The Sun and Nuclear Energy

- The Sun is the most direct and bountiful source of energy. It powers the flow of wind and water cycles on the Earth's surface and sustains all life.
- Plants use this energy to make their food by the process of photosynthesis. It is this food that provides sustenance to humans and other animals on the Earth.
- On studying the wavelength of light emitted by the Sun, it was concluded that it is largely made up of hydrogen. Hydrogen bums in the presence of oxygen and this process is called combustion. But combustion could hardly account for the massive amount of energy that we continue to receive from the Sun.
- In 1939 German physicist, Hans Bethe gave correct explanation for the massive energy of the Sun. He proposed that the Sun contains in its core hydrogen nuclei moving at very great speeds. Whenever these lighter nuclei fuse to form the nucleus of a heavier element, a large amount of energy is liberated. It is this energy which we receive when the Earth faces the Sun.
- Every square metre of the Earth's upper atmosphere receives 1.36 kJ of energy per second. However, all of this energy does not the surface of the Earth. Some of the light energy is reflected into space and some is absorbed by water vapour, ozone, dust and carbon dioxide present in the atmosphere. In fact, only 47 per cent of the energy that strikes the Earth's atmosphere reaches its surface and is absorbed.
- To understand the source of the Sun's energy, we must understand the structure of atom. The atom consists of a positively charged heavy nucleus.
- The nucleus consists of positively charged protons and neutral neutrons and negatively charged light electrons revolving around the nucleus.
- The mass of one proton is approximately equal to the mass of 1836 electrons.
- Although two atoms of an element always have the same number of protons, they can have different numbers of neutrons in their nucleus. For example, an atom of an element uranium always has 92 protons in its nucleus and 92 electrons orbiting around it. However, not all uranium atoms have the same number of neutrons in the nucleus. Some uranium atoms have 146 neutrons, while others have 143 neutrons. These two forms of uranium are called isotopes of uranium.
- Each isotope is designated by the total number of protons and neutrons (nucleons) in its nucleus. This number (number of protons + number of neutrons) is called the mass number (Z) of the atom. Thus, a uranium atom with 146 neutrons is designated as $U\text{-}238\,\,\left(238=92+146 \right)$,while a uranium atom with 143 neutrons is designated as $U\text{-}235\,\,\left(235=92+143 \right)$.
- The chemical symbol for uranium is U.
- Most of the uranium found on the Earth is of the kind U-238. The percentage of uranium U-235 is only about 0.7.
- When two protons moving at high speeds collide, one of the colliding protons transforms into neutron generating two new particles additionally. One of these particles is positively charged with the mass similar to that of an electron. It is called positron. The other particle does not have charge. It is called neutron. These nuclear reactions occur inside the Sun liberating huge amount of energy. Nuclei of deuterium, which is the heavier isotope of hydrogen, collide inside the Sun to produce helium. This is the source of energy liberated in the Sun, which in turn, emits lights of different wavelengths.
- This is called fusion reaction where hydrogen in the Sun is converted into helium, accompanied with the release of energy. For fusion of hydrogen to occur, the nuclei must collide at very high speeds. Such speed can be attained when the temperature is quite high (about $4,000,000{}^\circ C$). Scientists are trying to create such high temperatures in laboratories to induce fusion reactions that occur in the Sun.
- The naturally occurring element uranium is found in two forms, i.e., the isotopes U-238 and U-235. Both have same number of protons in their nuclei but not the same number of neutrons. The number of neutrons in U-235 is 143 and in U-238 is 146. The rarer of these two isotopes, U-235 has a very peculiar property. The nucleus of this variety is highly unstable. Even a slow, stray neutron colliding with it can rupture it completely. An extra neutron entering such a highly unstable nucleus can completely upset the delicate balance between the electrostatic and the nuclear forces in it. The nucleus of the U-235 atom then splits into smaller fragments, releasing huge amounts of energy in the process. The fragments flying apart in this explosion are mainly bunches of protons and neutrons which are, in fact, nuclei of smaller atoms. The bursting nucleus also emits two or three loose neutrons as well as light of a very small wavelength. The wavelength of this radiation is about a thousand times smaller than the wavelength of red light. This is often referred to as X-rays and the entire process is called nuclear fission which means to break apart.
- The energy released in nuclear disintegrations is used to heat water, which then turns turbines and generates electricity, i.e., the heat energy generated is converted to electricity. The apparatus where this reaction takes place is called a nuclear reactor.
- The fuel used in the reactor is uranium. Since, naturally occurring uranium has very little U-235, it must be first processed to increase the percentage of fissionable U-235. This process is called enrichment.
- Three per cent of the energy produced in India is obtained from nuclear reactors situated at various sites across the country. India's uranium comes chiefly from the Jaduguda mines in Bihar. It is processed, and fuel elements are fabricated at the Nuclear Fuels complex at Hyderabad. This enriched fuel is then sent to various reactors at Tarapur in Maharashtra, Kota in Rajasthan, Kalpakkam in Tamil Nadu and Narora in Uttar Pradesh.
- Nuclear energy production is also associated with release of radioactive substances in the environment. These need to be stringently controlled because some of these nuclear radiations are highly penetrating. If human body is exposed to them in large concentrations, irreparable damage can be caused to body cells.
- To prevent leakage of these dangerous and toxic radiations, the nuclear reactor is covered with a thick coat of radiation absorbing materials. However, a minor fault in the design of reactors or a natural calamity striking a perfectly designed reactor could result in the release of these radiations into the environment.
- The world has already witnessed major accidents in reactors, as in the United States at the nuclear power plant on Three Mile Island and the one Chernobyl in Russia, and one in the Fukushima reactor of Japan. The devastation caused by the release of radiation in these accidents is yet to be assessed correctly.
- Apart from the dangers arising from a possible accident at the reactor site, there is, of course, the additional danger of harmful waste matter produced at various steps of the nuclear cycle, which includes mining, enrichment of the area and, of course, the nuclear reaction inside the reactor. These generate a number of substances capable of emitting nuclear radiations. These substances are collectively termed as nuclear wastes. Though environmentally safe practices are followed for disposal of nuclear wastes, more accepted solutions are desirable for their disposal from a long-term point of view.
- We urgently need to accelerate research and development programmes aimed at devising economical and reliable means of safeguarding the biosphere from fuel wastes. Meanwhile, we must choose lifestyles and a social ethos, which would actively discourage wasteful use of energy, conserve scarce resources such as wood and kerosene, and promote maximum utilisation of renewable and non-polluting sources of energy, notably solar energy and energy is locked in biomass wastes.