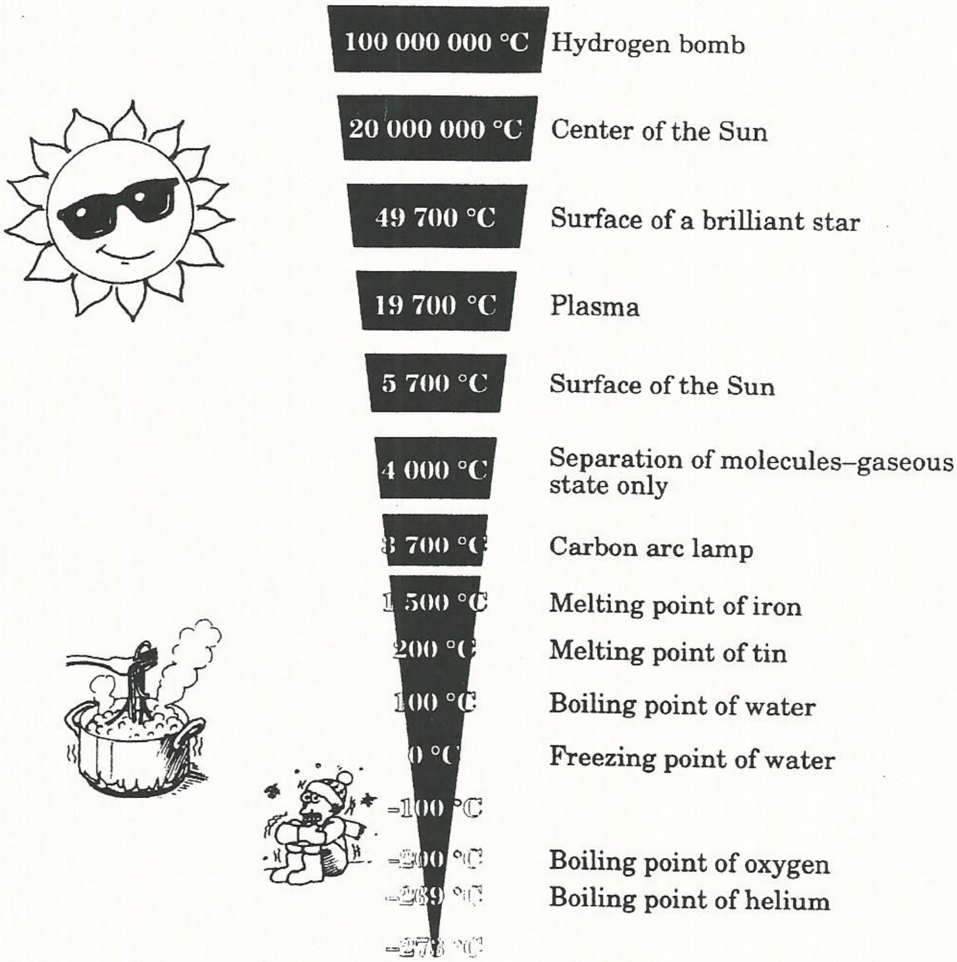
**Temperatures in Degrees Celsius**




Helium boils at −269 °C, which is only 4 degrees above absolute zero, the lowest possible temperature. At the other extreme, the temperature at the centre of a hydrogen bomb, where nuclear fusion takes place, is hotter than the temperature at the centre of the Sun.

### The Arrival of the H-Bomb

On March 1, 1954, two years after the first test explosion, the H-bomb officially became part of the American nuclear arsenal. (The first H-bomb was exploded by the Russians in August 1953.) On this day, on the Bikini atoll[2] in the Pacific Ocean, the Americans exploded a bomb 1000 times more powerful than the bomb dropped on Hiroshima. Some Japanese fishermen 150 kilometres away from the explosion site received serious radiation burns. The atoll's Polynesian inhabitants were evacuated and told they could return to their island within a few weeks; after all these years, they are still waiting for permission to return to their homeland which is still declared uninhabitable due to dangerously high radiation levels.

Advantages of Producing Energy Through Fusion Reactors Instead of Fission Reactors

1. Fusion produces more E than fission.

2. Constant heat must be provided for fusion, so there is no risk of it going out of control in a chain reaction.

3. Deuterium is abundant in sea water – lots of fuel for fusion.

4. Fusion releases very little radiation.

Main problem with Fusion Reactors:

The extremely high temperature required for fusion is very difficult to achieve and maintain.

Advantage of Using Nuclear Energy to Produce Electricity in Nuclear Submarines:

A very small mass of fuel will produce a huge amount of energy. Therefore the sub can stay at sea for long periods of time without refuelling, and the sub doesn't need to carry large masses of fuel.

Nuclear energy is also used to power submarines and cargo planes. The Russians and Americans actually possess a few "atomic" vessels which use a nuclear reactor to perform various functions.

Such a reactor acts like a miniature power station. It produces an electric current to meet the needs of a submarine the same way as would a thermal power station. The steam produced by fission is routed directly to the propellers to power the submarine. Similarly, by supplying the current for water electrolysis, the reactor also supplies the vessel with oxygen.

Space missiles on mission around the Earth or farther out in the solar system also run on nuclear energy. The space probes, *Voyager 1* and *Voyager 2*, which were sent to explore outer space, were powered by nuclear energy.

Radioactivity is also used in many other fields, from remote sensing to quality control in industry.

Mastering fission, like radioactivity, has opened a world of possibilities, both military and civilian. Yet, there is another type of nuclear reaction called fusion, which holds even more promise than fission. Although difficult to achieve, nuclear fusion is often perceived as the nuclear technology of tomorrow. The energy released by the Sun and other stars is produced by fusion.

Potential Power of Atomic Versus H-bomb

Remember: In A-bomb, the masses of U (or Pu) must be limited so that neither mass alone exceeds critical mass. Therefore the total mass of the two can only be so large.

H-bomb There is no limit to the mass that can be used. For fusion to occur a blast of heat is all that is required and then whatever mass of fusionable material that is present will undergo fusion. No limit to bomb's explosive poser.

**Exam Alerts:**

A-bomb

- This bomb was dropped on the cities of Hiroshima and Nagasaki.
- A limited amount of material must be used to make this bomb.
- Plutonium or Uranium can be used to make this bomb.
- In this bomb, the fissile material is divided into two separate blocks, each with a mass lower than the critical mass.
- This bomb produces less energy than the other type of bomb.

H-bomb

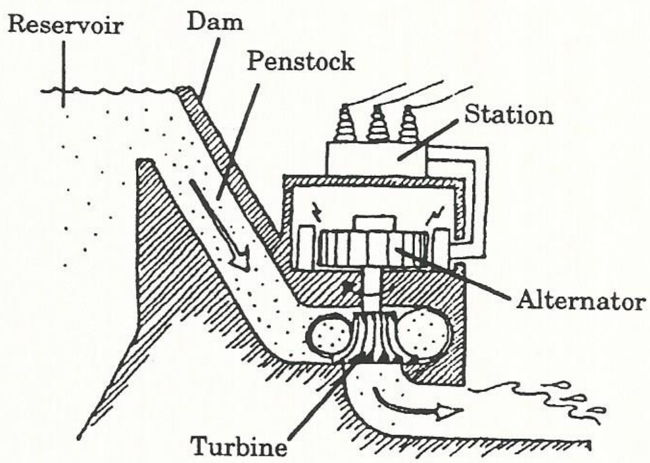
- In theory, there is no limit to the explosive power of this bomb.
- The other type of bomb is required to detonate this bomb.
- It is a thermonuclear bomb. ("thermo" = heat → since heat is required to initiate the fusion reaction).
- This bomb uses the principles of nuclear fission and nuclear fusion.
- This bomb produces more energy than the other type of bomb.
- This bomb is based on the principle of nuclear fusion.

The Operation of an Electric Power Station

Three types of Electric Power Stations: hydroelectric power station
conventional thermal power station } thermal power stations
nuclear power station

All three: a force is needed to activate a turbine which powers a generator.
Result: electricity

**Hydroelectric Power Station**

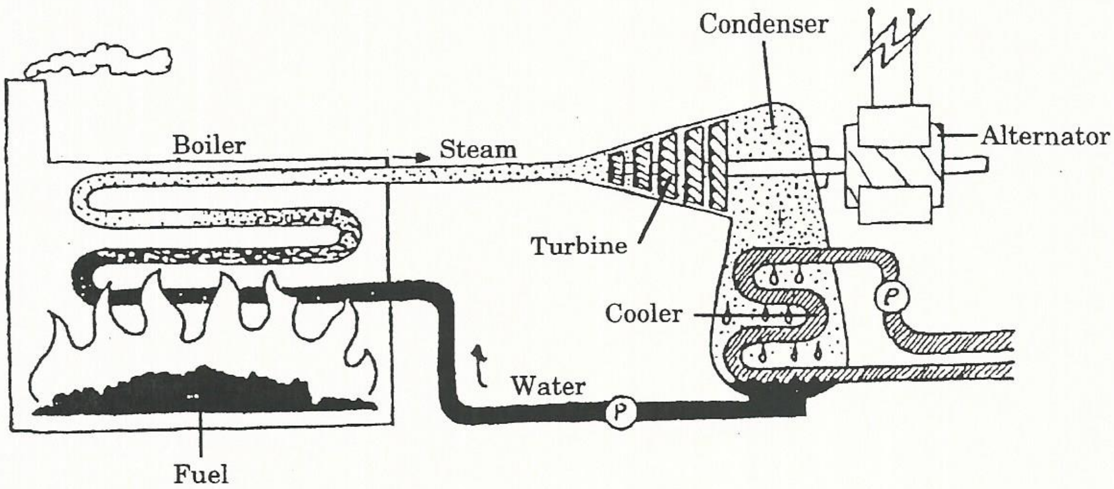



A hydroelectric power station converts water's gravitational potential energy into electrical energy.

Hydroelectric Power Station

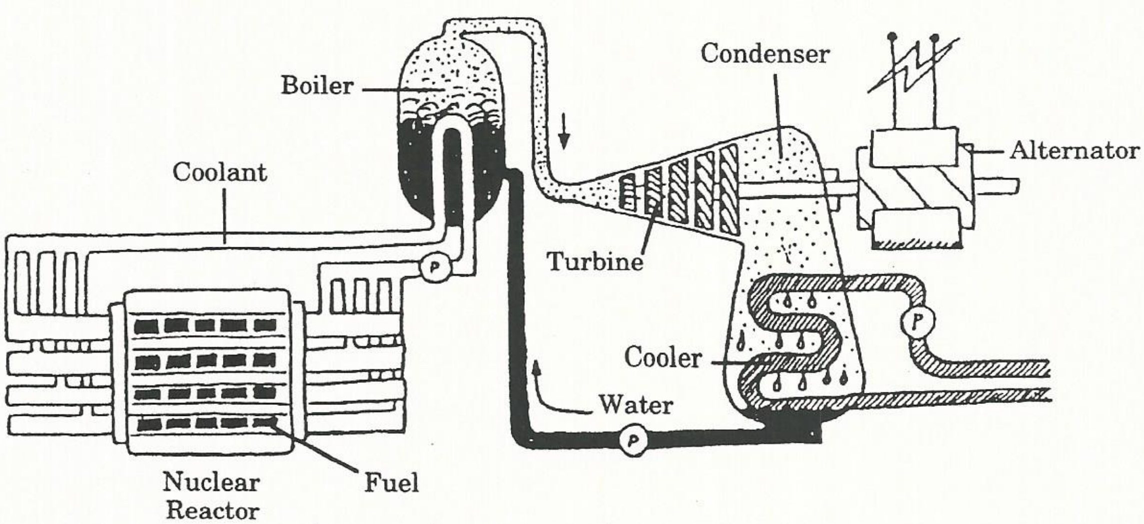
- flow of water is the source of E
- no condenser present (since it's not a thermal reaction, there is no need to condense steam back into water).
- this type of power station produces no waste!

**Conventional Thermal Power Station**




A conventional thermal power station uses energy from a fossil fuel (heating oil or coal). The steam produced is used to drive a turbine, which in turn drives a generator.

**Nuclear Power Station**




A nuclear power station operates on the same principle as a conventional thermal power station, only the oil or coal is replaced by nuclear fuel.

Thermal Power Station (includes conventional thermal power stations and nuclear power stations)

- power is provided by pressurized steam – the steam drives the turbine.

- thermal power stations:
  a) conventional thermal power stations:
     - Heat needed to produce steam from $H_2O$ comes from burning crude oil, heating oil, natural gas or coal.
  b) nuclear power stations:
     - heat needed to produce steam from $H_2O$ comes from a nuclear reaction (fission) (uses uranium or plutonium)

The CANDU Power Reactor

CAN – Canada
D – deuterium ($^{2}_{1}H$)
U – uranium

heavy water: (uses $^{2}_{1}H$ instead of $^{1}_{1}H$) : $D_2O$

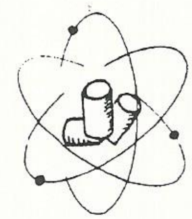
**Exam Alerts**

- Fission of uranium occurs inside the reactor.
- The U is encased in special fuel bundles.
- When the fuel bundles are changed, the reactor does not need to be shut down.
- Cadmium control rods are used to slow down the release of neutrons during the fission reaction (so the reaction is kept under control).
- Heavy water also slows down the neutrons by acting as an obstacle or moderator (there is $D_2O$ in the reactor core).
- The number of fissions per second in the reactor remains the same; it doesn't change with demand for electricity.
- The coolant ($D_2O$) circulates in a closed system.
- Heat from the fission reaction (in the nuclear reactor) is carried by the coolant to the boiler. The coolant can be thought to heat the ordinary water in the boiler and convert it into steam, which drives the turbine.
- The water in the boiler, not the coolant, is converted into steam.
- After driving the turbine, the steam is condensed in the condenser unit and later reheated (after being circulated back to the boiler).
- The cooling water in the condenser is not in a closed circuit; rather, the cooling water is pumped in from a source outside the power station (like a lake).
- The residue (waste) from the fission reaction is not reused – it is discarded.
- The same substance – $D_2O$ – is used as coolant and a moderator.

**Comparison of Energy Output of Different Fuels**

500 g of coal
produces 1.5 kWh

500 g of gas
produces 2.0 kWh



500 g of natural uranium
produces 30 000 kWh

Nuclear fuel produces 15 000 to 20 000 times more energy than the equivalent amount of coal or gas.

Nuclear Technology in Other Countries

Here are some differences:

| | **Canada (CANDU)** | **England** | **Russia** | **USA** |
|---|---|---|---|---|
| **Type of Fuel** | Natural Uranium | Enriched Uranium-235 | Enriched Uranium-235 | Enriched Uranium (more U-235 present) |
| **Moderator** | Heavy water | Graphite (a form of coal) | Graphite | Ordinary water |
| **Coolant** | Heavy water | Pressurized gas | Ordinary water | Ordinary water |

The nuclear accident that took place at Three Mile Island, Pennsylvannia on March 28, 1979 involved a nuclear reactor using ordinary water and enriched uranium. The problems began when a power surge in the cooling system caused the reactor to suddenly overheat. Although everything was quickly shut down, the temperature inside the reactor core continued to rise because of the radioactivity in the air, arousing fears of a meltdown. Luckily, the containment shell surrounding the reactor held safe, confining most of the radioactivity inside.

Some Medical Applications of Radioactivity

1. Locating and destroying tumors (Cobalt–60 used in cancer treatment).
2. Detecting diseases of the heart, lungs and other organs.
3. Indicating how the body absorbs certain substances.
4. Indicating if an organ is malfunctioning.

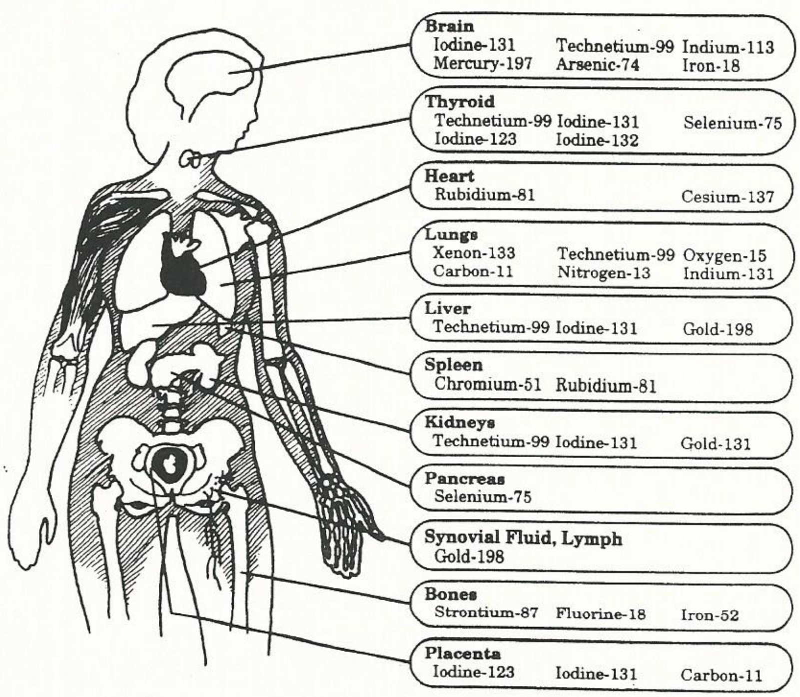
## Medical Applications of Cobalt-60

Much of the cobalt-60 used in medicine in Canada is produced at the Gentilly II power station. To create this isotope, cobalt-59, which is abundant in nature, is placed in the reactor where it absorbs an extra neutron and is transformed into cobalt-60. Canada produces 85% of the cobalt-60 used in the world today, and is a major manufacturer of cobalt therapy machines.

I-131 is used in CAT scans – it has a half-life of only 8 days. Using radioisotopes that have short half-lives is beneficial – won't take long for body to be rid of it.

For example, the thyroid gland naturally absorbs iodine to produce hormones.[5] Injecting the patient with iodine-131, a radioactive iodine isotope which is also absorbed by the thyroid, helps to detect an overactive or underactive thyroid.

**Radioactive Indicators**




Some radioactive isotopes are used as "tracers" to assess organ function.