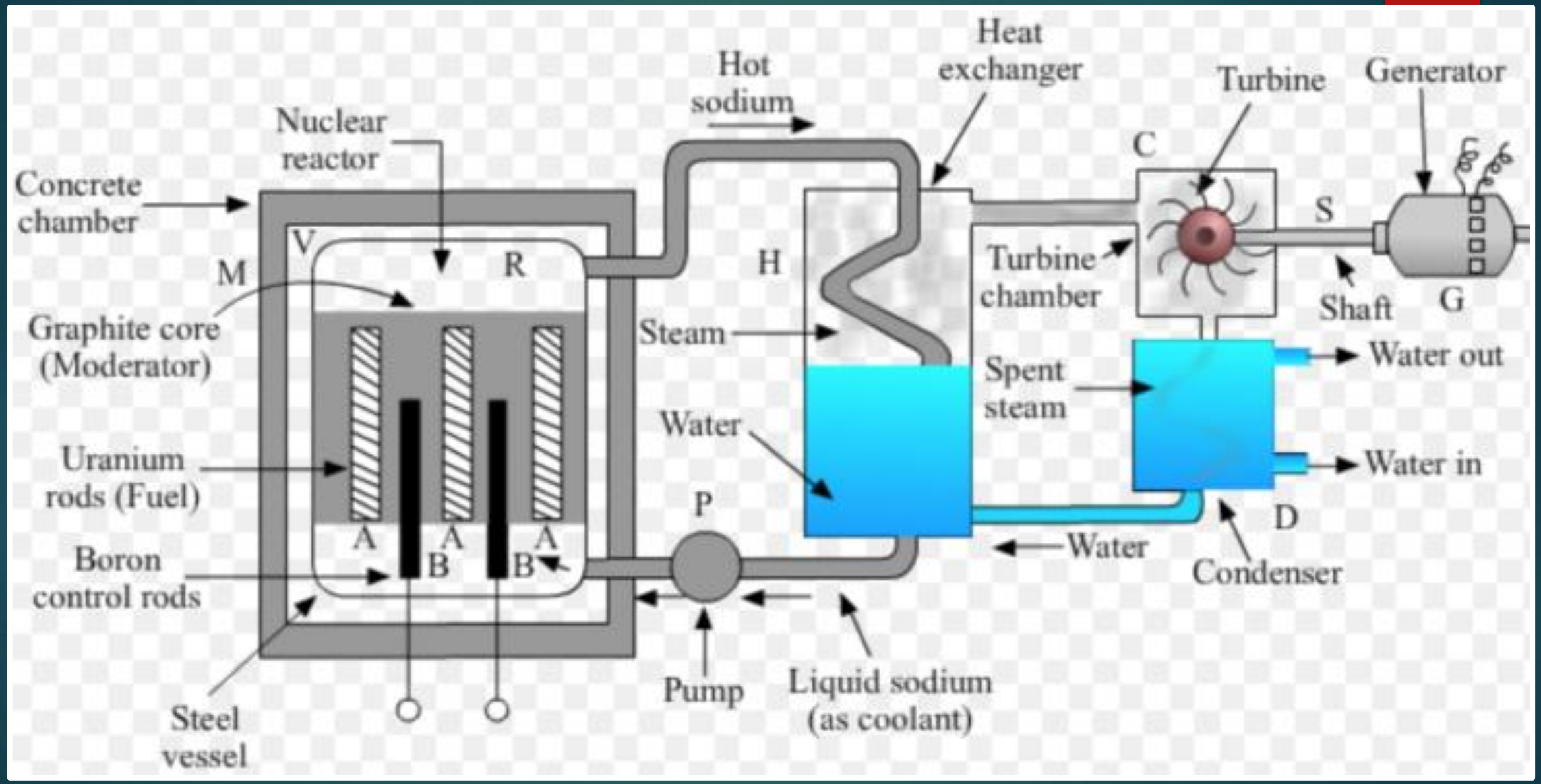
4. Coolant:

- Used to remove the heat produced and transfer it from the core of nuclear reactor to surroundings
- E.g. – water and heavy water – at ordinary temperature

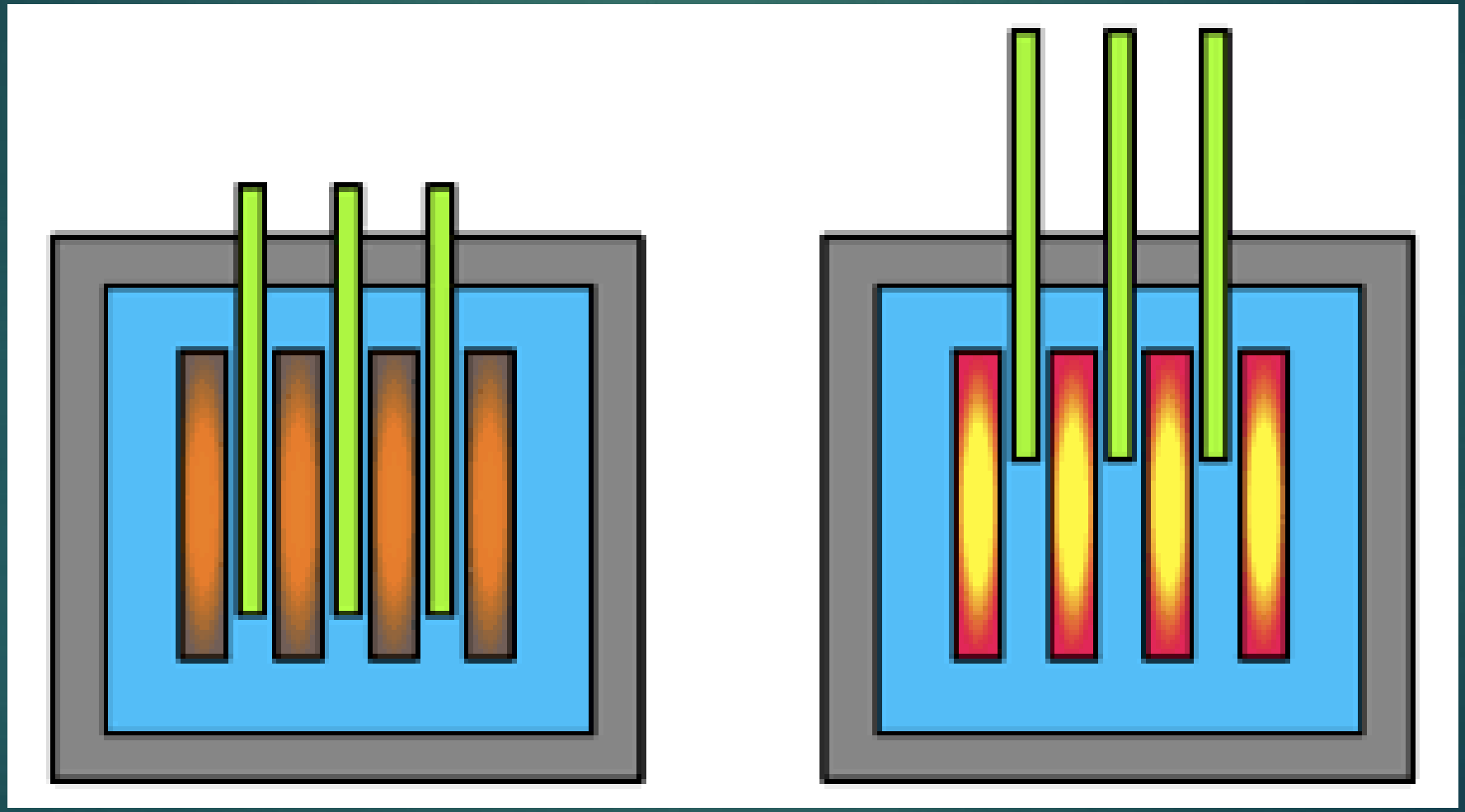
  liquid sodium – at high temperature

5. Shielding:

- Whole reactor protected with concentrate walls 2.0 - 2.5 meter thick
- Stops harmful radiations emitted during nuclear reactions from reaching the workers


Heat exchanger
Hot sodium
Nuclear reactor
Turbine
Generator
Concrete chamber
C
S
V
M
R
H
Turbine chamber
Shaft
G
Graphite core (Moderator)
Steam
Water out
Spent steam
Water
Uranium rods (Fuel)
Water in
P
A
A
A
B
B
D
Boron control rods
Water
Condenser
Steel vessel
Pump
Liquid sodium (as coolant)

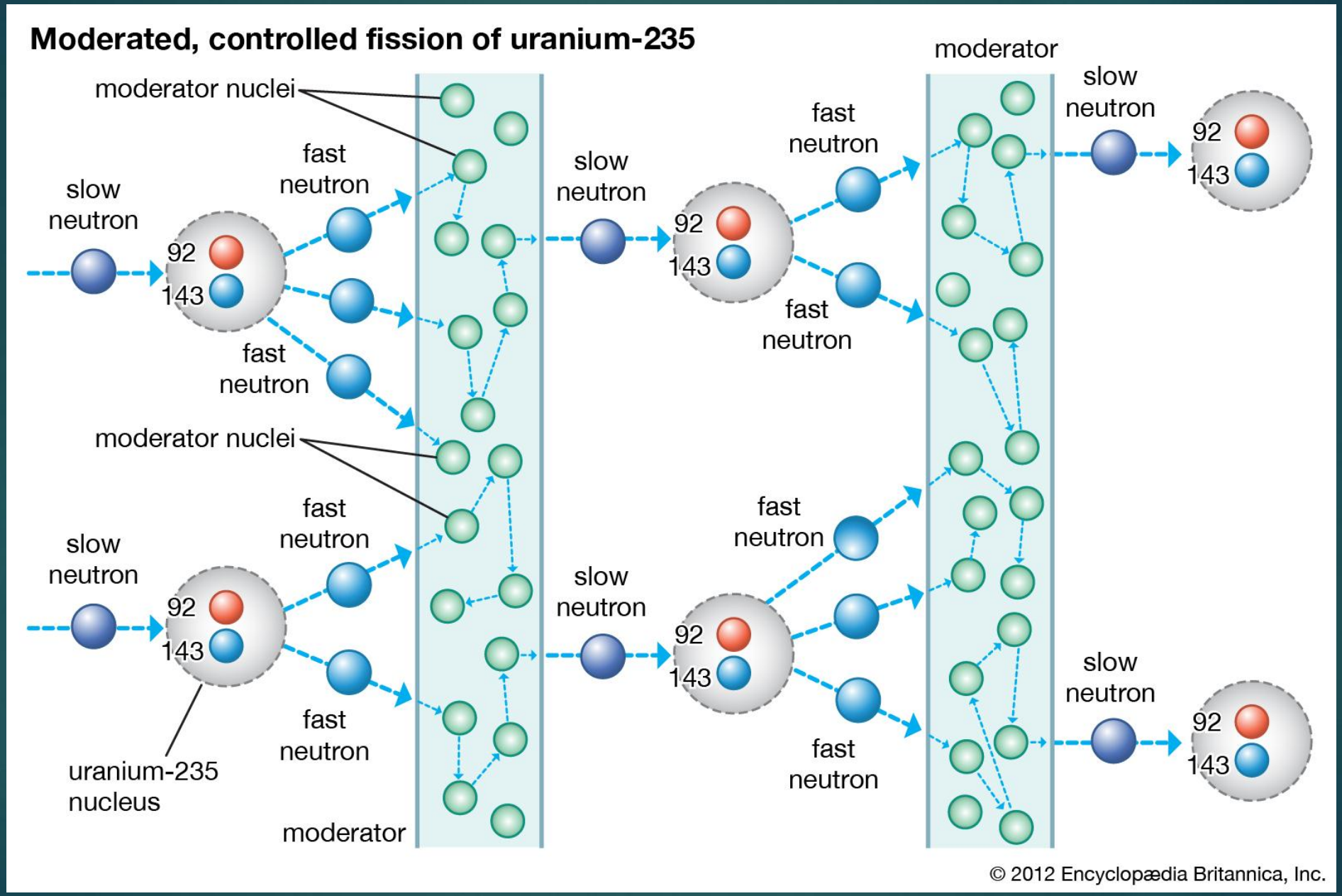
CONTROL RODS



WORKING

- Slow neutrons cause the fission of $_{92}U^{235}$ nuclei
- To start the nuclear chain reaction, control rods are slowly removed and to stop it they are inserted
- Controlled nuclear chain reaction is brought about.
- Energy produced is used for constructive purposes

- Heat produced in nuclear fission → coolant → water in heat exchanger → superheated steam → turbine coupled with electric generator → Electricity


Moderated, controlled fission of uranium-235
moderator nuclei
slow neutron
92
143
fast neutron
fast neutron
moderator nuclei
slow neutron
92
143
fast neutron
fast neutron
uranium-235 nucleus
moderator
slow neutron
92
143
fast neutron
fast neutron
moderator
slow neutron
92
143
fast neutron
fast neutron
moderator
slow neutron
92
143
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USES

- Nuclear reactors are used to produce radioactive isotopes which in turn are used in medicines, industry and agriculture
- In Electric Power Generation
- For the propulsion of ships, submarines and air crafts
- To produce neutron beam of high intensity which is used in the treatment of cancer and nuclear research

India has 22 nuclear reactors in operation in 7 nuclear power plants with a total installed capacity of 6,780 MW.

RADIATION HAZARDS

Harmful effects on an organism caused by radiations / Risks to the living tissue exposed to the natural radioactivity, X rays and nuclear radiations (α,β,γ).

- High energy nuclear particles and γ rays ionize the material through which they pass.
- Complex organic molecules are broken and the normal functioning of the biological system id disrupted
- Damage depends upon

i. Dose of Radiation
ii. Rate of Dose given
iii. Nature of organism exposed

- Dose of radiation is measured in Roentgen(R). One Roentgen is the quantity of radiations that produce 1.16×10^{12} pairs of ions in 1gm. of air.

  $1mR = 10^{-3}R$

- These units are called Dosage units or Exposure units and do not depend upon time
- The radiation absorbed per unit time is called exposure rate/dosage rate/Radiation absorbed dose(Rad)
- The harmful effects of radiations on humans –

A. Pathological / Somatic Effects
B. Genetic Effects

A. Pathological / Somatic Effects

- Damage to the general tissues of the body producing visible harm in the lifetime
- Occur in workers and scientists in the radiation field
- 20 rem(roentgen equivalent in man) produces no immediate effect
- A radiation dose of 100rem may cause cancer
- Dose exceeding 600 rem causes immediate death
- Permissible dose is 250 milli roentgen(250×10^{-3} R) per week

- Above permissible dose, the effects of large dose of radiation are –
  - Loss of hair
  - Loss of appetite
  - Sore throat
  - Blood spots under skin
  - Vomiting
  - Diarrhea
  - Nose bleeding
  - Fever
  - Blindness etc.

B. Genetic Effects

- Damage to the specialized cells in the reproductive organs, causing interference with the normal pattern of heredity
- There occurs mutation of the chromosomes of the cellular nuclei
- Mutations transferred from one generation to the next one
- Genetic effects are irreversible
- Safe limit of radiation exposure as regards the genetic damage is not yet precisely known

SAFETY MEASURES / SAFE HANDLING / PRECAUTIONS WHILE USING RADIO ISOTOPES

Radio isotopes are continuously emitting radiations. Following precautions to be observed to avoid radiation hazards –

- Radio isotopes to be stored in rooms with thick walls of lead, concrete or other suitable material
- Mechanical tongs and remote controlled equipment to be used
- Thick walled lead containers are employed
- Workers to wear lead aprons
- Radioactive contamination of the work area to be avoided at all costs