Nuclear Physics & Heat

Radio Activity:

The Phenomenon of nuclear decay of certain elements with the emission of radiations like alpha, beta, and gamma rays is called radioactivity and the elements which undergo this phenomenon are called radioactive elements.

Why?

The nucleus of some elements is unstable. Such nuclei undergo nuclear decay and get converted into more stable nuclei.

Natural Radioactivity:

The phenomenon of spontaneous emission of radiation from certain elements on their own is called natural radio activity.

Example: Uranium, Radium [Atomic Number > 82]
Technetium, Promethium [Atomic Number < 82ff ð

43 61

There have been 29 radioactive substance discovered so far.

Artificial (or) Induced Radioactivity:

The Phenomenon by which even light elements are made radioactive, by artificial or induced methods is called artificial radioactivity.

In 1934 Irene Curie and F. Joliot discovered this kind of radioactivity.

Example:

$${}_4Be^9 + {}_2He^4 \rightarrow {}_6C^{13+}$$

$${}_6C^{13+} \rightarrow {}_6C^{12} + {}_6n^1$$

$_4Be^9$ → Parent Nucleus | $_2He^+$ → alpha (Projectile) Particle

$_6C^{12}$ → Daughter Nucleus | $_0n^1$ → Ejected Particle

Units of Radioactivity:

Curie : 1 Curie = 3.7×10^{10} disintegrations per second
Rutherford: 1 Rd = 10^6 disintegrations Per second.
Becquerel: SI unit, quantity of one disintegration per second.
Roentgen (R): It is defined as the quantity of radio active substance which produces a charge of 2.58×10^{-4} C in 1 kg of air.

Alpha decay:

$_{92}U^{238} \rightarrow {}_{90}Th^{234} + {}_2He^4$ (α - decay)

Beta decay:

$_{15}P^{32} \rightarrow {}_{16}S^{32} + {}_{-1}e^0$ (β - decay)

Gamma decay:

In this decay only the energy level of the nucleus changes. Atomic number and mass number remains the same.

Nuclear Fission:

The process of breaking up of a heavier nucleus into two smaller nuclei with the release of a large amount of energy and a few neutrons is called 'nuclear fission'.

$_{92}U^{235} + {}_0n^1 \rightarrow {}_{56}Ba^{141} + {}_{36}Kr^{92} + 3{}_0n^1 + Q$ (energy)

The average energy released in each fission process is about 3.2×10^{-11} J.

Fissionable Materials:

A Fissionable material is a radio active element, which undergoes fission in a sustained manner when it absorbs a neutron. It is also termed as 'fissile material'.

eg: U^{235}, Plutonium (Pu^{239} and Pu^{241})

Fertile Material: There are some radioactive elements, which can be converted into fissionable material. They are called as fertile material.

eg: U^{238}, Thorium – 232, Plutonium – 240

Chain Reaction:-

A chain reaction is a self-propagating Process in which the number of neutrons goes on multiplying rapidly almost in geometric progression.

i) Controlled chain reaction (Neutron absorber)
ii) Uncontrolled chain reaction (Atom Bomb)

Critical Mass:

The minimum mass of a fissile material necessary to sustain the chain reaction is called critical mass. It depends upon the nature, density and size of the fissile material.

Mass of the fissile material < Critical mass (sub critical)
Mass of the fissile material > Critical mass (super critical)

$1ev = 1.602 \times 10^{-19}$ joule.

1 million electron volt = 1 Mew = 10^6 eV
The energy released in a nuclear fission process is about 200 MeV.

Nuclear Fusion:

The process in which two lighter nuclei combine to form a heavier nucleus is termed as nuclear fusion.

eg: $_1H^2 + _1H^2 \rightarrow _2He^4 + Q$ (energy)

$_1H^2$ – an isotope of hydrogen known as 'deuterium'.

The average energy released in each fusion reaction is about 3.84×10^{-12}J.

Mass Defect – Mass of the daughter nucleus is less than the sum of the masses of the two parent nuclei. This mass is converted into energy. This concept of mass-energy equivalence was proposed by Einstein in 1905.

$E = mc^2$ where C is the velocity of light.

Hiroshima Nuclear bomb – Little Boy (Uranium)

Nagasaki Nuclear bomb – Fat man (Plutonium)

Conditions necessary for Nuclear Fusion:-

i) 10^7 to 10^9 k High temperature
ii) High pressure to push the hydrogen nuclei closer to fuse with each other. Hence it is named as 'Thermonuclear reaction'.
iii) The repulsive force will be overcome by the kinetic energy of the nuclei at high temperature of the order of 10^7 to 10^9 K.

Stellar Energy:

The stars like our sun emit a large amount of energy in the form of light and heat. This energy is termed as the stellar energy. All stars contain a large amount of hydrogen.

Hydrogen Bomb : Atom Bomb + Nuclear Fusion.

Sun fuses about 620 million metric tons of hydrogen each second and radiates about 3.8×10^{26} joule of energy per second. When it reaches the earth its value is about 1.4 kilo joule per unit area in unit time.

Uses of Radio activity:

Agriculture: The radio isotope of phosphorus (P-32) helps to increase the productivity of crops

Medicine: Radio Sodium (Na^{24}) – used for effective functioning of heart.

Radio – Iodine (I^{131}) is used to cure goiter.
Radio – Iron (Fe^{59}) is used to diagnose anemia.
Radio Phosphorus (P^{32}) is used in the treatment of skin diseases.

Radio Cobalt (Co^{60})
Radio Gold (Au^{1987}) } Skin cancer

Industries: An isotope of californium (cf^{252}) is used in the airlines to detect the explosives in the luggage.

An isotope of Americium (Am^{241}) is used as smoke detector.

Archeological Research – Radio Carbon dating, age of earth, fossils, old paintings and monuments.

NUCLEAR REACTOR

A Nuclear reactor is a device in which the nuclear fission reaction takes place in a self-sustained and controlled manner to produce electricity. The first nuclear reactor was built in 1942 at Chicago, USA.

Components of a nuclear reactors

The essential components of a nuclear reactor are (i) fuel, (ii) moderator, (iii) control rod, (iv) coolant and (v) protection wall.

Fuel:

A fissile material is used as the fuel. The commonly used fuel material is uranium.

Moderator:

A moderator is used to slow down the high energy neutrons to provide slow neutrons. Graphite and heavy water are the commonly used moderators.

Control rod:

Control rods are used to control the number of neutrons in order to have sustained chain reaction. Mostly boron or cadmium rods are used as control rods. They absorb the neutrons.

Coolant:

A coolant is used to remove the heat produced in the reactor core, to produce steam. This steam is used to run a turbine in order to produce electricity. Water, air and helium are some of the coolants.

Protection wall:

A thick concrete lead wall is built around the nuclear reactor in order to prevent the harmful radiations from escaping into the environment.

Uses of a nuclear reactor

1. Nuclear reactors are widely used in power generation.
2. They are also used to produce radio isotopes, which are used in a variety of applications.
3. Some reactors help us to do research in the field of nuclear physics.
4. Breeder reactors are used to convert non-fissionable materials into fissionable materials.

Nuclear power plants in India

Indian Atomic Energy Commission (AEC) was established in August 1948 by the Department of Indian Scientific Research committee at Bombay (now Mumbai) in Maharashtra. It is the nodal agency for all the research done in the field of atomic energy. Dr. Homi Jahangir Bhaba was the first chairman of Indian Atomic Energy Commission. Now, it is known as Bhaba Atomic Research Centre (BARC).

Nuclear power is the fifth largest source of power in India. Tarapur Atomic Power Station is India's first nuclear power station. Now, there are a total of seven power stations, one each in Maharashtra, Rajasthan, Gujarat, Uttar Pradesh and two in Tamilnadu. In Tamilnadu, we have nuclear power stations in Kalpakkam and Kudankulam. Apsara was the first nuclear reactor built in India and Asia. Now, there are 22 nuclear reactors which are operating in India. Some other operating reactors are

- Cirus
- Dhuruva
- Purnima

Heat

All substances in our surrounding are made up of molecules. These molecules are generally at motion and posses kinetic energy. At the same time each molecule exerts a force of attraction on other molecules and so they posses potential energy.

Internal energy = kinetic energy + potential energy

This is internal energy when flows out is called heat energy.

EFFECT OF HEAT ENERGY

1.Change in Temperature:

When heat energy is added to a substance, the kinetic energy of its particles increases and so the particles move at higher speed. This causes rise in temperature.

2.Change in State:

Solid→ liquid→ gas

3.Chemical changes:

Since heat is a form of energy it plays a major role in chemical changes. In some cases, chemical reactions need heat to begin and also heat determines the speed at which reactions occur. When we cook food, we light the wood and it catches fire and the food particles become soft because of the heat energy.

4.Expansion of substance:

When heat is added to a substance, the molecules gain energy and vibrate and force other molecules apart. As a result, expansion takes place.

Example: some space being left in railway tracks, when thermometer is place in warm water.

All forms of matter (solid, liquid, gas) undergo expansion on heating.

a) Expansion of solid

- Linear expansion (length)

- Super facial expansion (area)
- Cubical expansion (volume)

b) Expansion on liquids:

When a liquid is heated, it is done by keeping the liquid in some container and supplying heat energy to the liquid through the container. The thermal energy supplied will be partly used in expanding the container and partly used in expanding the liquid. Thus what we observe may not be the actual or real expansion of the liquid. Hence for liquids we can define.

a) Real expansion
b) Apparent expansion

Coefficient of real expansion is defined as the ratio of the true rise in the volume of the liquid per degree rise in temperature to its unit volume

S.I unit is k^{-1}

Coefficient of apparent expansion is defined as the ratio of the apparent rise in the volume of the liquid per degree rise in temperature to its unit volume.

S.I unit is k^{-1-}

FUNDAMENTAL LAWS OF GASES

1) Boyle's law:

When the temperature of a gas is kept constant, the volume of a fixed mass of gas is inversely proportional to it's pressure.

$$P \propto \frac{1}{V}$$

2) Charle's law: (The law of volume)

When the pressure of gas is kept constant the volume of a gas is directly proportional to the temperature of a gas.

$$V \propto T$$

3) **Avogodro's law:**

It states that at constant pressure and temperature, the volume of a gas is directly proportional, the volume of a gas is directly proportional to number of atoms or molecules present in it

$V \propto N$

It is the total number of atoms per mole of the substance. It is equal to 6.023×10^{23}/mol.

Transfer of Heat:

Heat transfer takes place in three ways.

1) Conduction (Solid):

The process of transfer of heat in solids from a region of higher temperature to a region of lower temperature without the actual movement of molecules is called conduction.

In solids, molecules are closely arranges to that they cannot move freely.

Conduction in daily life

- Aluminium is used for making utensils to cook food quickly
- Mercury is used in thermometers.
- We wear woolen clothes in winter to keep ourselves warm. Air, is a bad conductor of heat.

2) Convection (Fluids):

It is a flow of heat through a fluid from places of higher temperature to places of lower temperature by movement of the fluid itself.

Example

- Hot air balloon
- Breezes
- Winds

3) Radiation:

Radiation is the flow of heat from one place to another by means of electromagnetic waves.

It can occur even in vacuum whereas conduction and convection need matter to be present.

Example

- White coloured clothes good reflectors of heat
- Base of cooking utensils is blackened because black surface absorbs more heat from the surrounding
- Surface of airplane is highly polished, because it reflects most of the heat radiations from the sun.

Specific Heat Capacity:

Its is defined as the amount of heat required to raise the temperature of 1kg of the substance by 1°c or 1k.

S.I unit – $JKg^{-1}K^{-1}$ (or) J/Kg°C (or) J/g°C

Water has the highest heat capacity and its Value is 4200) J/Kg°K.

Ice (solid state) – 2100 $JKg^{-1}K^{-1}$
Steam (Gas state) – 460 $JKg^{-1}K^{-1}$

It means that water absorbs a large amount of heat for unit rise in temperature. It is because of this reason temperature of water in the lake does not change during day time.

Heat Capacity (Or) Thermal Capacity:

It is the heat required to raise the temperature of entire mass of the body by 1°C.

Heat capacity = $\frac{Quantity\ of\ heat\ required}{raise\ in\ temperature}$

SI unit is J/K (or) Cal/°C. (or) kcal/°C.

Latent Heat :

When a substance changes from one state to another a considerable amount of heat energy is absorbed or liberated. This energy is called latent heat.

Specific latent heat is the amount of heat energy absorbed or liberated by unit mass of a substance during change of state without causing any change temperature.

S.I unit J/Kg.

Heat

1. Ice has a specific heat capacity of ____.
   a. 4200$Jkg^{-1}k^{-1}$ b. 460 $Jkg^{-1}k^{-1}$ **c. 2100 $Jkg^{-1}k^{-1}$** d. 2200 $Jkg^{-1}k^{-1}$
   பனிக்கட்டியின் தன் வெப்ப ஏற்புத் திறனில் அளவு _____?
   a. 4200$Jkg^{-1}k^{-1}$ b. 460 $Jkg^{-1}k^{-1}$ **c. 2100 $Jkg^{-1}k^{-1}$** d. 2200 $Jkg^{-1}k^{-1}$

2. The amount of heat energy absorbed or released by a substance during a change in its physical states without any change in its temperature. It is known as ____
   a. Specific latent heat b. Sublimation
   c. Latent heat d. Heat capacity
   வெப்பநிலை மாறாத நிலையில் ஒரு பொருள் தன் நிலையை மாற்றிக்கொள்ளும் போது உட்கவரும் அல்லது வெளியிடும் வெப்ப ஆற்றல் ____ ஆகும்.
   a. தன் உள்ளுறை வெப்பம் b. பதங்கமாதல்
   c. உள்ளுறை வெப்பம் d. வெப்பத் திறன்

3. When two objects of same mass are heated at equal rates, the object with smaller specific heat capacity will have a ___?
   a. temperature decrease **b. faster temperature increase**
   c. faster temperature decrease d. None of the above
   ஒரே நிறையுடைய இரண்டு வெவ்வேறு பொருள்களை ஒரே வீதத்தில் வெப்பப்படுத்தும் போது குறைந்த தன்வெப்ப ஏற்புத்திறனுடைய பொருளின் நிலை ____?
   a. வெப்பநிலை குறையும் b. வெப்பநிலை வேகமாக அதிகரிக்கும்
   c. வெப்பநிலை வேகமாக குறையும் d. மேற்கண்ட எதுவுமில்லை

4. Thermal expansion is the tendency of matter to change in shape, area and volume due to a ____?
   a. Change in laten heat **b. Change in temperature**
   c. Change in heat capacity d. Change in volume
   _____ பொருள்களின் வடிவம், பரப்பு மற்றும் பருமனில் ஏற்படும் மாற்றமே வெப்ப விரிவு எனப்படும்.
   a. உள்ளுறை வெப்பம் மாற்றத்தினால் b. வெப்பநிலை மாற்றத்தினால்
   c. வெப்பதிறன் மாற்றத்தினால் d. பருமன் மாற்றத்தினால்

5. When the hot boiled egg is drop in cold water the egg shell can be removed easily. It is because ____

a. different thermal expansion b. different volume

c. different temperature d. none of the above

வேகவைக்கப்பட்ட சூடான முட்டையை குளிர்த்த தண்ணீரில் போட்டு அதன் ஓட்டினை உரித்தால் அது முட்டைமிலிருந்து எளிதாக பிரிந்து வரும். இதற்கு காரணம் _____?

a. வெவ்வேறு வெப்பவிரிவைப் பெற்றிருப்பதினால்

b. வெவ்வேறு பருமன் பெற்றிருப்பதினால்

c. வெவ்வேறு வெப்பநிலை பெற்றிருப்பதினால்

d. மேற்கண்ட எதுவுமில்லை