Nuclear Reaction: Fusion

Fusion is a nuclear reaction whereby two light atomic nuclei fuse or combine to form a single larger, heavier nucleus

The fusion process generates tremendous amounts of energy; or for fusion to occur, a large amount of energy is needed to overcome the electrical charges of the nuclei and fuse them together

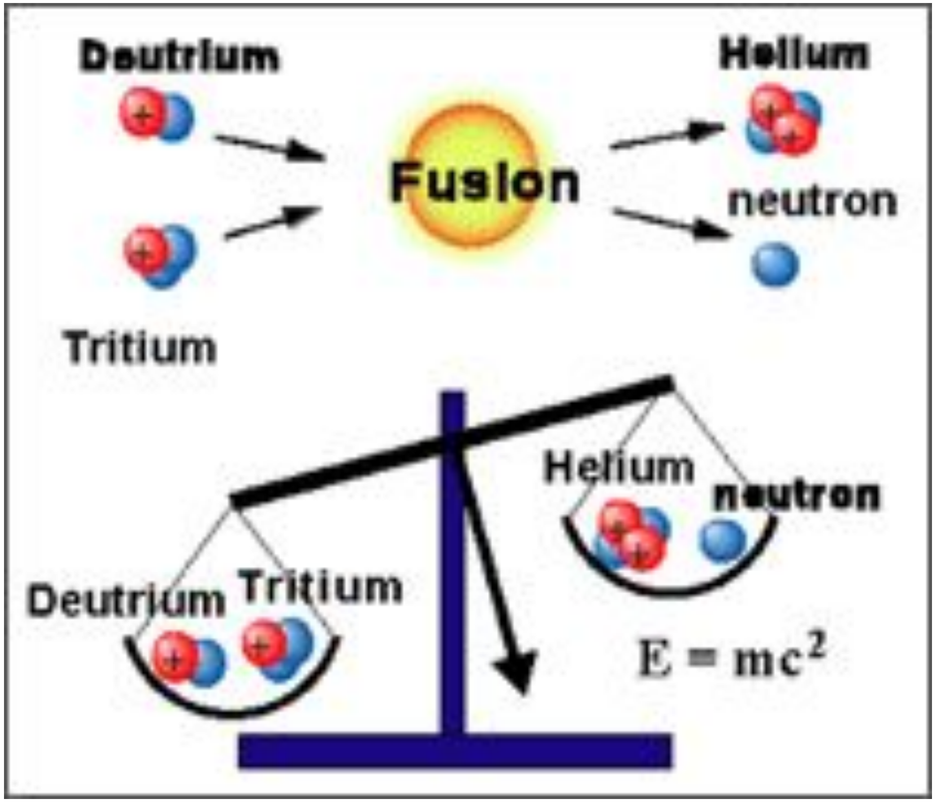
The fusion of two nuclei lighter than iron or nickel generally releases energy

The fusion of nuclei heavier than them absorbs energy

Nuclear Fusion

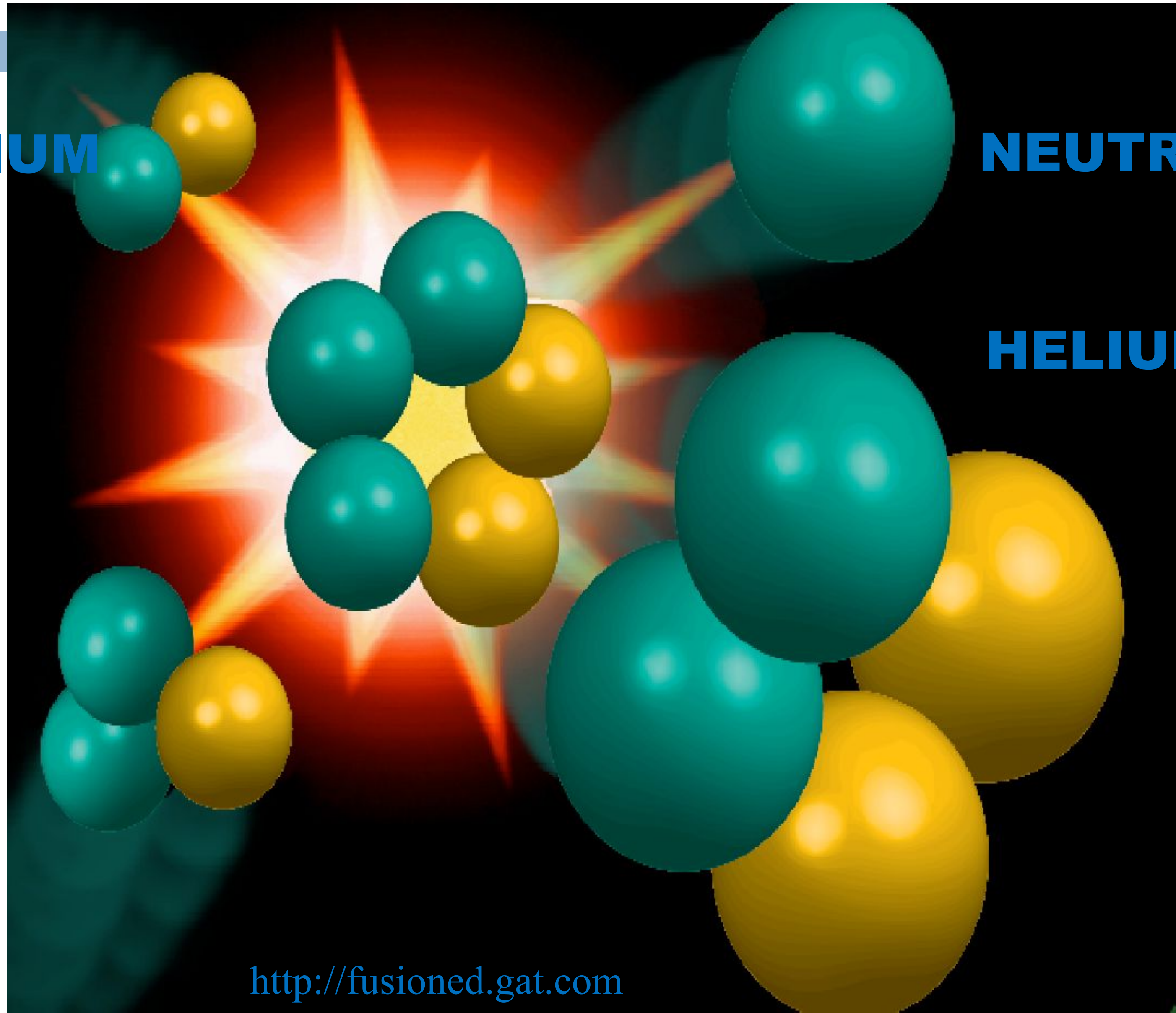
- **Fusion reactions do not occur naturally on our planet but are the principal type of reaction found in stars**
- **The large masses, densities, and high temperatures of stars provide the initial energies needed to fuel fusion reactions**
- **The sun fuses hydrogen atoms to produce helium, subatomic particles, and vast amounts of energy**
- **Nuclear fusion reactions are also called thermonuclear reactions**

Nuclear Fusion



- **Nuclear fusion produces less nuclear waste than nuclear fission and the materials are easier to obtain**

FUSION

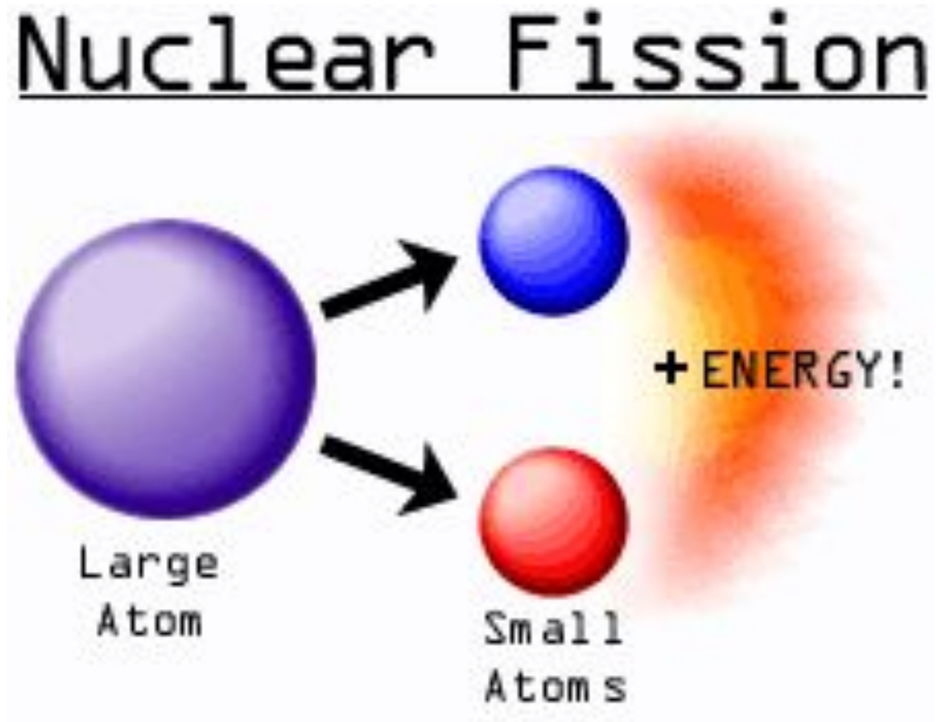


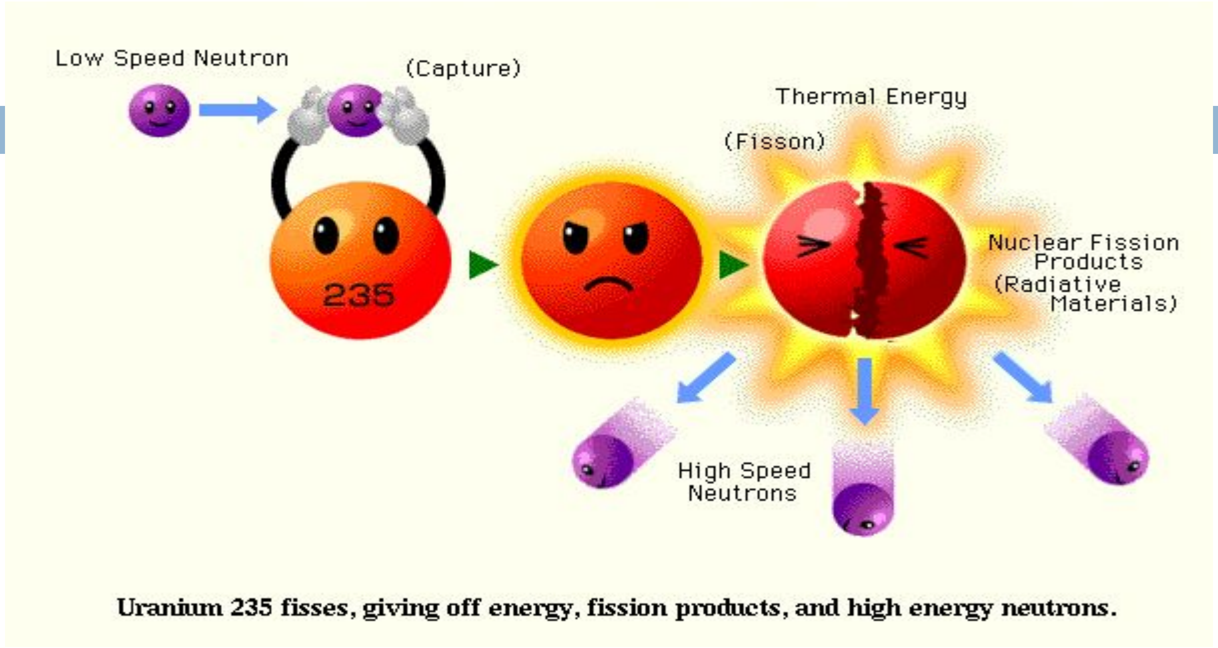
Best Example of Fusion

Every second, the sun converts 500 million metric tons of hydrogen to helium. Due to the process of fusion, 5 million metric tons of excess material is converted into energy in each second. This means that every year, 157,680,000,000,000 metric tons are converted into energy

Nuclear Fission

- Nuclear fission is the process of splitting a nucleus into two nuclei with smaller masses
- Fission means “to divide”





Uranium 235 fisses, giving off energy, fission products, and high energy neutrons.

- **Only large nuclei with atomic numbers above 90 can undergo fission**

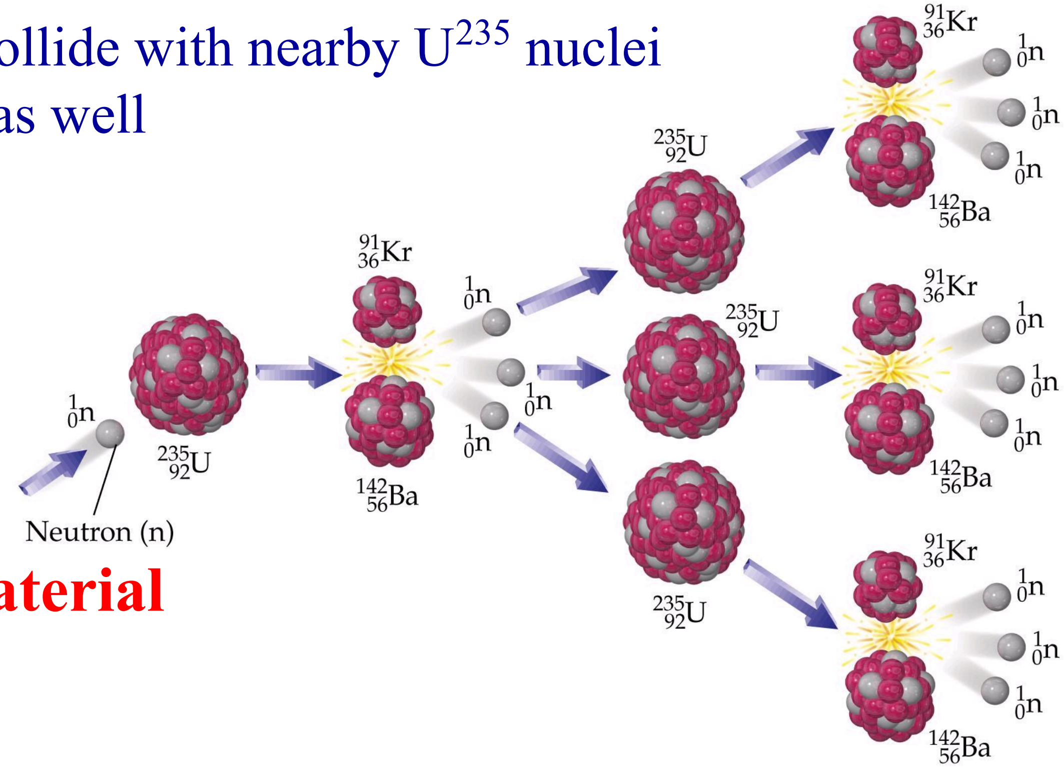
- **Products of fission reaction usually include two or three individual neutrons, the total mass of the product is somewhat less than the mass of Uranium-235**

Neutrons may

1 - **Cause another fission by colliding with a U^{235} nucleus**

- Creates two smaller nuclides and free neutrons
- The free neutrons potentially collide with nearby U^{235} nuclei
- May cause the nuclide to split as well

Each split (fission) is accompanied by a large quantity of **E-N-E-R-G-Y**



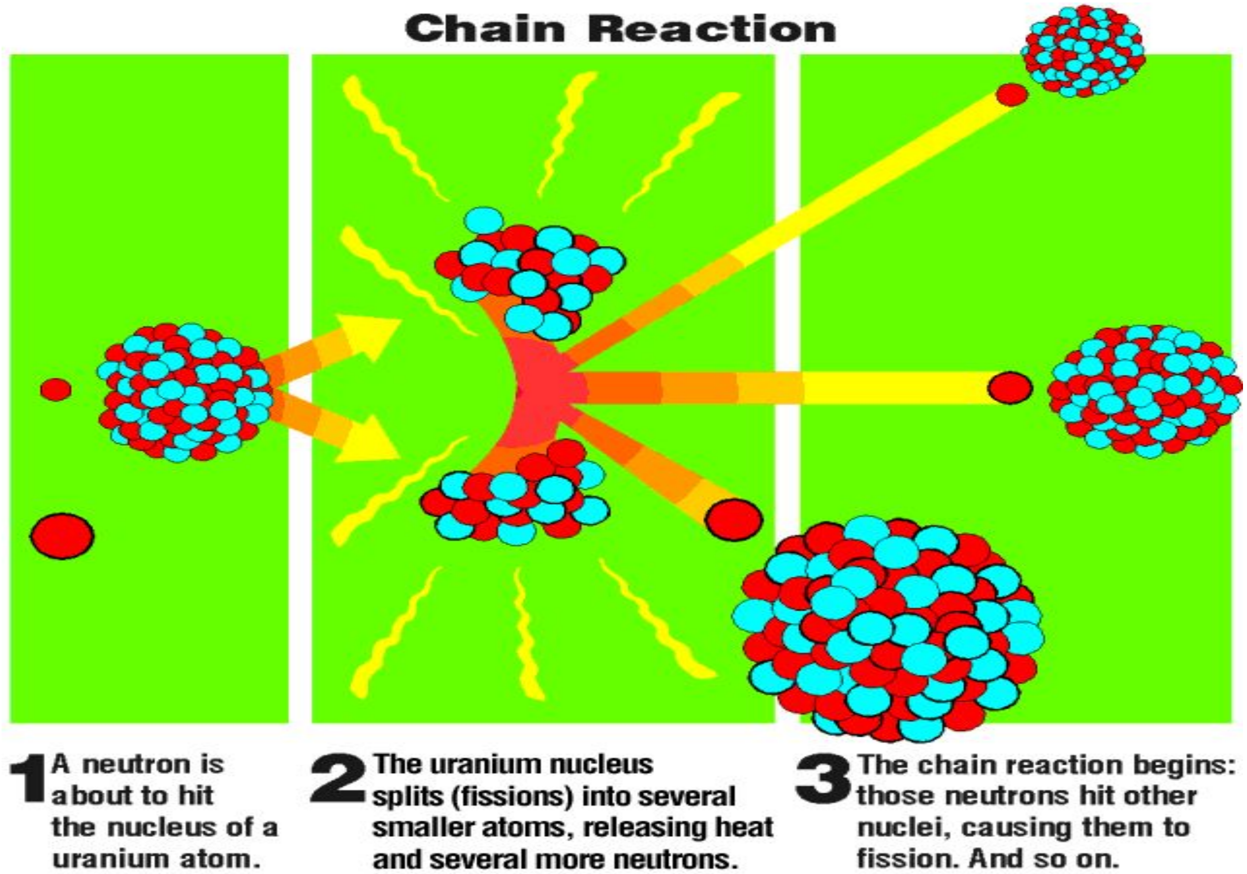
2 - **Be absorbed in other material**

3 - **Lost in the system**

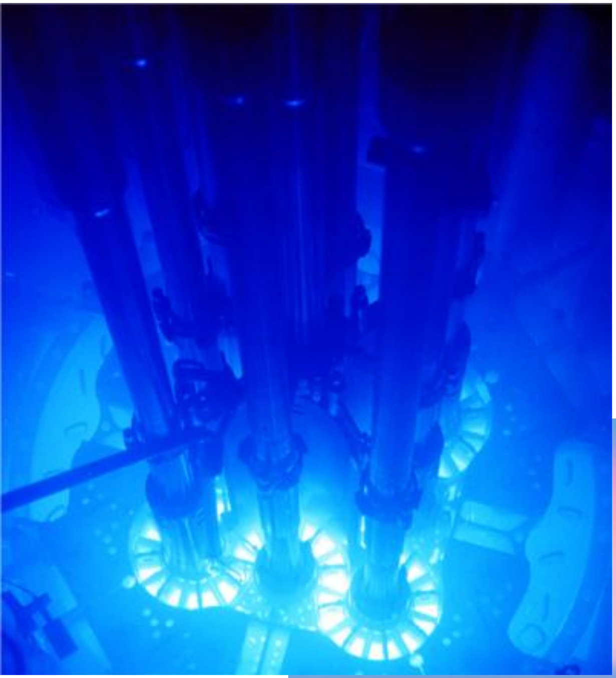
If sufficient neutrons are present, we may achieve a **chain reaction**

Chain Reaction

- A chain reaction is an ongoing series of fission reactions. Billions of reactions occur each second in a chain reaction



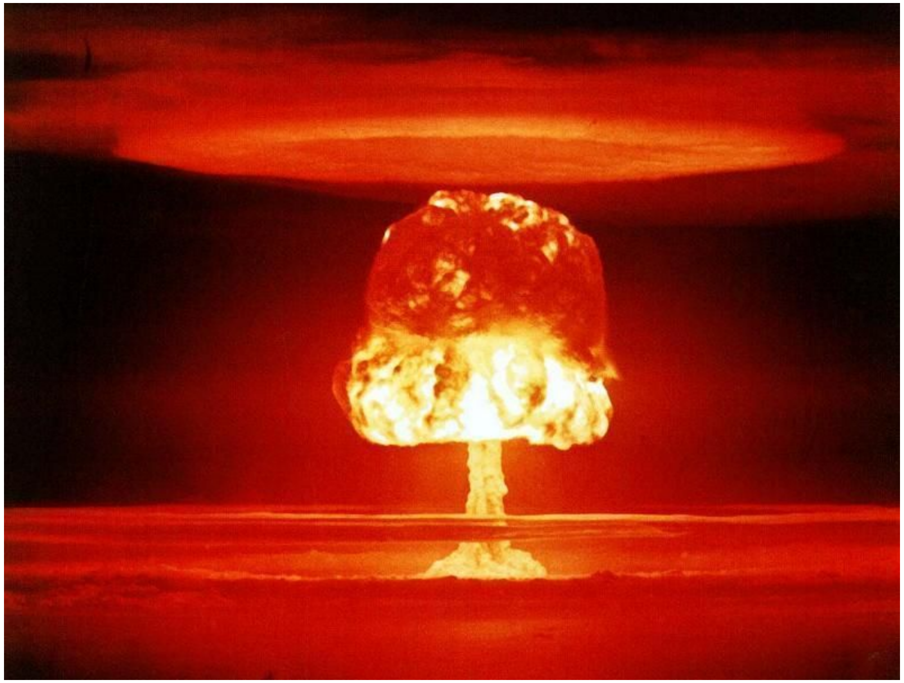
Controlled Chain Reaction



- On earth, nuclear fission reactions take place in nuclear reactors, which use controlled chain reactions to generate electricity.

Un-Controlled Chain Reaction

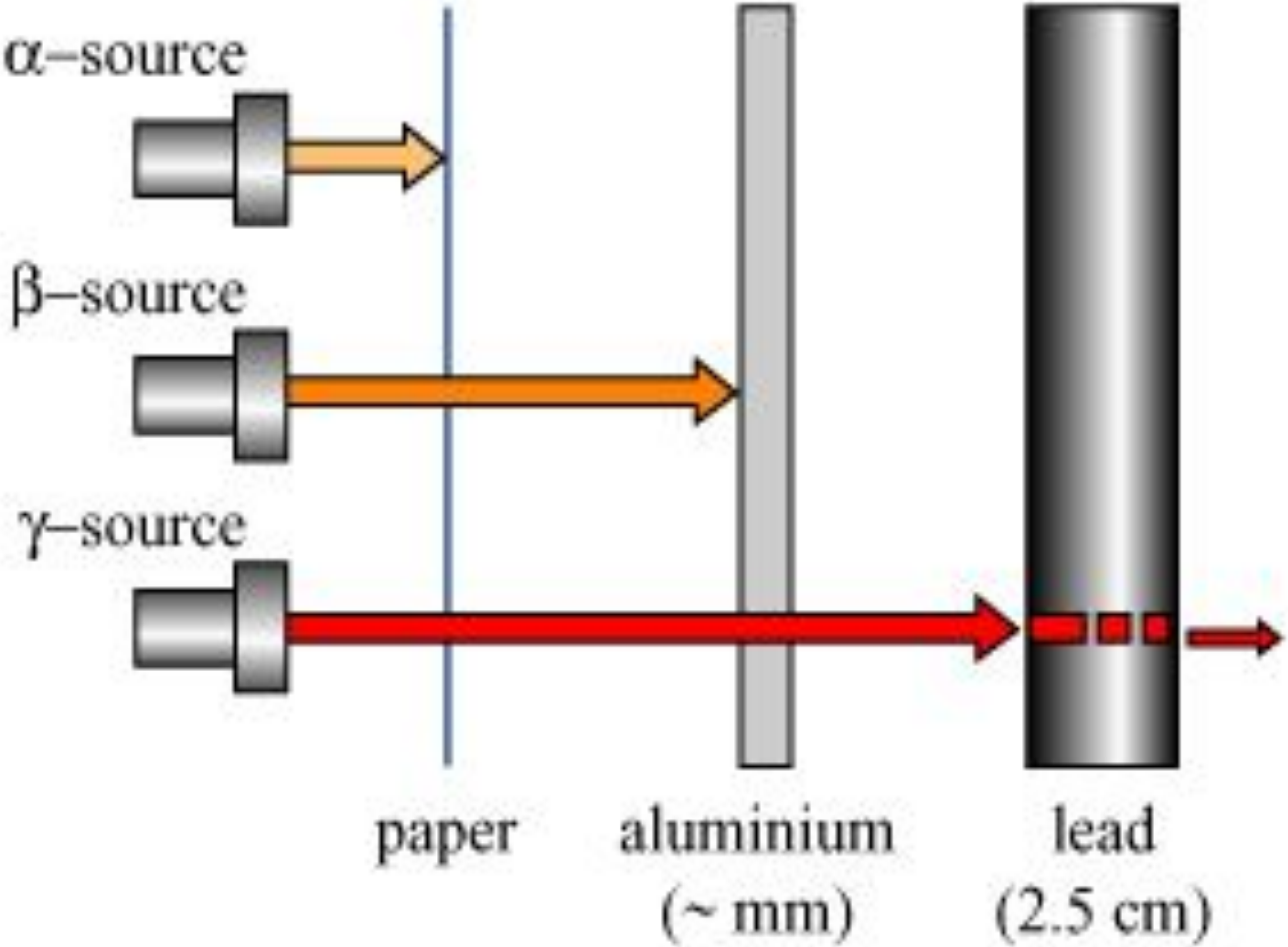
- **Uncontrolled chain reactions take place during the explosion of an atomic bomb**



RADIATION

- **Emission** or **transmission** of energy in the form of **waves** or **particles** through space or material medium.

- **Includes:**
  - Electromagnetic waves (gamma-γ or x-ray), or
  - High speed particles (alpha-α, beta-β, neutron-η, etc.)

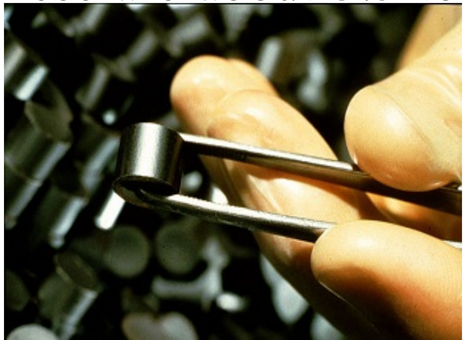

α–source
β–source
γ–source
paper
aluminium
(~ mm)
lead
(2.5 cm)

Nuclear Fuels

Fuel Uranium is the basic fuel. **Usually pellets of uranium oxide (UO_2) are arranged in tubes to form fuel rods.** The rods are arranged into fuel assemblies in the reactor core.

The commonly used fuels are **U-235, Pu-236** or Thorium. It can be U-235, U-238, Pu-236 or **Th-232**. **Uranium is mostly preferred as it has high melting point.**

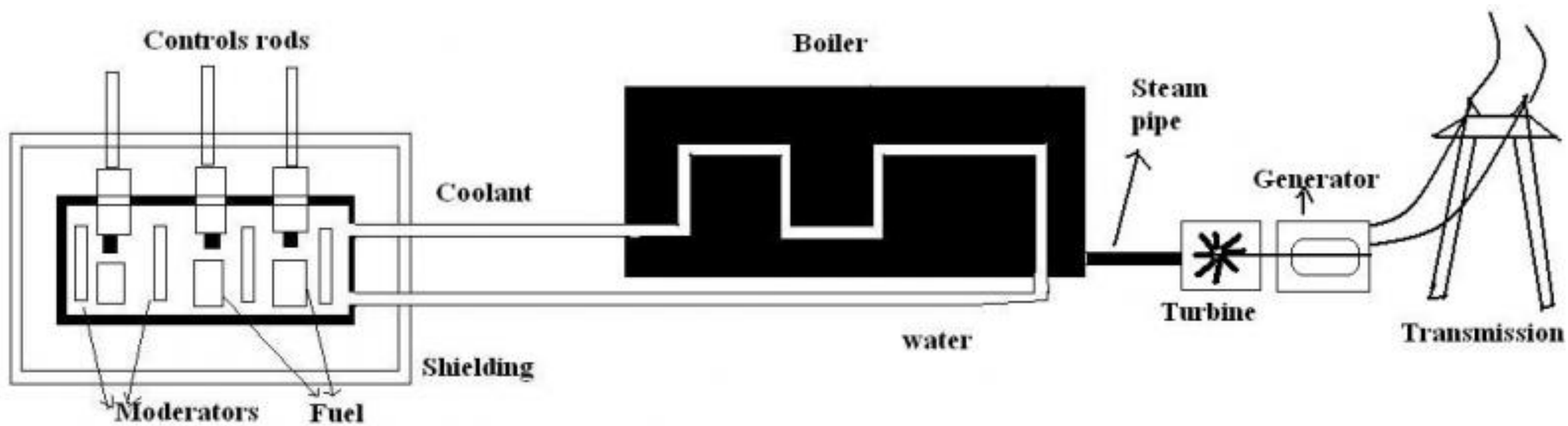
The fuel pellets (usually about 1 cm diameter and 1.5 cm long) are typically arranged in a **long zirconium alloy (zircaloy) tube to form a fuel rod, the zirconium being hard, corrosion-resistant and transparent to neutrons**. Numerous rods form a fuel assembly, which is an open lattice and can be lifted into and out of the reactor core. In the most common reactors these are about 3.5 to 4 metres long.



Nuclear reactor

Moderator Material in the core which **slows down the neutrons** released from fission so that they cause more fission. It is usually water, but may be **heavy water, graphite and Beryllium** are also used.

Control rods These are made with neutron-absorbing material such as **cadmium, hafnium or boron,** and are inserted or withdrawn from the core to control the rate of reaction, or to halt it. **These rods absorb neutrons and stop the chain reaction to proceed further.** These are **made up of steel containing a high percentage of material like cadmium or boron which can absorb neutrons**. When control rods are **completely inserted into the moderator block then all the neutrons is absorbed and reaction comes to halt.**



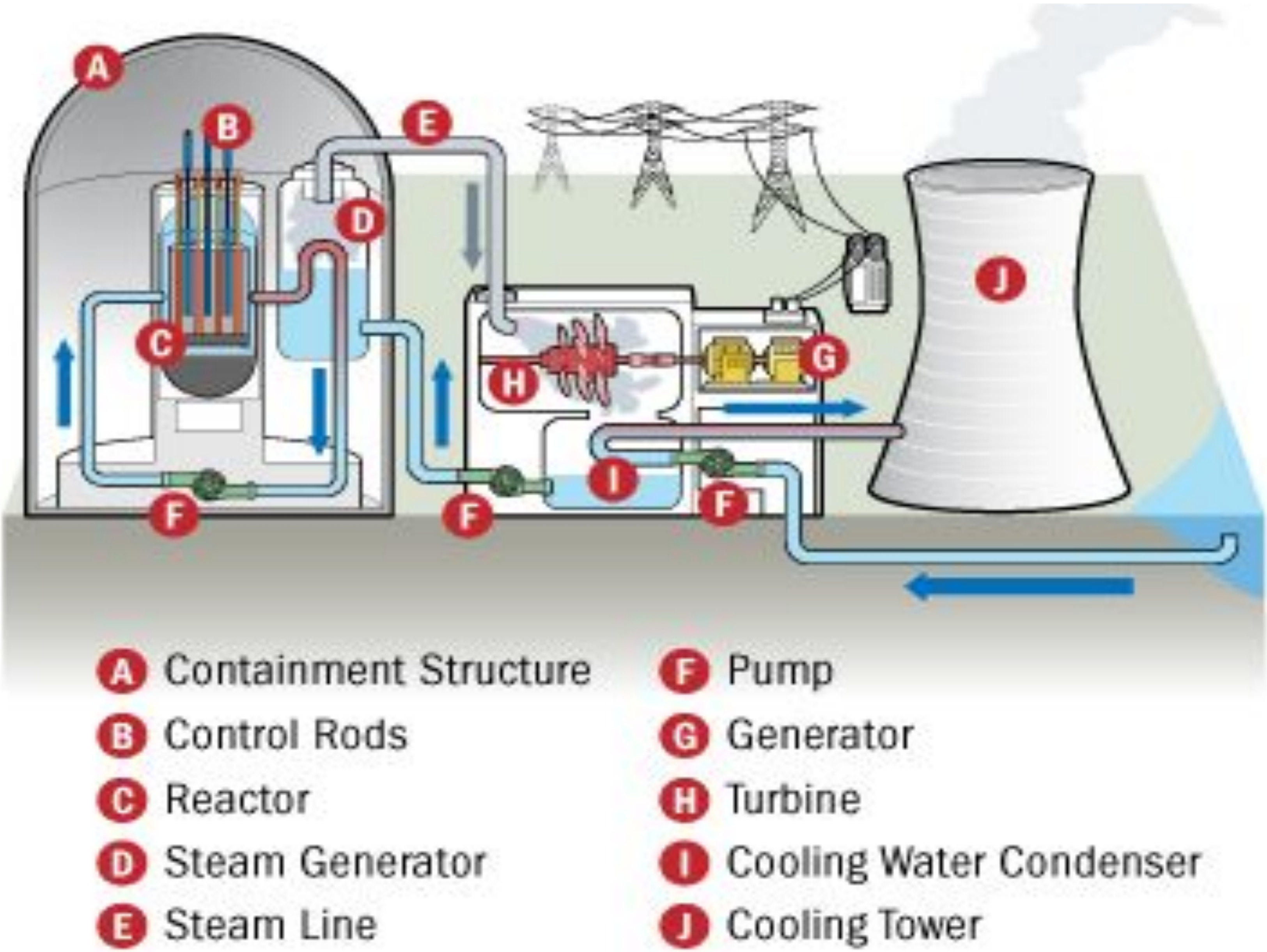
Nuclear reactor

Coolant The coolant is substance in a pipe to the steam generator where water is boiled. This is where heat-exchange process occurs. Heat is absorbed by the coolant that is produced in the reactor. Typical coolants are **water, carbon dioxide gas or liquid sodium.**

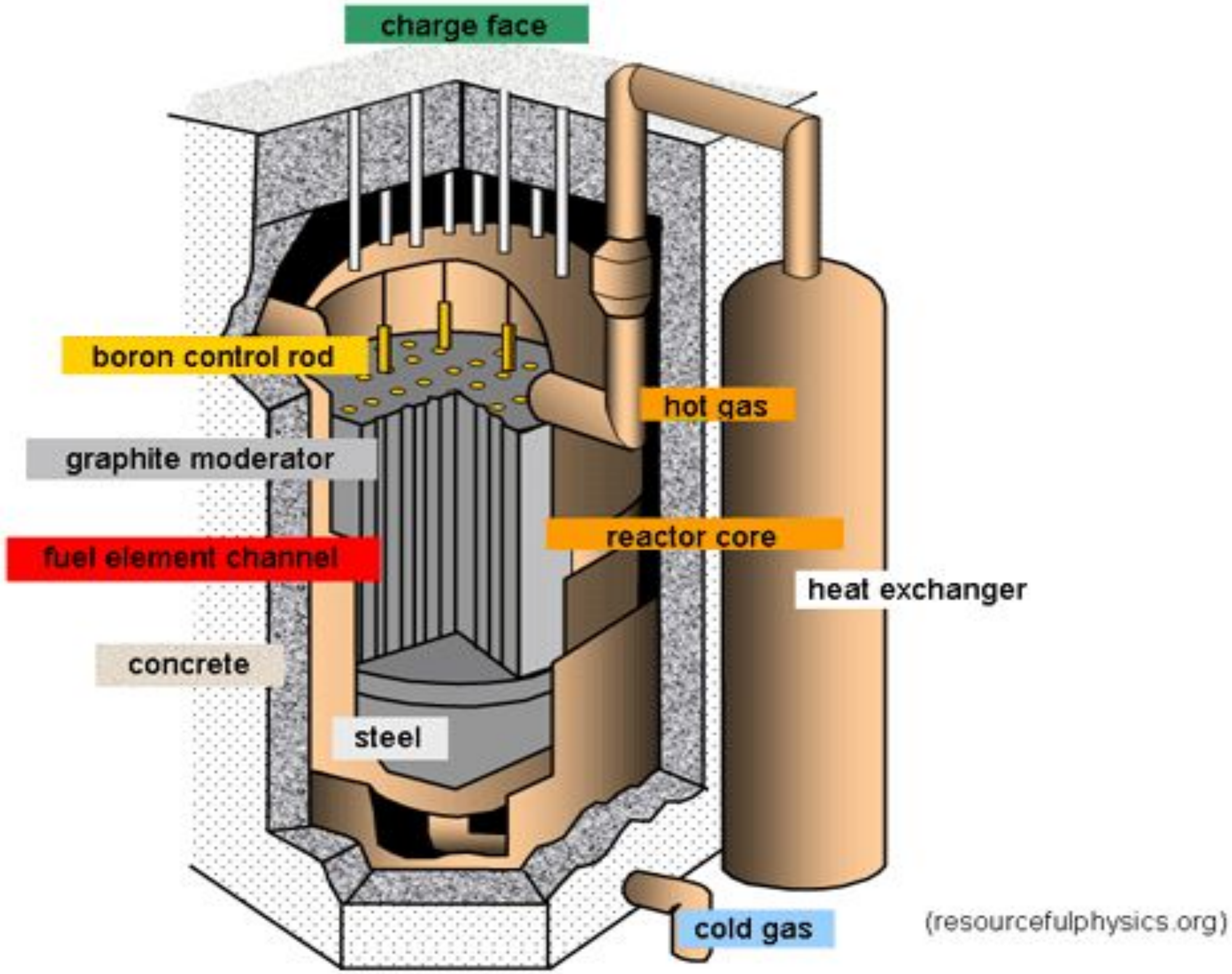
Shielding / Containment : Shielding prevents radiations to reach outside the reactor. **Lead blocks and concrete** enclosure that is strong enough of several meters thickness are used for shielding.

Turbine : Steam produced in the boiler is now passes to a turbine. The force of the steam jet causes the turbine to rotate. Heat energy (steam) is converted to mechanical energy (moving turbine)

Generator: The generator consists of coils that change the mechanical energy into electric energy. The turbine moves and the change in magnetic flux cause electricity. This is transmitted to substations for distribution of electric power.

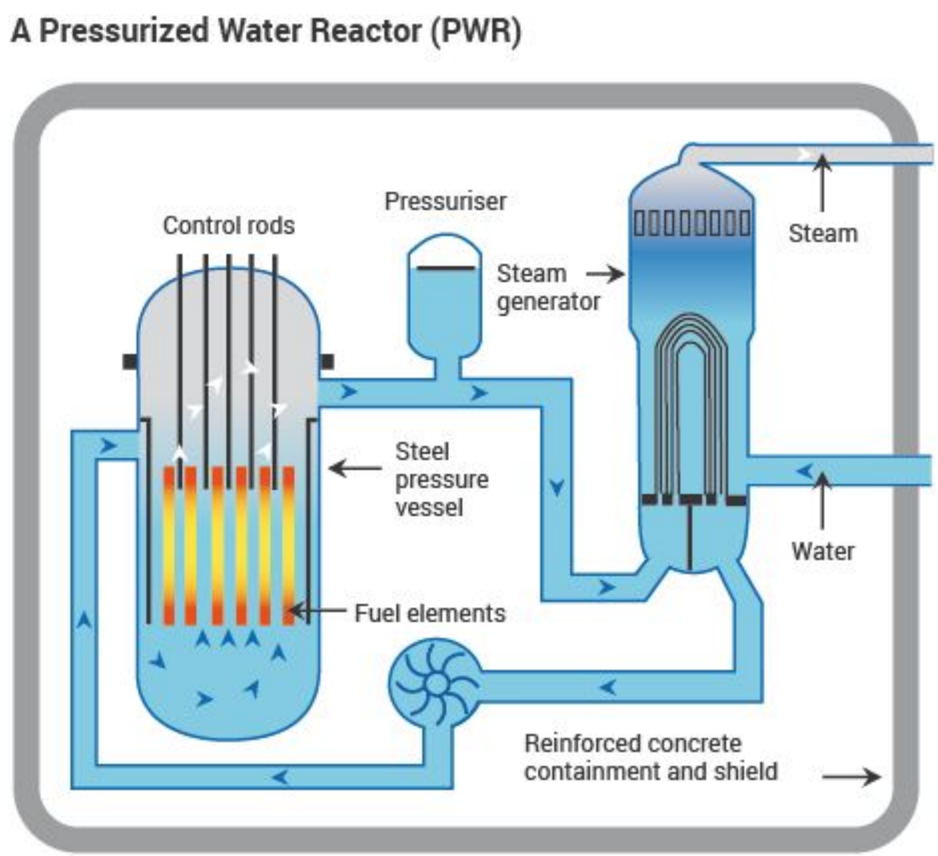

A
B
C
D
E
F
F
F
G
H
I
J
A Containment Structure
B Control Rods
C Reactor
D Steam Generator
E Steam Line
F Pump
G Generator
H Turbine
I Cooling Water Condenser
J Cooling Tower

Principal parts of a nuclear reactor



Types of Nuclear Reactor

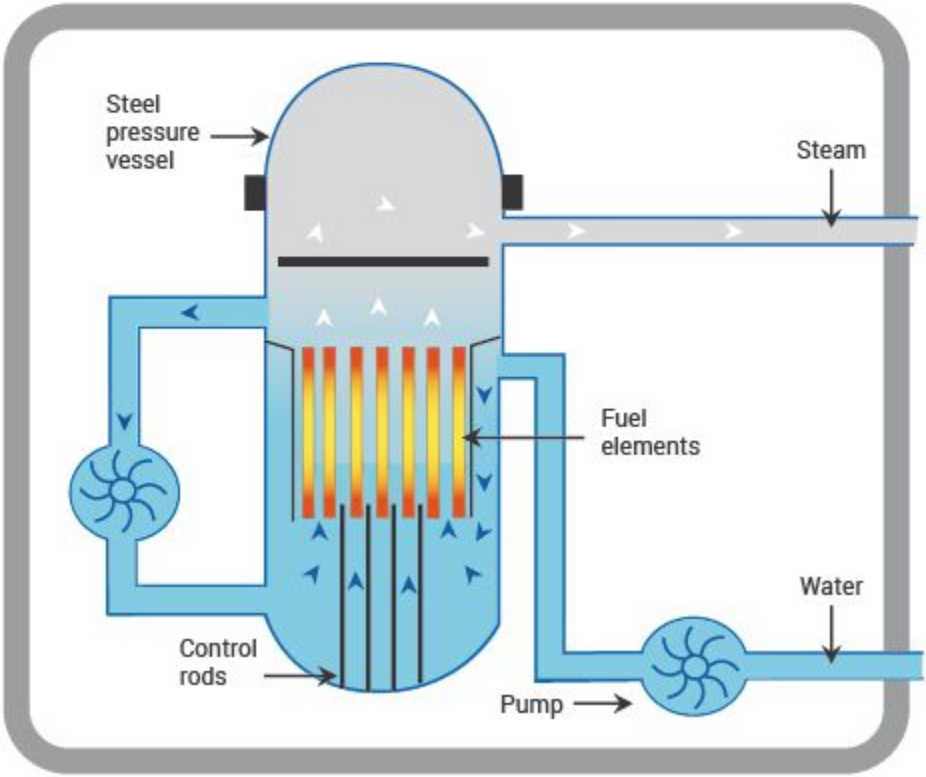
Pressurised Water Reactor (PWR) which has water at over 300°C under pressure in its primary cooling/heat transfer circuit, and generates steam in a secondary circuit. In a pressurized water reactor, the water is pumped into contact with the core and then kept under pressure, so that it can't turn into steam. That pressurized water then is brought into contact with a second supply of unpressurized water, which is what turns to steam to turn the turbines.



These are the second generation of British gas-cooled reactors, using graphite moderator and carbon dioxide as primary coolant.

Types of Nuclear Reactor

Boiling Water Reactor (BWR) makes steam in the primary circuit above the reactor core, at similar temperatures and pressure. With BWRs, the water that comes directly into contact with the reactor core is allowed to become steam for generating electricity



Pressurised heavy water reactor (PHWR)
CANDU Reactor – use less enriched Uranium

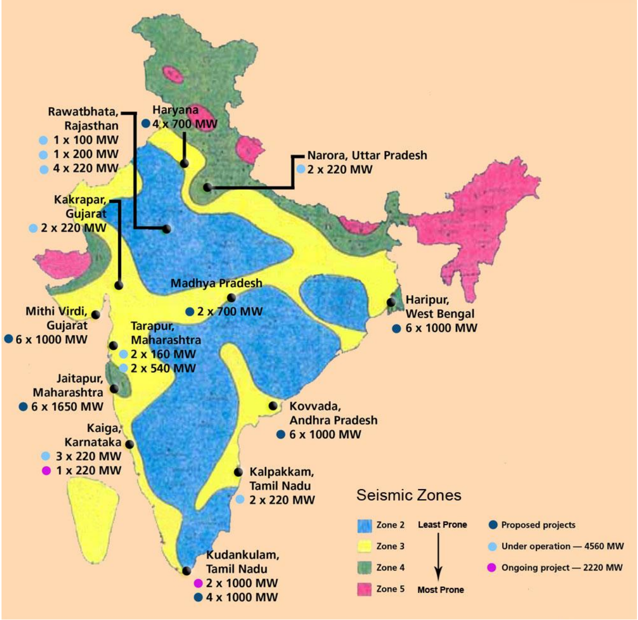
Advanced Gas Cooled Reactor (AGCR)

Nuclear Reactor in India

List of Operational Nuclear Power Plants in India			
Name Of Nuclear Power Station	Location	Operator	Capacity
Kakrapar Atomic Power Station – 1993	Gujarat	NPCIL	440
(Kalpakkam) Madras Atomic Power Station – 1984	Tamil Nadu	NPCIL	440
Narora Atomic Power Station- 1991	Uttar Pradesh	NPCIL	440
Kaiga Nuclear Power Plant -2000	Karnataka	NPCIL	880
Rajasthan Atomic Power Station – 1973	Rajasthan	NPCIL	1,180
Tarapur Atomic Power Station – 1969	Maharashtra	NPCIL	1,400
Kudankulam Nuclear Power Plant – 2013	Tamil Nadu	NPCIL	2,000

Currently, India has 22 operational nuclear reactors, out of which,
18 reactors are Pressurised Heavy Water Reactors (PHWRs)
and 4 are Light Water Reactors (LWRs).

7 sites of Nuclear Power Plants in India



Fuelling a nuclear power reactor

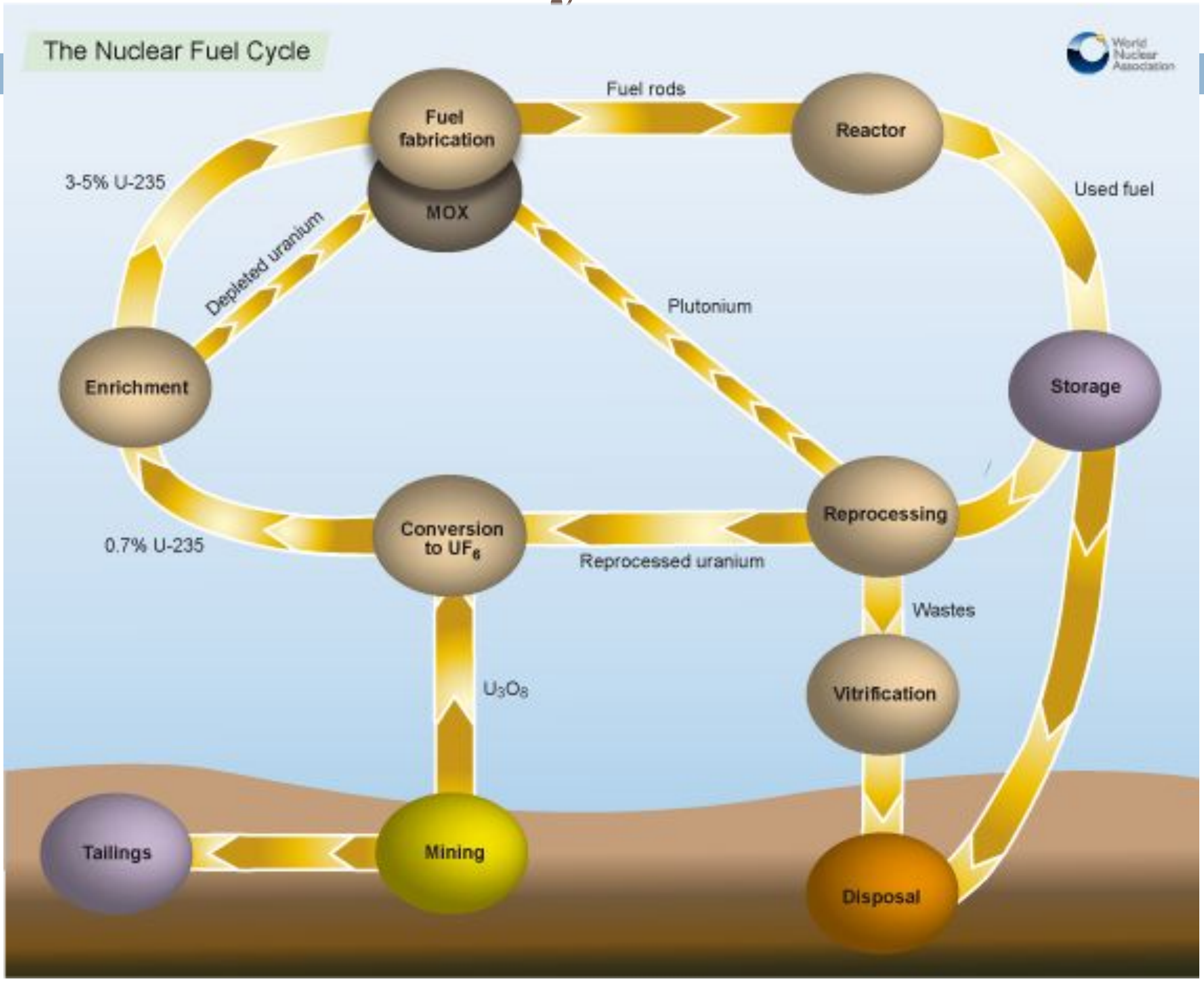
- Most reactors need to be shut down for refuelling, so that the pressure vessel can be opened up. In this case refuelling is at intervals of 1-2 years, when a quarter to a third of the fuel assemblies are replaced with fresh ones.

- The **CANDU and RBMK types have pressure tubes (rather than a pressure vessel enclosing the reactor core) and can be refuelled under load by disconnecting individual pressure tubes.**

- **If graphite or heavy water is used as moderator, it is possible to run a power reactor on natural instead of enriched uranium.**

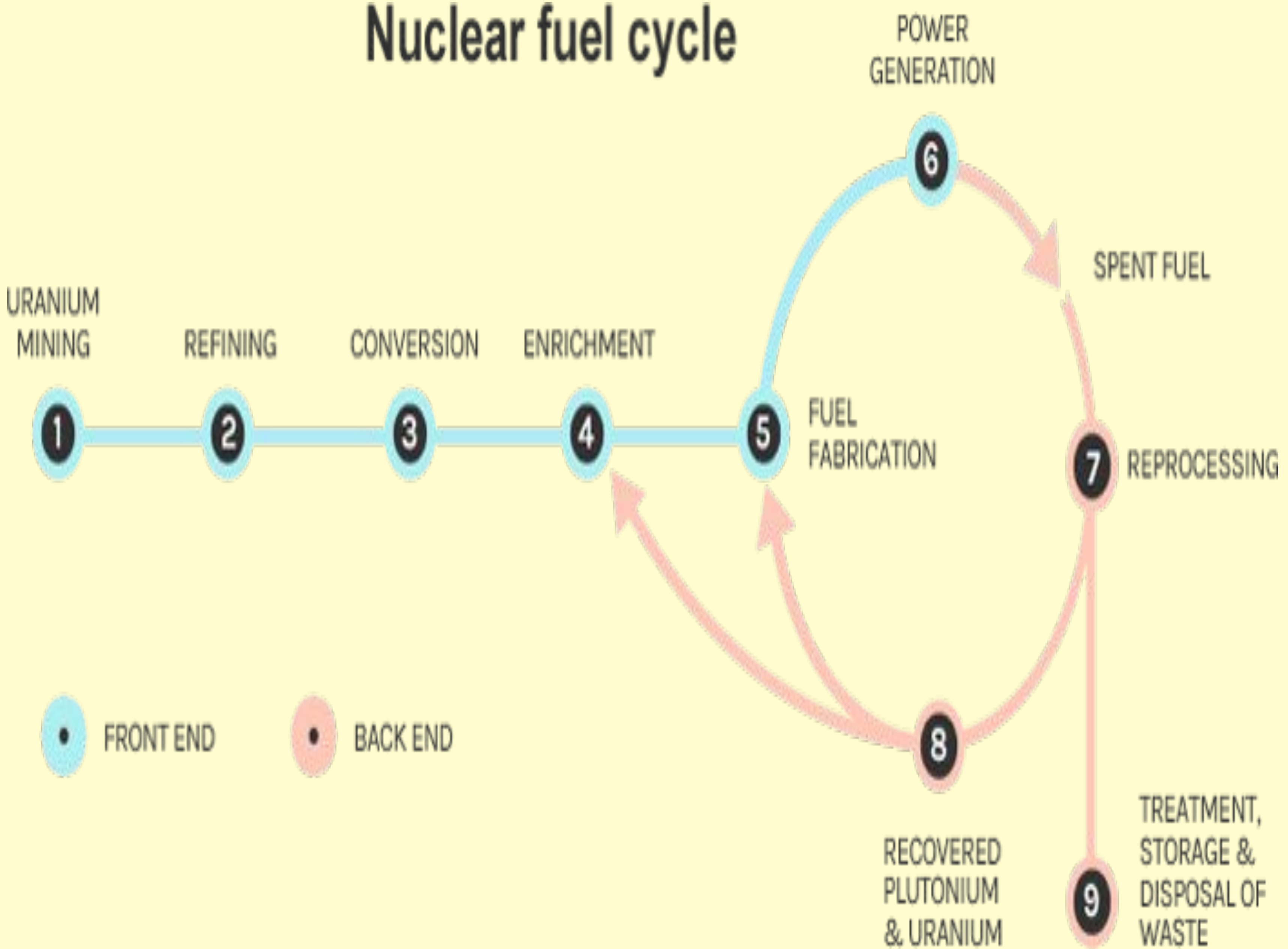
- The moderator can be ordinary water, and such reactors are collectively called light water reactors. Because the light water absorbs neutrons as well as slowing them, it is less efficient as a moderator than heavy water or graphite.

Nuclear Fuel Cycle



Jaduguda Uranium Mine, Jharkhand and Tummalapalle uranium mine, Andhra Pradesh

Nuclear fuel cycle



FRONT END PROCESS OF NUCLEAR FUEL CYCLE

1. Mining
Extraction of Uranium from ground

2. Milling
Uranium is converted into yellowcake

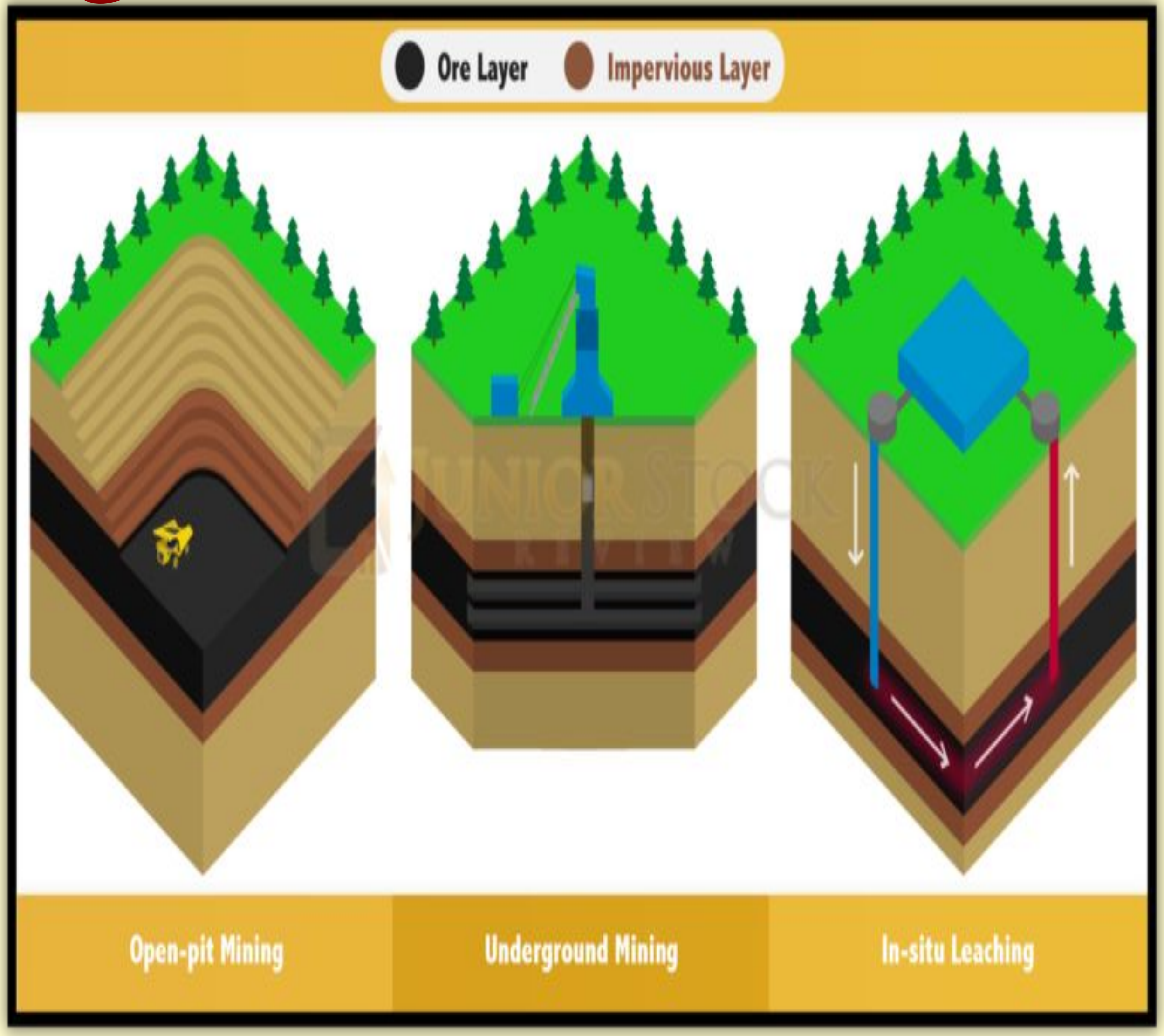
3. Conversion
Yellowcake is converted into UF6

4. Enrichment
increase the proportion of U-235

5. Fuel Fabrication
Convert Uranium into fuel for nuclear reactor

6. Power Generation
Generation of electricity in a nuclear reactor

MINING



*When mined, it yields a mixed **uranium oxide** product, U_3O_8. **Uraninite, or pitchblende**, is the most common uranium mineral. The concentration of uranium in the ore can range from **0.03 to 20%.***

OPEN PIT MINING

Open pit mines are used where the deposits are shallow.

UNDERGROUND MINING

Underground mines has to be undertaken where the deposits are more than 100m below the surface.

IN-SITU RECOVERY

Acidic or alkaline mining solution is passed directly through the underground ore body via a series of bores or wells and uranium is brought to the surface in a dissolved state for purification.

MILLING

- ✔ The mined uranium ore is crushed and chemically treated to separate the uranium, usually by the addition of acid or alkali.

- ✔ The usable mill product is an **uranium oxide concentrate termed yellowcake**, a powder form of uranium oxide (U_3O_8).

- ✔ The yellowcake is usually heated to remove impurities, thus increasing the U_3O_8 concentration.

- ✔ In yellow cake, the uranium concentration is raised to more than 80%.

- ✔ The remaining crushed rock, called '**tailings**', must be appropriately disposed of.

CONVERSIO N

- The conversion phase mostly deals with **converting yellowcake to the gaseous form to allow enrichment**.

- A minority of nuclear power plants do not require enriched uranium and for these power plants, the yellow cake (U_3O_8) is converted to uranium dioxide(UO_2) at the conversion plant.

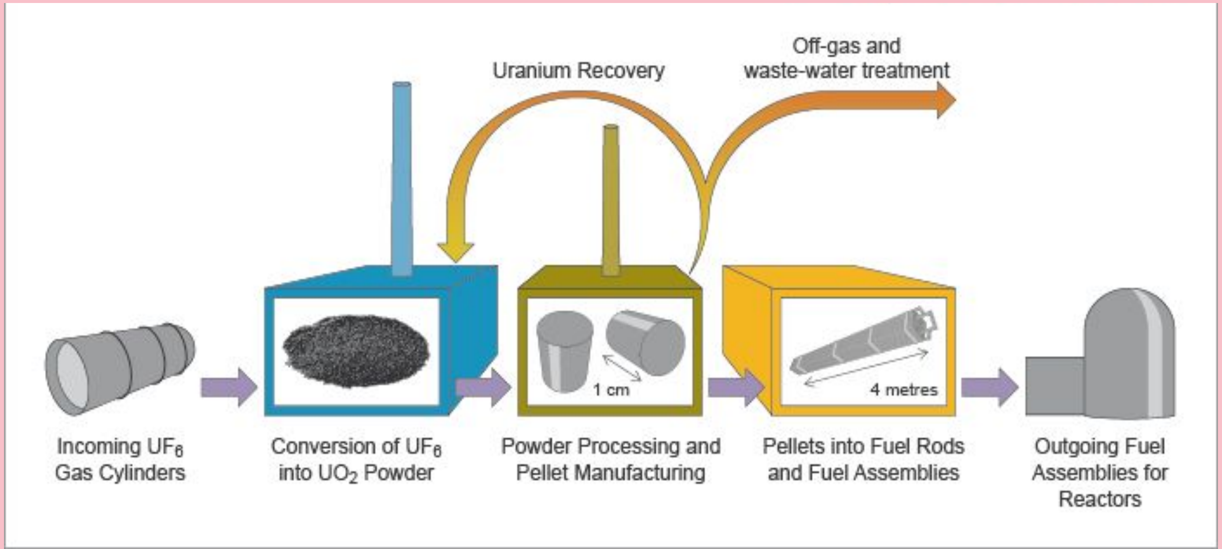
- Most power plants, however, require enriched uranium. As enrichment— the next step of the nuclear fuel cycle — requires the material to be in the gaseous form, **the yellow cake is converted into uranium hexafluoride (UF_6)**.

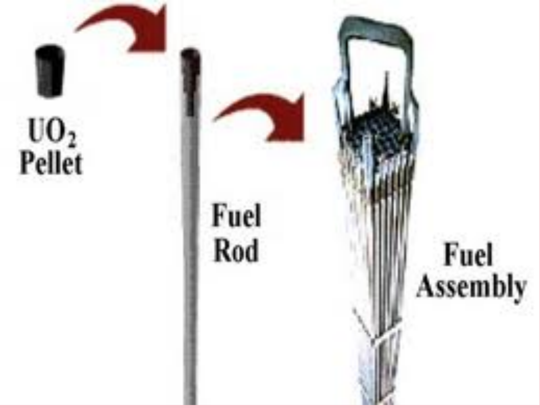
FUEL FABRICATION

- All of the current generation of power reactors use **uranium dioxide(UO_2) fuel in the form of ceramic pellets**.

- In a fuel fabrication plant, enriched uranium hexafluoride is converted into fuel for nuclear reactors. Converted first into **uranium dioxide powder**, it is then processed into pellets by pressed and **sintered (baked) at high temperatures(over 1400°C).** These pellets are then sealed in tubes called **fuel rods**. Several fuel rods, depending on the reactor type, are assembled to form **fuel assemblies**.

- These tubes are generally made of **zirconium alloys**. They hold the fuel pellets and contain any radioactive gases released from the fuel pellets.





POWER GENERATION

- Once the fuel is loaded inside a nuclear reactor, controlled **fission** can occur.

- **Fissioning, or splitting**, of uranium atoms produces energy.

- The process of producing electricity begins when uranium atoms are split (i.e., fission) by particles known as neutrons. U235 has a unique quality that causes it to break apart when it collides with a neutron.

- **44 million kilowatt-hours of electricity is produced from one tonne of natural uranium equivalent to 20,000 tonnes of black coal**

Used Fuel

With time, the concentration of fission fragments and heavy elements formed will increase to the point where it is no longer practical to continue to use the fuel. So after 18-36 months the used fuel is removed from the reactor

When removed from a reactor, the fuel will be emitting both radiation, principally from the fission fragments, and heat. It is unloaded into a storage pond immediately adjacent to the reactor to allow the radiation levels to decrease. *In the ponds the water shields the radiation and absorbs the heat, which is removed by circulating the water to external heat exchangers.* Used fuel is held in such pools for several months and sometimes many years. It may be transferred to naturally-ventilated *dry storage on site after about five years.*

There are two alternatives for used fuel:

- **reprocessing to recover and recycle the usable portion of it**
- **long-term storage and final disposal without reprocessing**

Reprocessing

Used fuel still contains about 96% of its original uranium, of which the fissionable U-235 content has been reduced to less than 1%. About 3% of the used fuel comprises waste products and the remaining 1% is plutonium (Pu) produced while the fuel was in the reactor and not 'burned'

Reprocessing separates uranium and plutonium from waste products (and from the fuel assembly cladding) by chopping up the fuel rods and dissolving them in acid to separate the various materials. It enables recycling of the uranium and plutonium into fresh fuel, and produces a significantly reduced amount of waste (compared with treating all used fuel as waste). Remaining 3% of high-level radioactive wastes can be stored in liquid form and subsequently solidified

Processing of Used Nuclear Fuel

Used nuclear fuel has long been reprocessed to extract fissile materials for recycling and to reduce the volume of high-level wastes. Recycling is largely based on the conversion of fertile U-238 to fissile plutonium

Reprocessing of used fuel has been done to recover unused uranium and plutonium in the used fuel elements and thereby close the fuel cycle, gaining some 25% to 30% more energy from the original uranium in the process and thus contributing to energy security. A secondary reason is to reduce the volume of material to be disposed of as high-level waste to about one-fifth. In addition, the level of radioactivity in the waste from reprocessing is much smaller and after about 100 years falls much more rapidly than in used fuel itself.

Uranium and Plutonium Recycling

The uranium recovered from reprocessing, which typically contains a slightly higher concentration of U-235 than occurs in nature, can be reused as fuel after conversion and enrichment.

The plutonium can be directly made into mixed oxide (MOX) fuel, in which uranium and plutonium oxides are combined

About eight fuel assemblies reprocessed can yield one MOX fuel assembly

It avoids the need to purchase about 12 tonnes of natural uranium from a mine

Wastes

Wastes from the nuclear fuel cycle are categorised as high-, medium- or low-level wastes by the amount of radiation that they emit. These wastes come from a number of sources and include:

- low-level waste produced at all stages of the fuel cycle;
- intermediate-level waste produced during reactor operation and by reprocessing;
- high-level waste, which is waste containing the highly-radioactive fission products separated in reprocessing. Separated high-level wastes also contain long-lived transuranic elements.

After reprocessing, the liquid high-level waste can be calcined (heated strongly) to produce a dry powder which is incorporated into borosilicate (Pyrex) glass to immobilise it.
The glass is then poured into stainless steel canisters, each holding 400 kg of glass. A year's waste from a 1000 MWe reactor is contained in five tonnes of such glass, or about 12 canisters 1.3 metres high and 0.4 metres in diameter. These can readily be transported and stored, with appropriate shielding

The general consensus favours its placement into deep geological repositories, about 500 metres down, initially recoverable before being permanently sealed

Radioactive Waste

Radioactive (or nuclear) waste is a byproduct from nuclear reactors, fuel processing plants, and institutions such as hospitals and research facilities. It also results from the decommissioning of nuclear reactors and other nuclear facilities that are permanently shut down.

Two broad classifications

High-level Waste - High-level radioactive waste results primarily from the fuel used by reactors to produce electricity
Low Level Waste - Low-level radioactive waste results from reactor operations and from medical, academic, industrial, and other commercial uses

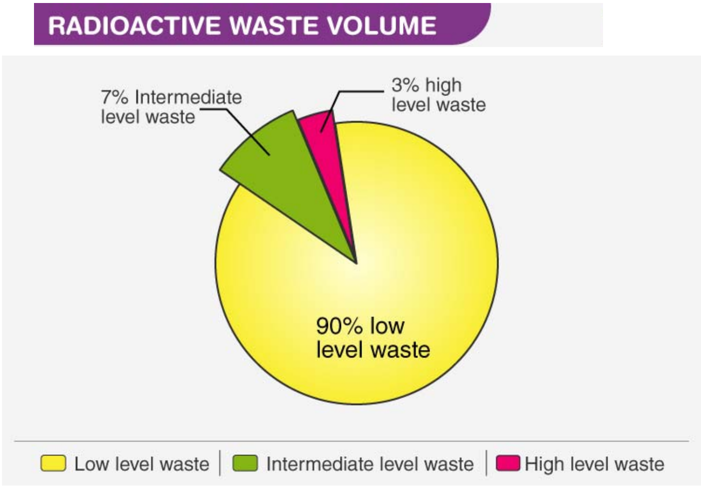
The heavier nuclide may then absorb another neutron to become an even heavier element. These heavier atoms are known *as transuranics*.

International Atomic Energy Agency

Low level waste (LLW): Waste that is above clearance levels, but with limited amounts of long lived radionuclides. Such waste requires robust isolation and containment for periods of up to a few hundred years and is suitable for disposal in engineered near surface facilities.

Intermediate level waste (ILW): Waste that, because of its content, particularly of long lived radionuclides, requires a greater degree of containment and isolation than that provided by near surface disposal.

High level waste (HLW): Waste with levels of activity concentration high enough to generate significant quantities of heat by the radioactive decay process or waste with large amounts of long lived radionuclides that need to be considered in the design of a disposal facility for such waste. Disposal in deep, stable geological formations usually several hundred metres or more below the surface is the generally recognized option for disposal of HLW.



NUCLEAR WASTE AND ITS DISPOSAL

NUCLEAR POWER

435 NUCLEAR PLANTS WORLDWIDE
10,500 TONNES OF SPENT FUEL PER YEAR

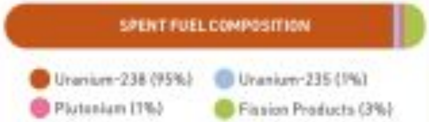
As of 2019, nuclear power plants operate in 30 countries. Six countries have outright bans on use of nuclear reactors to generate electricity.

10% OF THE WORLD'S ELECTRICITY

Nuclear fuel releases many times more energy per gram than fossil fuels. Nuclear plants don't release carbon dioxide while they are operating.

WHAT IS NUCLEAR WASTE?

About 3% of spent nuclear fuel consists of radioactive fission products. In some countries, the spent fuel is reprocessed to separate the waste from uranium and plutonium.



Radioactive waste contains unstable isotopes of elements which decay and emit alpha, beta or gamma radiation. Eventually they decay into non-radioactive elements.

HALF LIVES: UP TO 32 YEARS

Cs-137 Sr-90 Cm-243 Cm-244 Co-60

HALF LIVES: 460-24,000 YEARS

Th-229 Pu-239 Pu-240 Am-241 Am-243

HALF LIVES: 77,000-16,000,000 YEARS

Nb-94 I-129 Cs-135 Tc-99 Th-230 Np-237

As well as the radioactivity produced by nuclear waste, it also produces heat as isotopes decay. This poses issues for storage and disposal.

TYPES OF NUCLEAR WASTE

LOW LEVEL WASTE (LLW)

90% of all radioactive waste (by volume)
1% of the total radioactivity of all waste

LLW is defined as not exceeding 4 giga-becquerels per tonne (GBq/t) of alpha activity or 12 GBq/t of beta-gamma activity.

INTERMEDIATE LEVEL WASTE (ILW)

7% of all radioactive waste (by volume)
4% of the total radioactivity of all waste

ILW produces more radiation than LLW, but doesn't generate as much heat as HLW. It includes metal fuel cladding.

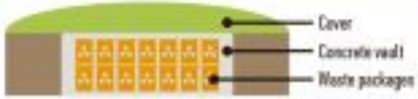
HIGH LEVEL WASTE (HLW)

3% of all radioactive waste (by volume)
95% of the total radioactivity of all waste

HLW is defined as producing more than 2 kilowatts per metre cubed of heat due to its radioactivity. It requires shielding during transport and cooling before permanent disposal. It includes used fuel and separated waste.

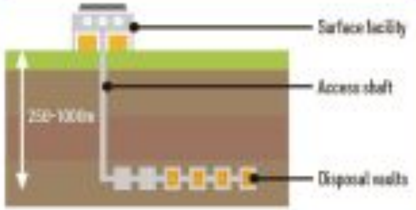
WASTE STORAGE & DISPOSAL

NEAR-SURFACE DISPOSAL



Low level waste's radioactivity is usually compacted into steel canisters and stored in concrete vaults underground. When full, vaults are sealed, covered and left. They ensure no significant radiation reaches the surface.

DEEP GEOLOGICAL DISPOSAL



Intermediate and high level waste generate heat and greater levels of radioactivity. Most countries plan to use deep geological disposal. The rock and soil acts as a barrier to the radiation. Before this, high level waste is incorporated into glass and stored for up to fifty years to allow heat to dissipate.

Radioactive waste disposal

- **Deep geological repositories**
- **Ocean dumping**
- **Seabed burial**
- **Sub-seabed disposal**
- **Transforming radioactive waste to non-radioactive stable waste**
- **Dispatching to the Sun**

Radiation

Ionising radiation (high energy, forms ions)

X rays, gamma, alpha, beta

Non-ionizing radiation (can excite atom, heat radio wave, solar radiation

Corpuscular

(stream of atomic and sub-atomic particles which transfer energy when strike. Eg alpha, beta) Internal emitters

EMR

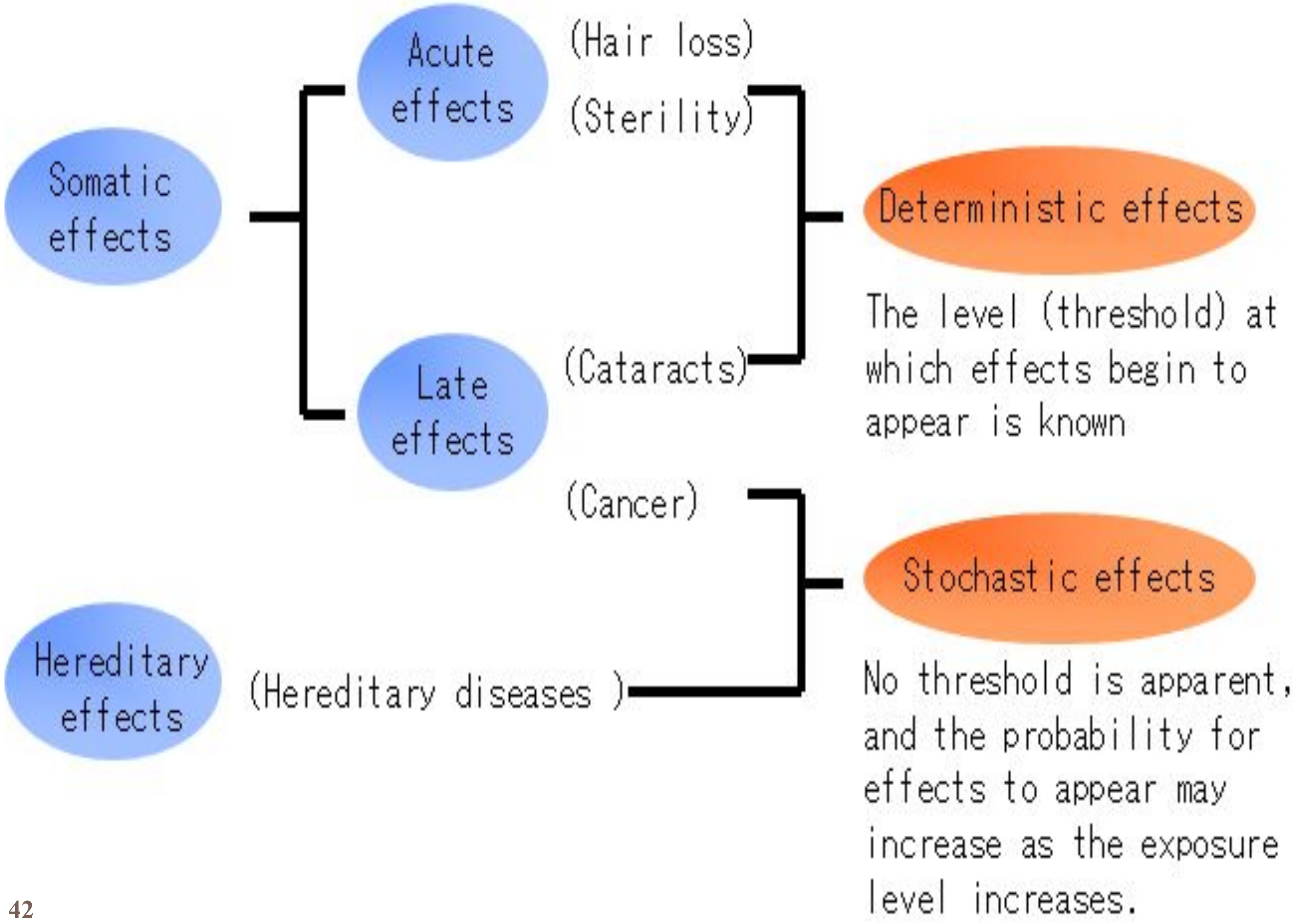
(shorter waves can penetrate the living tissue. Eg gamma, x rays)

External Emitters

Isotopes of elements that emit ionising radiation are radioactive isotope or radio nuclides

Effect of alpha, beta is greatest when absorbed, ingested or deposited in or near living tissue

The penetration of alpha, beta and gamma increase from alpha to gamma but ionisation and local damage are of reverse order


Somatic effects
Acute effects
Late effects
Hereditary effects
(Hair loss)
(Sterility)
(Cataracts)
(Cancer)
(Hereditary diseases)
Deterministic effects
The level (threshold) at which effects begin to appear is known
Stochastic effects
No threshold is apparent, and the probability for effects to appear may increase as the exposure level increases.

Stochastic effects

- "Stochastic" refers to the **likelihood or probability** that an effect will happen.
- Associated with **long-term and low-level (chronic) exposure**
- A **single photon** can cause an effect
- Appear in **non-exposed** persons as well as **exposed** persons
- Show up **years** after exposure
- Consist primarily of **cancer and genetic effects**

Stochastic effects

- Radiation can cause **changes in DNA**, the "blueprints" that ensure cell repair and replacement and this is called **mutation** if body fails to repair.
- The mutations can be **teratogenic** or **genetic**.
- **Teratogenic mutations** are caused by exposure of the fetus in the uterus and affect only the individual who was exposed.
- **Genetic mutations** are passed on to offspring.
- it can **never be determined** for certain that an **occurrence** of cancer or genetic damage was due to a **specific exposure**
- **No identification method**

Non stochastic effects /Deterministic Effects

- Occurs when very large dosages of radiation are received in a short amount of time
- These effects will often be evident within hours or days
- Examples include erythema (skin reddening), skin and tissue burns, cataract formation, CNS damage, Hair loss , radiation sickness and death.
- Each of these effects differs from the others in that both its threshold dose and the time over which the dose was received cause the effect (i.e. acute vs. chronic exposure)

Effects of Radiations

Acute and Delayed Effects

A single accidental exposure to a high dose of radiation during a short period of time is referred to as an ***acute exposure***, and may produce biological effects within a short period after exposure. These effects include:

- **Skin damage**
- **Nausea and vomiting**
- **Malaise and fatigue**
- **Increased temperature**
- **Blood changes**
- **Bone marrow damage**
- **Damage to cells lining the small intestine**
- **Damage to blood vessels in the brain**

Clinical consequences of radiation exposure

At a molecular level, the primary consequence of radiation exposure is **DNA damage.** This damage will be fully repaired or innocuous or will result in **dysfunction, carcinogenesis, or cell death.**
The clinical effect of radiation exposure will depend on numerous variables, including the **type of exposure** (total or partial body exposure vs. internal or external contamination), the **type of tissue exposed** (tissue that is sensitive to radiation vs. tissue that is insensitive), the **type of radiation** (e.g., gamma vs. beta), the **depth of penetration of radiation** in the body (low vs. high energy), **the total absorbed dose, and the period over which the dose is absorbed (dose rate).**

Acute Radiation Sickness

When most or all of the human body is exposed to a single dose of more than 1 Gy of radiation, acute radiation sickness can occur. Plant workers or members of the emergency response team.

Clinical consequences of radiation exposure

Much of the short-term morbidity and mortality associated with a high total or near-total body dose is due to **hematologic, gastrointestinal, or cutaneous sequelae**. In the Chernobyl accident, all 134 patients with acute radiation sickness had **bone marrow depression**, 19 had widespread **radiation dermatitis**, and 15 had severe **gastrointestinal complications.**

Hematologic and gastrointestinal complications are common because bone marrow and intestinal epithelium are especially radiosensitive as a result of their high intrinsic replication rate.

Increased Long-Term Cancer Risks

Exposure Pathways

Each of the different routes, or pathways, by which people can be exposed to radiation result in exposure to different parts of the body. Health physicists must analyze the potential for and effects of exposure via each of the three basic pathways, inhalation, ingestion, and direct exposure, when calculating exposures or estimating the effects of exposures.

Inhalation
Ingestion
Direct Exposure

Nuclear Accidents

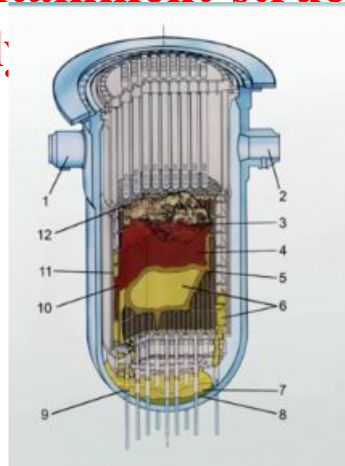
In the event of an accident, **the primary concern is that the support structure (core)** containing the fuel and the fission products may become damaged and allow radioactive elements to escape into the environment.

The reactor core and even the fuel **itself can partially or completely melt.** Elevated temperatures and pressures can result in explosions within the reactor, dispersing radioactive material.

In most plants, the potential effects of a cooling-system failure are minimized by surrounding the **reactor core with a steel-walled vessel, which in turn is surrounded by an airtight, steel-reinforced concrete containment structure that is designed to contain the radioactive material indefinitel**

Meltdown

an accident in which severe overheating of the nuclear reactor results in the melting of the reactor's core



Nuclear Accidents and Disasters

- **Chernobyl Nuclear Accident, Ukrain, USSR, 1986**
- **Three Mile Island Nuclear Accident, USA, 1979**
- **Fukushima Nuclear Disaster, Japan in 2011**

Nuclear Accidents and Disasters

In the partial meltdown at **Three Mile Island**, the plant's containment structure fulfilled its purpose, and a minimal amount of radiation was released. However, there was no such containment structure in place at the Chernobyl reactor — the explosions and the subsequent fire sent a giant plume of radioactive material into the atmosphere.

Although the Three Mile Island accident has not yet led to identifiable health effects, the Chernobyl accident resulted in 28 deaths related to radiation exposure in the year after the accident.

Fukushima Nuclear Disaster - Following a major earthquake, a **15-metre tsunami disabled the power supply and cooling of three Fukushima Daiichi reactors**, causing a nuclear accident on 11 March 2011. All three cores largely melted in the first three days. There have been no deaths or cases of radiation sickness from the nuclear accident, but over 100,000 people were evacuated from their homes to ensure this.

Chernobyl disaster

- **At 1.00 am April 25, 1986 - safety test for more energy requirement**
- **Steam was reduced by lowering the control rods (**cadmium, hafnium or boron**)**
- **Test was delayed; shift change output gone down from 700 to 30MW**
- **For immediate need of power many control rods and later all were withdrawn**
- **This was a second serious safety violation**
- **At the final stages of test; signal indicated excessive reaction**
- **Automatic reactor shutdown was blocked**
- **Power output rose beyond normal level and continued to rise**
- **Emergency system could not stop reaction as core was meltdown**
- **In 4.5 seconds energy increased 2000 times**
- **Reactor exploded; 24,000 had received high doses of radiation**
- **Increased frequency of thyroid cancer in children**

National Solar Mission

- The Jawaharlal Nehru National Solar Mission (JNNSM) is also known as the **National Solar Mission.** It is a major initiative of the Government of India to promote solar power in the country. The mission **was launched in 2010** with the objective of establishing India as a global leader in solar energy. This is achieved by creating the policy conditions for its diffusion across the country as quickly as possible.
- **Major Objectives of JNNSM**
- To attain 100 GW of solar energy by 2022 (increased from the initial 20 GW).
- To lessen the detrimental effect on the environment due to power generation.
- To foster the use of cleaner fuel.
- To foster both on-grid and off-grid power.
- The Mission has **adopted a 3 - phase approach,** Phase 1 (up to 2012 - 13), Phase 2 (2013 - 17) and Phase 3 (2017 - 22).
- Setting up an enabling environment for solar technology penetration in the country both at a centralized and decentralized level.

- **Solar Rooftop Yojana, Pradhan Mantri Kisan Urja Suraksha Evam Utthaan Mahabhiyan Yojana (PM KUSUM), Solar Parks**

Hydraulic fracturing Technique – Shale oil

- **Oil shale** is an organic-rich fine-grained sedimentary rock containing kerogen (a solid mixture of organic chemical compounds) from which liquid hydrocarbons can be produced, called shale oil (not to be confused with tight oil—crude oil occurring naturally in shales). Shale oil is a substitute for conventional crude oil; however, extracting shale oil from oil shale is more costly than the production of conventional crude oil both financially and in terms of its environmental impact