# Unit 17

# INFORMATION AND COMMUNICATION TECHNOLOGY

## After studying this unit, students will be able to:

- describe the components of information technology.
- explain briefly the transmission of
  1. electric signals through wires
  2. radiowaves through air
  3. light signals through optical fibres
- describe function and use of fax machine, cell phone, photo phone and computer.
- make a list of the use of E-mail and internet.
- describe the use of information storage devices such as audio cassettes, video cassettes, hard discs, floppy, compact discs and flash drive.
- identify the functions of word processing, data managing, monitoring and controlling.

## Science, Technology and Society Connections

**The students will be able to:**

- compare the advantages of high-tech. communication devices with the traditional system through library or internet search.
- access the risks and benefits to society and the environment of introducing ICT (e.g. effects on personal privacy, criminal activities, health and transfer of information).
- make a list of the use of computer technology in various fields of daily life.

We are living in the age of information and communication technology. It is not long ago when the telephone was the only device of communication within the country or abroad. Now-a-days, in addition to telephone, mobile phone, fax machine, computer and internet are the main sources of contact. These sources have shortened the distances and have brought in contact the whole world. In this chapter, we will study some basic phenomena and devices which are used in modern day information and communication technology. But before going ahead we should know what this information and telecommunication technology is.

## 17.1 INFORMATION AND COMMUNICATION TECHNOLOGY

In computer terminology, processed data is called information. Computer processes the data and converts it into useful information. This information is transmitted to distant places in the form of sound, picture and computerized data.

Information and Communication Technology (ICT) is basically an electronic based system of information transmission, reception, processing and retrieval. ICT is a blend of two fields: information technology and telecommunication. The two terms are defined as follows:

1. The scientific method used to store information, to arrange it for proper use and to communicate it to others is called information technology.
2. The method that is used to communicate information to far off places instantly is called telecommunication.

*Information and Communication Technology (ICT) is defined as the scientific methods and means to store, process and transmit vast amounts of information in seconds with the help of electronic equipments.*

**For your information**

All modern telecommunications use some form of electromagnetic radiation. Radiowaves carry information to local radio and TV. Microwaves are used for mobile phones, radar and transmission to satellites in space.

## 17.2 COMPONENTS OF COMPUTER BASED INFORMATION SYSTEM (CBIS)

There are five parts that must come together in order to produce

a Computer-Based Information System (CBIS) as shown in Fig.17.1. These are called the components of information technology. Now we discuss these components briefly.

**1. Hardware**: The term hardware refers to machinery. This includes the central processing unit (CPU), and all of its support equipment. Among the support equipments are input and output devices, storage devices and communication devices.

**2. Software:** The term software refers to computer programs and the manuals that support them. Computer programs are machine-readable instructions that direct the circuitry within the hardware parts of the CBIS to produce useful information from data. Programs are generally stored on some input / output medium, often a disk or tape.

**3. Data:** Data are facts and figures that are used by programs to produce useful information. It may be in the form of text, graphic or figure that can be recorded and that have specific meaning. Like programs, data are generally stored in machine-readable form on disk or tape until the computer needs them.

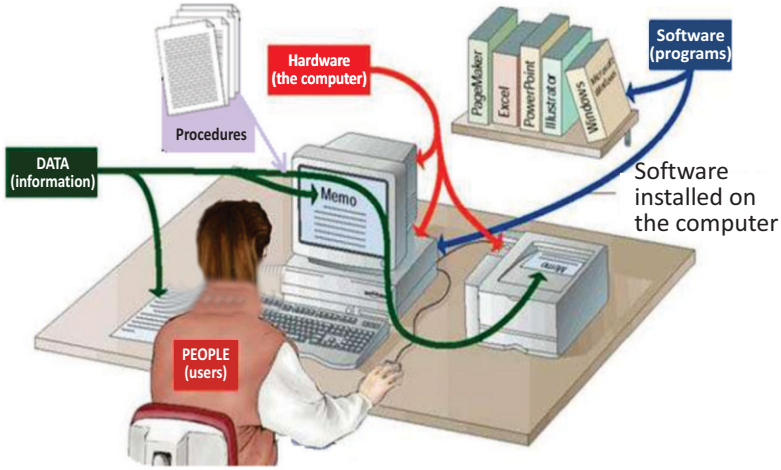



**Fig. 17.1:** Components of CBIS

**4. Procedures:** These are set of instructions and rules to design and use information system. These are written in manuals and documents for use. These rules or methods may change from time to time. The Information System must be flexible to incorporate these changes.

**5. People:** Every CBIS needs people if it is to be useful, who influence the success or failure of information systems. People design and operate the software, they feed input data, build the hardware for the smooth running of any CBIS. People write the procedures and it is ultimately people who determine the success or failure of a CBIS.

## 17.3 FLOW OF INFORMATION

Flow of information means the transfer of information from one place to another through different electronic and optical equipments. In telephone, information is sent through wires in the form of electrical signals. In radio, television and cell phone information is sent either through space in the form of electromagnet waves, or through optical fibres in the form of light. Radiowaves are continuously refracted by different layers in the Earth's atmosphere. This leads to weaken the signal, making it difficult to be received over long distances. Unlike radiowaves, microwaves are not refracted. They are used for satellite communication.

Fig. 17.2 shows the elements of a communication system. There are three essential parts of any communication system: transmitter, transmission channel, and receiver.

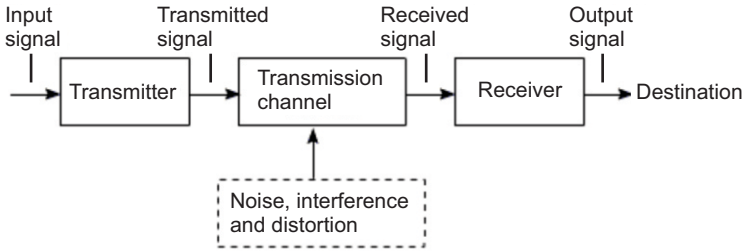
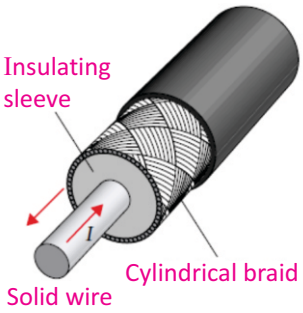



Fig. 17.2

The transmitter processes the input signal. The transmission channel is the medium which sends the signal from source to destination. It may be a pair of wires, a coaxial cable, a radio-wave or optical fibre cable. So, the signal power progressively decreases with increasing distance. The receiver takes the output signal from the transmission channel and delivers it to the transducer after processing it. The receiver may amplify the input signal to compensate for transmission loss.

**For your information**




Coaxial cable wires are used to transmit electric signals such as cable TV to our homes. To prevent electric and magnetic interference from outside, a covering of conducting material surrounds the coaxial wires.

## 17.4 TRANSMISSION OF ELECTRICAL SIGNAL THROUGH WIRES

Alexander Graham Bell in 1876 made a simple telephone model to send voice in the form of electrical signal from one place to another. It consists of a metal reed, an electric coil, and a vibrating diaphragm. Modern telephone also uses diaphragms to turn voices into electrical signal that are transmitted over phone lines. Telephone system has two parts: the mouthpiece and the earpiece (Fig.17.3).

The mouthpiece and receiver contain carbon granules and a thin metal diaphragm. When we speak into the mouthpiece, the sound vibrations also vibrate the diaphragm. A slight vibration of the diaphragm compresses the carbon and thus an electrical current can flow through the wire.

This process is reversed at the other end of the line by the receiver. The electrical current flowing through an electromagnet in the receiver produces a varying magnetic field. This magnetic field attracts the thin metal diaphragm in the receiver, causing it to vibrate. This vibration of the diaphragm produces sound waves.


**Fig.17.3:** Telephone diagram

**Interesting information**

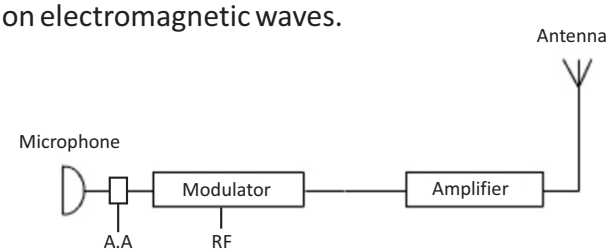
The speed of sound in air is just 1246 km per hour and it cannot go far away from its source. Therefore, it is converted into electromagnetic wave so that they can be sent to far off areas with the speed of light.

## 17.5 TRANSMISSIONS OF RADIOWAVES THROUGH SPACE

Electrical signals representing information from a microphone, a TV camera, or a computer can be sent from one place to another place using either cables or radiowaves. Information in the form of audio frequency (AF) signals may be transmitted directly by cable. However, in order to send information over a long distance, it has to be superimposed on electromagnetic waves.

**Do you know?**

Radiowaves are electromagnetic waves and they travel with the speed of light. Marconi has the distinction that he transmitted the first radio signal through the air.




**Transmitter**

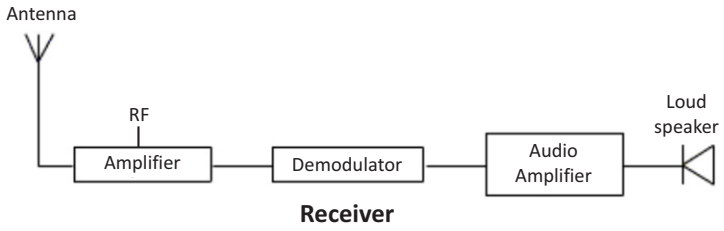



**Fig. 17.4:** Radio transmission and receiving system

Sound waves produced at the radio station are changed into electrical signals through microphone. These electric signals are then fed into the transmission antenna which consists of two metal rods. Signals falling on the transmission antenna oscillate the charges which then emit these electrical signals in the form of electromagnetic radiowaves.

At the receiving end, the receiver selects and amplifies the modulated signal. The demodulator then extracts the information signal and delivers it to the receptor. Radio transmission and receiving system is shown in Fig. 17.4.

## FAX MACHINE

Telefacsimile's or Fax machines (Fig. 17.5) are must for many businesses around the world. A fax machine basically scans a page to convert its text and graphic into electronic signals and transmits it to another fax machine through telephone line. The receiving machine converts the signals and uses a printer (usually built in) to create the copy of the message that was sent.

## CELL PHONE

Radio technology is applied in mobile phone (Fig. 17.6). It is a type of radio having two way communications. A cell phone carries a radio transmitter and a receiver inside it. It sends and receives the message in the form of radiowaves.

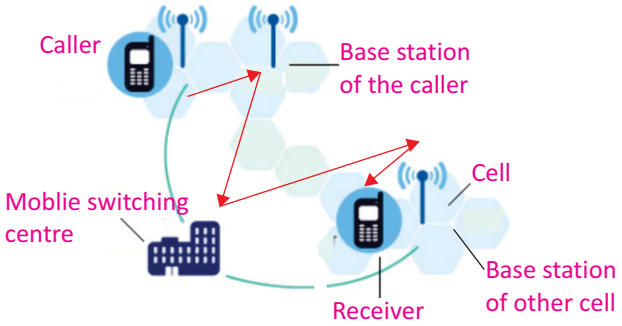



**Fig. 17.7:** Cell phone network


Radio

**For your information**

Radio tuning circuit consists of coils of fine wire wounded on a rod which is connected to the antenna. The coils are connected to variable capacitors. The tuned circuit selects signals of only particular frequency. It does not amplify the signals from transmitters with slightly lower or higher frequencies. The voltage rises and falls as the frequency of the received signal increases or decreases relative to the constant frequency of the oscillator.

**Fig.17.5:** Fax machine

**Fig. 17.6:** Cell phone

Cell phone network system consists of cells and **Base Stations (BSs)** and **Mobile Switching Centre (MSC)** (Fig. 17.7). A base station is a wireless communication station set up at a particular geographical location. The geographical area covered by a single base station is known as a cell. The group of cells forms a cluster. All BSs within a cluster are connected to a **MSC** using land lines. The MSC stores information about the subscribers located within the cluster and is responsible for directing calls to them. When a caller calls another cell phone, sound waves of the caller are converted into radiowaves signal. This radio signal of particular frequency is sent to the local base station of the caller where the signal is assigned a specific radio frequency. This signal is then sent to the base station of the receiver through MSC. Then the call is transferred to the cell phone of the receiver. Mobile receiver again changes the radiowaves into sound.

### PHOTO PHONE

Modern version of photo phone or video phone is shown in Fig 17.8. Contrary to a common telephone, users can see the pictures of each other. By using the photo and phone numbers of our friends or family members on this telephone, we can call them by pressing the pad with their photos. Thus, we can communicate with our relatives or friends on photo phone with the physical appearance of each other.

**Fig.17.8:** Photo phone

## 17.6 TRANSMISSION OF LIGHT SIGNALS THROUGH OPTICAL FIBRES

Waves of visible light have a much higher frequency than that of radiowaves. This means, rate of sending information with light beams is larger than that with radiowaves or microwaves. An optical fibre has been used as transmission channel for this purpose. An optical fibre with a coating of lower refractive index is a thin strand of high-quality glass that absorbs very little light. An optical fibre cable is a bundle

**Do you know?**

A mobile phone sends text messages and takes and transmits images. The new 3G technology will make video phones common place.

of glass fibres with thickness of a human hair.

Light that enters the core at one end of the optical fibre goes straight and hits the inner wall (the cladding) of fibre optics. If the angle of incidence with cladding is less than the critical angle, some of the light will escape the fibre optics and is lost (Fig. 17.9). However, if the angle of incidence is greater than the critical angle, light is totally reflected into the fibre optics. Then the totally reflected beam of light travels in a straight line until it hits the inner wall again, and so on. The advantage of optical fibre is that it can be used for sending very high data rates over long distances. This feature of fibre optics distinguishes it from wires. When electrical signals are transmitted through wires, the signal lost increases with increasing data rate. This decreases the range of the signal.

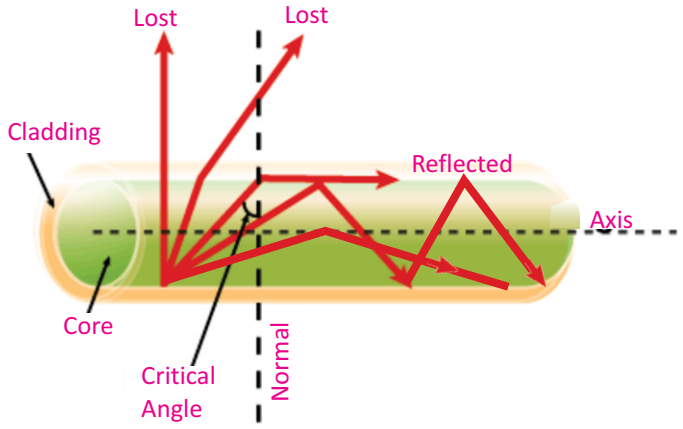



**Fig. 17.9:** Light entering a glass rod at greater than the critical angle is trapped inside the glass

Each optical fibre in a multi-mode cable is about 10 times thicker than fibre optics used in a single-mode cable. This means light beams can travel through the core by following different paths, hence the name multiple-mode. Multi-mode cables can send information only over relatively short distances and are used to link computer networks together.

## COMPUTER

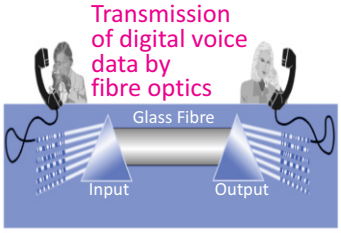
Computer (Fig. 17.10) is an electronic computing machine used for adding, subtracting or multiplying. Computers work through an interaction of hardware and software. Hardware

**For your information**

Microwave, digital and optical fibre technologies are combined to give us today's telecommunication systems. Microwaves travel in straight lines through the space and give a very strong signal. We can connect to the other side of the world in milliseconds. Communication satellites including **INTELSAT** and **SATCOM** are geostationary satellites that stay over the same position above the Earth surface and receive and transmit digital signals across the world.

**Do you know?**

Cell phone transmissions are made with microwaves.




Most of the data transmitted across the Internet is also carried by light. A network of fibre optic cables across the country carrying data from one computer to another.

refers to the parts of a computer that you can see and touch. These include CPU, monitor, keyboard, mouse, printer, etc. The most important piece of hardware is the central processing unit (CPU) that contains a tiny rectangular chip called microprocessor. It is the "brain" of computer—the part that translates instructions and performs calculations.

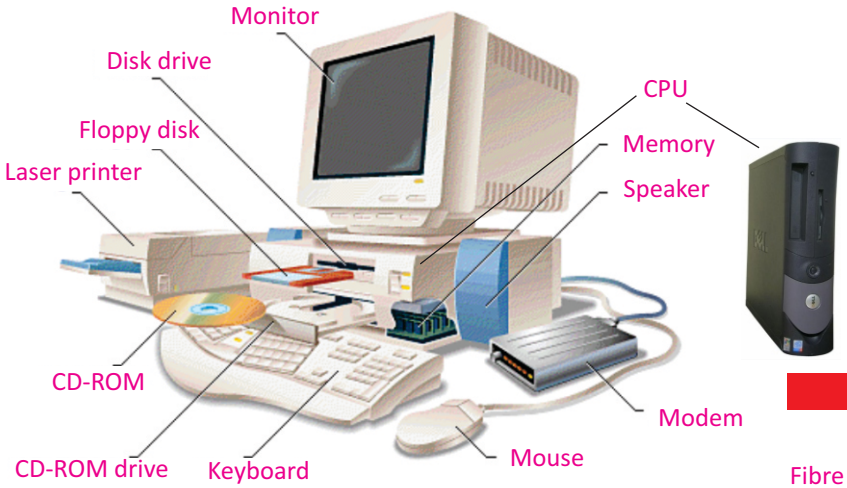
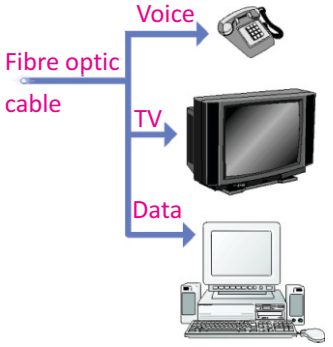



**Fig. 17.10:** Parts of a computer

Software refers to the instructions, or programs, that tell the hardware what to do. A word processing program that you can use to write letters on your computer is a type of software. The operating system (OS) is software that manages your computer and the devices connected to it. Two well known operating systems are Windows and Linux operating system.

Computer plays an important role in our daily life. In offices, computers are used for preparing letters, documents and reports. In hotels, computers are used for advance booking of rooms, preparing bills and providing enquiry services. In railways, computers are used for rail reservation, printing of tickets and preparation of reservation charts. Doctors use computers for diagnosing illness and treatment of diseases. Architects use them for building designing and city planning. In meteorology department, computers are used for weather forecasting. Now usual desktop computers have been replaced by laptops to a great extent. Laptops (Fig 17.11) are

**Do you know?**




A single fibreoptic cable can carry more than enough information to support television, telephone, and computer data.

**Fig. 17.11:** Laptop

more compact and hence are portable.

## 17.7 INFORMATION STORAGE DEVICES

A storage device is a device designed to store information in computer. Storage devices work on different principles using electronics, magnetism and laser technology.

### PRIMARY MEMORY

It is based on electronics and consists of integrated circuits (ICs). It consists of two parts; Read only memory (ROM), which starts the computer and Random access memory (RAM), which is used in computer as temporary memory. RAM vanishes when the computer is switched off.

### SECONDARY STORAGE DEVICES

The data storage devices are generally the secondary memory of the computer. It is used to store the data permanently in the computer. When we open a program data is moved from the secondary storage into the primary storage. The secondary storage devices are audio-video cassettes and hard disk etc.

### AUDIO AND VIDEO CASSETTES

These devices are based on magnetism. Audio cassettes consist of a tape of magnetic material on which sound is recorded in a particular pattern of a magnetic field(Fig. 17.12). For this purpose, microphone changes sound waves into electric pulses, which are amplified by an amplifier. Magnetic tape is moved across the head of audio cassette recorder which is in fact an electromagnet (Fig 17.13).

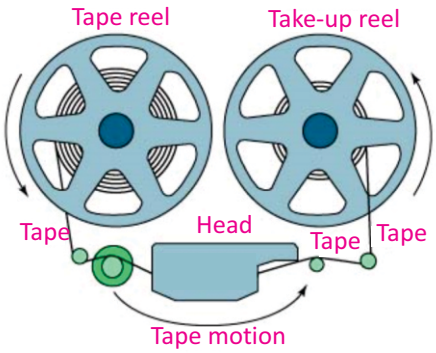



**Fig. 17.13: A** magnetic tape storage mechanism

**For your information**

Computers use data in binary from i.e., in the form of 0's and 1's. A bit is a single numeric value, either '1' or '0', that encodes a single unit of digital information. A byte is equal to eight bits. Larger units of digital data are kilobytes (kB), megabyte (MB) and gigabyte (GB). These are defined as below:

1 kB = 1024 bytes
1 MB = 1024 kilobytes
1 GB = 1024 megabytes

**Fig. 17.12:** Audio cassettes

**Interesting information**

The most powerful and swift computer which can send an information in one thousand billionth part of a second is called super computer. It contains many processors.

Thus magnetic tape is magnetized in a particular pattern according to rise and fall of current. In this way, sound is stored in a specific magnetic pattern on this tape.

To produce the sound again, the tape is moved past the play back head. Changes in the magnetic field on the tape induce alternating current signals in the coil wound on the head. These signals are amplified and sent to the loudspeakers which reproduce the recorded sound. In video tape/cassettes (Fig.17.14), pictures are recorded alongwith sound.

**Fig. 17.14:** Video cassettes

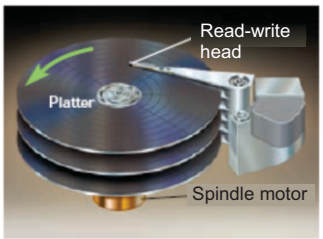
## MAGNETIC DISKS

There are different types of magnetic disks coated with a layer of some magnetic material. The read/write head of disks are similar to the record replay head on a tape recorder. It magnetizes parts of the surface to record information. The difference is that a disk is a digital medium– binary numbers are written and read. A floppy disc (Fig.17.15) is a small magnetically sensitive, flexible plastic wafer housed in a plastic case. It is coated with a magnetic oxide similar to the material used to coat cassettes and video tapes. Most personal computers include at least one disk drive that allows the computer to write it and read from floppy disk

**Fig. 17.15:** Floppy disk

Floppies are inexpensive, convenient, and reliable, but they lack the storage capacity and drive speed for many large jobs. Data stored on floppy disks is also subject to loss as a result of stray magnetic fields. As far as floppy disks are concerned, they are reliable only for short-term storage and cannot be used longer and no attempts should be made to save the data for a longer period. As the magnetic fields weaken the data will also be lost.

**For your information**




In computer hard drive, each platter has a magnetizable coating on each side. The spindle motor turns the platters at several thousand resolutions per minute (rpm). There is one read-write head on each surface of each platter.

## HARD DISK

Most users rely on hard disks as their primary storage devices. A hard disk is a rigid, magnetically sensitive disk that spins rapidly and continuously inside the computer chassis or in a separate box connected to the computer housing (Fig.17.16). This type of hard disk is never removed by the user. A typical hard disk consists of several

platters, each accessed via a read/write head on a moveable arm.

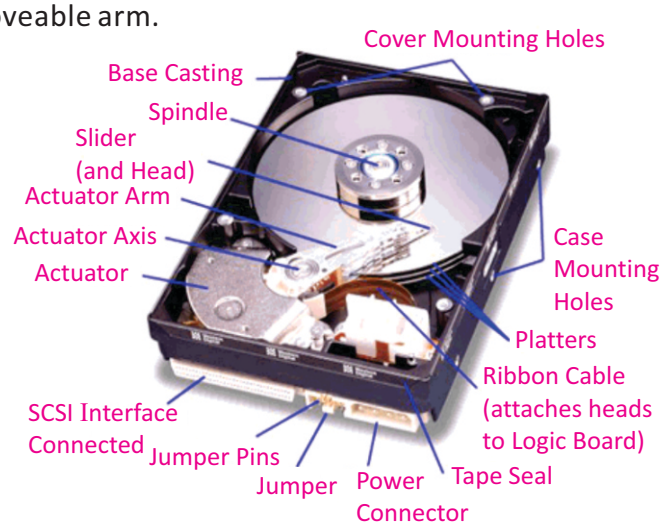



**Fig.17.16:** Hard disk

## COMPACT DISC (CDs)

This is based on laser technology. It is a molded plastic disc on which digital data is stored in the form of microscopic reflecting and non-reflecting spots which are called "pits" and "lands" respectively (Fig.17.17). Pits are the spiral tracks encoded on the top surface of CD and lands are the areas between pits (Fig. 17.18). A fine laser beam scans the surface of the rotating disk to read the data. Pits and lands reflect different amount of the laser light falling on the surface of CD. This pattern of different amount of the light reflected by the pits and the lands is converted into binary data. The presence of pit indicates '1' and absence of pit indicates '0'.

A CD can store over 680 megabyte of computer data. A DVD, the same size as traditional CD, is able to store upto 17gigabytes of data.

**Fig. 17.17:** Compact disk (CD)

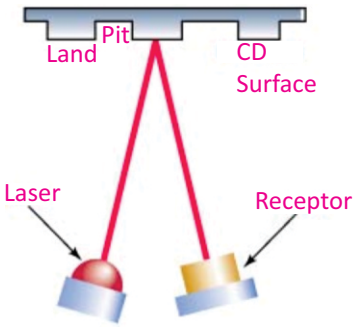



**Fig. 17.18**

## FLASH DRIVE

It is also an electronic based device and consists of data storage ICs. A flash drive is a small storage device that can be used to transport files from one computer to another (Fig. 17.19). They are slightly larger than a stick of gum, yet many of these devices can carry all your homework for an entire year! We can keep one on a key chain, carry it around our neck, or attach it to our book bag.

A flash drive is easy to use. Once we have created a paper or


**Fig. 17.19:** Flashdrive

other work, we can simply plug our flash drive into a USB port. We must make a backup of our created paper or project on our flash drive and save it separate from our computer. A flash drive will also come in handy if you are able to print out homework at school. You can write a paper at home, save it to your flash drive, and then plug the drive into a USB port on a school computer.

## 17.8 APPLICATIONS OF COMPUTER

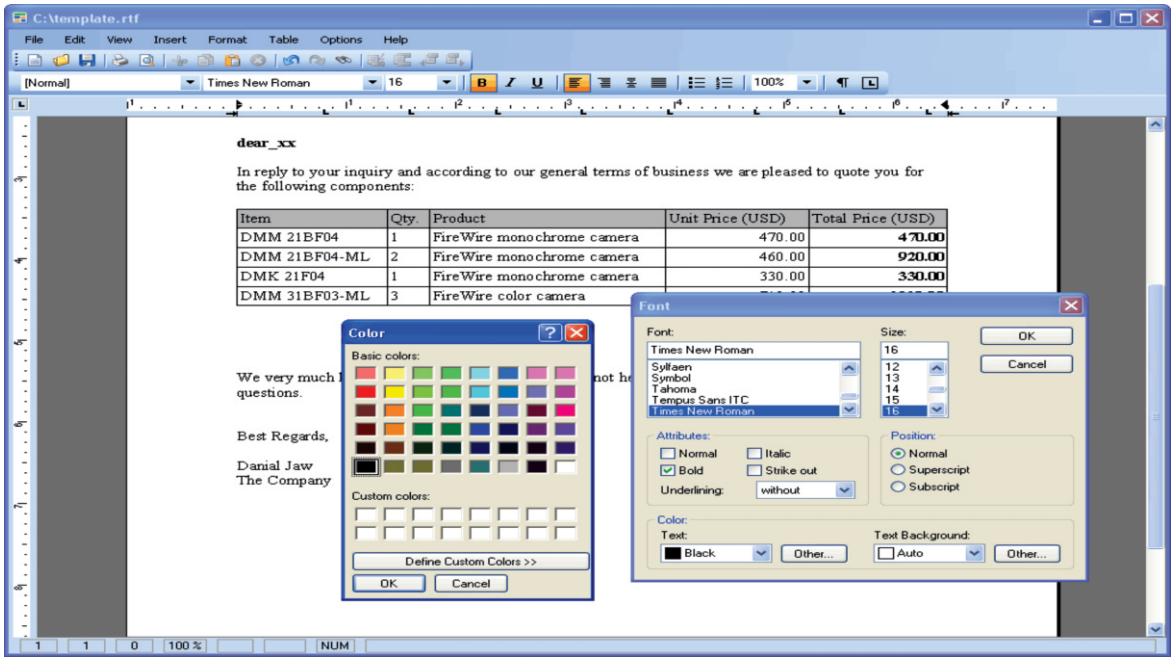
### WORD PROCESSING

Word processing is such a use of computer through which we can write a letter, article, book or prepare a report. Word processing is a computer program. Using this program we can develop any document, see it on the screen after typing. We can edit the document, add some new text or delete the previous text or make amendments in it. We can move text from one page to another, even from one document to another. Document can be stored in memory and its print can also be taken. By means of modern word processing, we can write it in different styles and in different colours. We can also use graphics.

Some other features of word processing are shown below in the icon of word processing:

**Do you know?**

If the CD is made of metal or glass, it is called hard disk and if it is made of soft elastic material then it is called floppy.



### DATA MANAGEMENT – MONITORING AND CONTROL

To collect all information regarding a subject for any purpose and to store them in the computer in more than one inter linked files which may help when needed, is called 'data managing'.

The educational institutions, libraries, hospitals and industries store the concerned information by data management. Additions and deletions are made in the data according to the requirement, which help in the improvement of the management of the institutions.

In big departmental stores and super markets, optical scanners are used to read, with the help of a Laser Beam, the barcodes of a product which indicate the number at which this product is recorded in the register (Fig.17.20). In this way, the detail about its price is obtained. The central computer monitors the bills and the related record of the sold goods. It also helps placing the order of goods being sold in a large quantity and to decide about less selling goods.

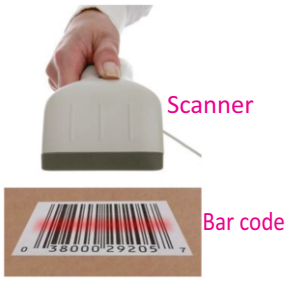



**Fig. 17.20:** Bar code scanning

**Electronic Banking**

Now-a-days, home banking is operating on telephones. We can find our bank balance from the bank on phone, can pay all kinds of bills and transfer our funds by pressing a key of our personal identification number. The bank computer, after our identification, sends us all required information. With the help of ATM machines, we can draw money at any time we want.

## 17.9 INTERNET

When many computer networks of the world were connected together, with the objective of communicating with each other, Internet was formed. In other words, we can say that Internet is a network of networks, which spreads all across the globe. Initially, the size of Internet was small. Soon, people became aware of its utility and advantages and within short span of time, numerous computers and networks got themselves connected to Internet. Its size has increased multi folds within few years. Today Internet comprises of several million computers. There is hardly any country of the world and important city of the country, where Internet is not available.

A conceptual diagram of Internet is illustrated in Fig.17.21. Internet is basically a large computers network, which extends all across the globe. In Internet, millions of computers remain connected together through well-laid communication system.


**Fig. 17.21:** Schematic diagram of Internet

Recall that telephone communication system is well-defined, time proven system. Internet makes use of this system and many other systems to connect all the computers. Thus like a telephone connection, any computer of any city can establish a connection with any other computer of any other city and exchange data or messages with it.

## INTERNET SERVICES

The main services used on the internet include:

- Web browsing - this function allows users to view web pages.
- E-mail - Allows people to send and receive text messages.

**Interesting information**

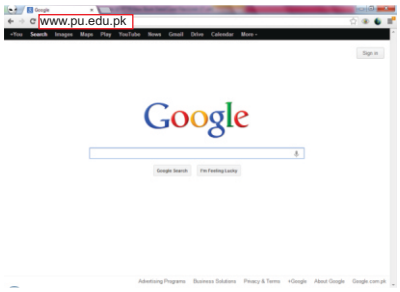
Internet is a global web of more than several million nets in which more than 50 million computers are operating and several millions people participate through the world. The number is increasing day by day. Contact can be made at anytime during the day or night on internet.

## BROWSERS

A browser is an application which provides a window to the Web. All browsers are designed to display the pages of information located at Web sites around the world. The most popular browsers on the market today include Internet Explorer, The World, Opera, Safari, Mozilla Firefox, Chrome, etc. (Fig. 17.22).


**Fig.17.22:** Icons of different web browsers

We can search anything through search engine like Google Chrome, Internet Explorer, Mozilla Firfox, etc.




Google Chrome Search Engine


Desired Web

## Electronic Mail

One of the most widely used application of internet is electronic mail (or e-mail), which provides very fast delivery

of messages to any enabled site on the Internet. Communication through e-mail is more quick and reliable. Through our e-mail, we can communicate with our friends and institution with more ease and pace. Some advantages of e-mail are as follows:

**Fast Communication–** We can send messages anywhere in the world instantly.

**Cost Free Service–** If we have an internet access, then we can avail the e-mail service free of cost.

**Simple to Use-** After initial set up of e-mail account, it is easy to use.

**More Efficient–** We can send our message to many friends or people only in one action.

**Versatile-** Pictures or other files can also be sent through e-mail.

Internet has proved to be very beneficial to us. Here is the list of use of internet.

**i. Faster Communication** **ii. Big Source of Information**
**iii. Source of Entertainment** **iv. Access to Social Media**
**v. Access to Online Services** **vi. E-commerce**
**vii. E-Learning**

Yahoo mail icon

**For your information**

Access of internet to people is increasing day by day. Internet is a useful source of information and knowledge. With broadband you can download information in seconds. E-mail transmits and receives your messages almost instantaneously. . You can talk to your friends and relatives across the continents. A web-cam enables us to hear and see the person you are speaking to.

## 17.20 Risks of ICT to Society and the Environment

In this modern age, we are expected to rely upon information technology. But blind faith in modern technology may be dangerous in many cases.

Over use of computer is dangerous for our health. Computer crimes are also very common these days. Computer crime is defined as any crime accomplished through knowledge or use of computer technology.

There is also a word theft. Theft is the most common form of crime. Computers are used to steal money, goods, information and computer resources.

Piracy is another issue of importance which is common on computer. it is the illegal duplication of copyright material like books, papers and software etc.

Hacking is still another illegal activity which is committed on computers. It is an unauthorized access to computer systems of other persons. Computers hackers can damage some organizations by stealing their credit cards and valuable

**For your information**

E-commerce is the way of doing business on the web. We can order our favourite book or any other items on line. For instance, Amazon.com has been selling books, music and video successfully for years. As time passes on, supermarkets and trading companies will be selling more of their goods on line.

information.

One way to reduce the risk of security breaches is to make sure that only authorized person have access to computer equipment. We may be granted access to computer based on some passwords as described below:

We can use a key, an ID card with photo, an ID number, a lock combination, our voice print or finger print as password to secure our computer.

**Point to ponder!**


What is the impact of ICT in education?

## SUMMARY

- The scientific method used to store information, to arrange it for proper use and to communicate it to others is called information technology.
- The methods and means that are used to communicate information to distant places instantly is called telecommunication.
- Information and Communication Technology (ICT) is defined as the scientific methods and means to store, process and transmit vast amounts of information in seconds with the help of electronic equipment.
- Flow of information means the transfer of the information from one place to another through different electronic and optical equipments.
- In telephone, information can be sent through wires in the form of electrical signals. In radio, television and cell phone information can be sent either through space in the form of electromagnetic waves or it can be sent through optical fibres in the form of light signals.
- There are five parts that must come together in order to produce a Computer-Based Information System (CBIS). These are called the components of information technology. These are: hardware, software, data, procedures and people.
- Information storing devices store the information for later use and benefits. These include audio cassettes, video tapes, compact discs, laser disks, floppy disks, and hard disks.
- Telephone changes sound into electrical signals and sends these signals to the receiver. The receiver changes the electrical signals again to sound by a system fitted in the receiver.
- Mobile phone is a sort of radio with two-way communication. It sends and receives the message in the form of radiowaves.
- Fax machine is the means to send the copy of documents from one place to another through telephone lines.

- Radio is an instrument which transmits the sound waves to us.
- Computer is an electronic computing machine that is used for adding, subtracting and multiplying.
- Hardware refers to the parts of a computer that we can see and touch i.e., key board, monitor, printer, scanner, mouse, etc.
- The most important piece of hardware is the central processing unit (CPU). It is the "brain" of computer—the part that translates instructions and performs arithmetic calculations.
- Software refers to the instructions, or programs, that are installed in the hardware to perform different tasks. Window and Linux Operating Systems (OS) are examples of softwares.
- Word processing is such a use of computer through which we can write a letter, prepare reports and books. By means of this, we can develop any document and see it on the screen after typing.
- To collect information for a special purpose and to store it in a computer in a file form, which may help at times when needed, is called data managing.
- Internet is a network of large number of computers which is major source of information and world communication.

## MULTIPLE CHOICE QUESTIONS

**Choose the correct answer from the following choices:**

i. In computer terminology information means
   (a) any data (b) raw data
   (c) processed data (d) large data

ii. Which is the most suitable means of reliable continuous communication between an orbiting satellite and Earth?
   (a) microwaves (b) radiowaves
   (c) sound waves (d) any light wave

iii. The basic operations performed by a computer are
   (a) arithmetic operations (b) non-arithmetic operations
   (c) logical operations (d) both (a) and (c)

iv. The brain of any computer system is
   (a) monitor (b) memory
   (c) CPU (d) control unit

v. Which of the following is not processing?
   (a) arranging (b) manipulating
   (c) calculating (d) gathering

vi. From which of the following we can get information almost about everything.
(a) book (b) teacher
(c) computer (d) internet

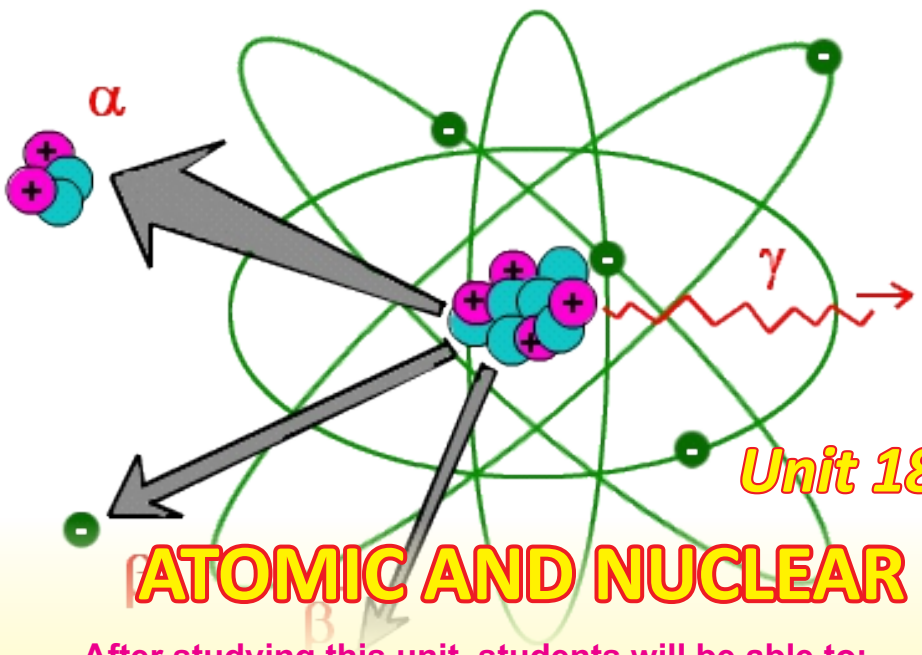
vii. What does the term e-mail stand for?
(a) emergency mail (b) electronic mail
(c) extra mail (d) external mail

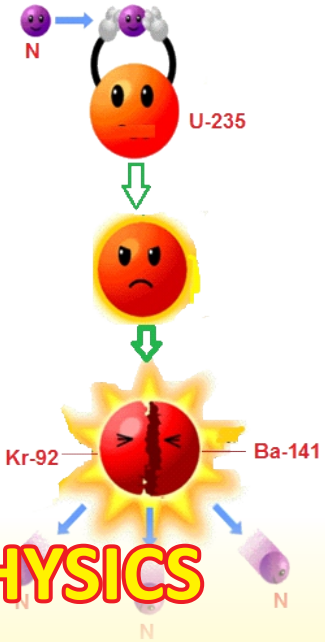
## REVIEW QUESTIONS

17.1. What is difference between data and information?
17.2. What do you understand by Information and Communication Technology (ICT)?
17.3. What are the components of information technology? Clearly indicate the function of each component.
17.4. Differentiate between the primary memory and the secondary memory.
17.5. Name different information storage devices and describe their uses.
17.6. Explain briefly the transmission of radiowaves through space.
17.7. How light signals are sent through optical fibre?
17.8. What is computer? What is the role of computer in everyday life?
17.9. What is the difference between hardware and software? Name different softwares.
17.10. What do you understand by the term word processing and data managing?
17.11. What is Internet? Internet is a useful source of knowledge and information. Discuss.
17.12. Discuss the role of information technology in school education.

## CONCEPTUAL QUESTIONS

17.1. Why optical fibre is more useful tool for the communication process?
17.2. Which is more reliable floppy disk or a hard disk?
17.3. What is the difference between RAM and ROM memories?




Unit 18

# ATOMIC AND NUCLEAR PHYSICS

## After studying this unit, students will be able to:

- describe the structure of an atom in terms of a nucleus and electrons.
- describe the composition of the nucleus in terms of protons and neutrons.
- explain that number of protons in a nucleus distinguishes one element from the other.
- represent various nuclides by using the symbol of proton number *Z*, nucleon number *A* and the nuclide notation *X*.
- explain that some nuclei are unstable, give out radiation to get rid of excess energy and are said to be radioactive.
- describe that the three types of radiation are $\alpha$, $\beta$ & $\gamma$.
- state, for radioactive emissions:
  - their nature
  - their relative ionizing effects
  - their relative penetrating abilities
- explain that an element may change into another element when radioactivity occurs.
- represent changes in the composition of the nucleus by symbolic equations when alpha or beta particles are emitted.
- describe that radioactive emissions occur randomly over space and time.
- explain the meaning of hal-life of a radioactive material.
- describe what are radioisotopes. What makes them useful for various applications?
- describe briefly the processes of fission and fusion.
- show an awareness of the existence of background radiation and its sources.
- describe the process of carbon dating to estimate the age of ancient objects.
- describe hazards of radioactive materials.

## Science, Technology and Society Connections

**The students will be able to:**

- describe how radioactive materials are handled, used, stored and disposed of, in a safe way.
- make a list of some applications of radioisotopes in medical, agriculture and industrial fields.
- make estimation of age of ancient objects by the process of carbon dating.

Scientists were always interested to know the smallest particle of matter. Greek Philosopher Democritus in 585 BC postulated that matter is built from small particles called atoms. The atom means indivisible in Greek language. Rutherford in 1911, discovered that atom had a central part called the nucleus. In this unit, we will describe different aspects of atomic and nuclear physics such as radioactivity, half-life, nuclear reactions, fission and fusion.

**For your information**

The word atom is derived from the Greek word "otomos", meaning "indivisible." At one time, atoms were thought to be the smallest particles of matter. Today we know that atoms are composite systems and contain even smaller particles: protons, neutrons and electrons.

## 18.1 ATOM AND ATOMIC NUCLEUS

Rutherford discovered that the positive charge in an atom was concentrated in a small region called nucleus. The nucleus contains protons and neutrons which are collectively called nucleons. Atom also contains electrons which revolve in nearly circular orbits about the positively charged nucleus (Fig. 18.1). The simplest atom is that of hydrogen, nucleus of which is a single proton. We describe an element with respect to its nucleus and use the following quantities:

The **atomic number** $Z$ is equal to the number of protons in the nucleus.

The **neutron number** $N$ is equal to the number of neutrons in the nucleus.

The **atomic mass number** $A$ is equal to the number of nucleons (protons + neutrons) in the nucleus i.e., $A = Z + N$.

The mass of neutron is nearly equal to that of proton. But proton is about 1836 times heavier than an electron. So the mass of an atom is nearly equal to the sum of masses of protons and neutrons.

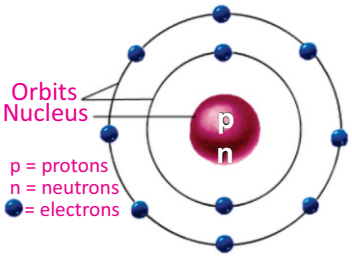



**Fig.18.1:** The nucleus of an atom consists of protons and neutrons

Generally, an atom is represented by the symbol ${}^{A}_{Z}X$. For example, nuclide of hydrogen atom having only one proton is ${}^{1}_{1}H$.

**Example 18.1:** Find the number of protons and neutrons in the nuclide defined by ${}^{13}_{6}X$.

**Solution:** From the symbol, we have

Atomic number $Z$ = number of protons = 6

Atomic mass $A$ = number of protons + number of neutrons = 13
But number of protons are 6, so number of neutrons will be 7.
So the element is an isotope of carbon-6, and is written as ${}^{13}_{6}C$.

### ISOTOPES

Isotopes are atoms of an element which have same number of protons but different number of neutrons in their nuclie. Three isotopes of Hydrogen are shown in Fig.18.2. Protium (${}^{1}_{1}H$) contains one proton in the nucleus and one electron that revolves round the nucleus. Deuterium (${}^{2}_{1}H$) contains one proton, one neutron and one electron. Tritium (${}^{3}_{1}H$) contains one proton, two neutrons and one electron.

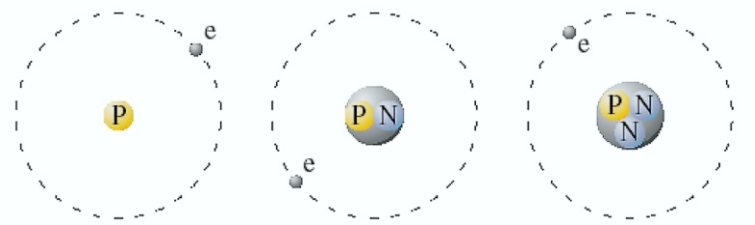
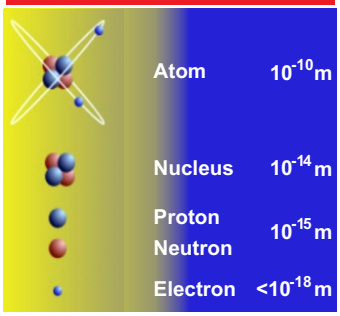



**Fig.18.2:** Three isotopes of hydrogen Protium (${}^{1}_{1}H$), Deutrium (${}^{2}_{1}H$) and Tritium (${}^{3}_{1}H$).

**For your information**




Size of atom and its constituents.

## 18.2 NATURAL RADIOACTIVITY

In 1896, Becquerel accidentally discovered that uranium salt crystals emit an invisible radiation that can darken a photographic plate. He also observed that the radiation had the ability to ionize a gas. Subsequent experiments by other scientists showed that other substances also emited radiations. The most significant investigations of this type were conducted by Marie Curie and her husband Pierre. They discovered two new elements which emitted radiations. These were named polonium and radium. This process of emission of radiations by some elements was called natural radioactivity by Marie Curie.
Subsequent experiments performed by Henrey Becquerel suggested that radioactivity was the result of the decay or disintegration of unstable nuclei.

*The spontaneous emission of radiation by unstable nuclei is called natural radioactivity. And the elements which emit such radiations are called radioactive elements.*

Three types of radiation are usually emitted by a radioactive

**Do you know?**

The positively charged protons in a nucleus have huge electrical forces of repulsion between them. Why do not they fly apart in response to this force? Because there is an attractive force between the nucleons called the strong force. This force acts over only a very short distance. Without this strong nuclear force, there would be no atoms beyond hydrogen.

substance. They are: alpha ($\alpha$) particles; beta ($\beta$) particles; and gamma ($\gamma$) rays. These three forms of radiations were studied by using the scheme shown in Fig. 18.3. The radioactive source is placed inside the magnetic field. The radiation emitted from the source splits into three components: $\alpha$ and $\beta$-radiations bend in opposite direction in the magnetic field while $\gamma$-radiation does not change its direction.

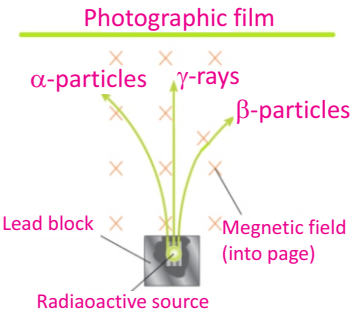



**Fig.18.3:** Three types of radiations can be distinguished from their path followed in an external magnetic field

## 18.3 BACKGROUND RADIATIONS

Radiations present in atmosphere due to different radioactive substances are called background radiations (Fig.18.4). Everywhere in rocks, soil, water, and air of our planet are traces of radioactive elements. This natural radiation is called the background radiation. It is as much part of our environment as sunshine and rain. Fortunately, our bodies can tolerate it. Only places where radiation is very high can be injurious to health.

The Earth, and all living things on it also receive radiation from outer space. This radiation is called cosmic radiation which primarily consists of protons, electrons, alpha particles and larger nuclei. The cosmic radiation interacts with atoms in the atmosphere to create a shower of secondary radiation, including X-rays, muons, protons, alpha particles, electrons, and neutrons.

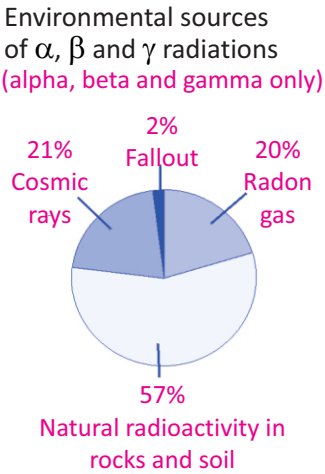



**Fig.18.4:** The sources of background radiation from the environment

## 18.4 NUCLEAR TRANSMUTATIONS

We know that during natural radioactivity, an unstable nucleus of radioactive element disintegrates to become more stable.

*The spontaneous process in which a parent unstable nuclide changes into a more stable daughter nuclide with the emission of radiations is called nuclear transmutation*

Now we represent radioactive decay by means of a nuclear equation in which an unstable parent nuclide *X* changes into a daughter nuclide *Y* with the emission of an alpha particle, beta particle or gamma particle.

### 1. Alpha ($\alpha$)-decay

**General Equation:**

$$^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He + \text{Energy}$$

parent nuclide — daughter nuclide — $\alpha$-particle

**Example:** $^{226}_{88}Ra \longrightarrow {}^{222}_{86}Rn + {}^{4}_{2}He + \text{Energy}$

radium — radon — $\alpha$-particle

It means in alpha decay, the proton number or atomic number $Z$ of the parent nuclide reduces by 2 and its mass number or nucleon number $A$ decreases by 4.

**For your information**

The SI unit for radioactivity is the becquerel, Bq. In SI base units, 1 Bq = 1disintegration per second (dps). This is a very small unit. For example, 1.0 g of radium has an activity of 3.7 3 × $10^{10}$ Bq. Therefore, the kilobecquerel (kBq) and the megabecquerel (MBq) are commonly used. The activity of 1.0 g of radium is 3.73×$10^{4}$MBq.

### 2. Beta ($\beta$)-decay

**General Equation:**

$$^{A}_{Z}Z \longrightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}e + \text{Energy}$$

parent nuclide — daughter nuclide — $\beta$-particle

**Example:** $^{14}_{6}C \longrightarrow {}^{14}_{6}N + {}^{0}_{-1}e + \text{Energy}$

carbon — nitrogen — $\beta$-particle

In beta ($\beta$)-decay , the parent nuclide has its proton number $Z$ increased by 1 but its mass number or nucleon number $A$ remains unchanged.

### 3. Gamma ($\gamma$)-decay

**General Equation:**

$$^{A}_{Z}X^{\star} \longrightarrow {}^{Z}_{6}X + \gamma$$

parent nuclide — daughter nuclide — gamma rays

**Example:** $^{60}_{27}Co^{\star} \longrightarrow {}^{60}_{27}Co + {}^{0}_{0}\gamma + \text{Energy}$

cobalt — cobalt — $\gamma$-rays

Gamma rays are usually emitted alongwith either an alpha or a beta particle.

**Physics Insight**

when alpha and beta particles are slowed down by collisions, they become harmless. in fact, they combine to form neutral helium atoms.

### Nature and Properties of Radiations

Alpha particle is a helium nucleus comprising of two protons and two neutrons with a charge of 2e. An unstable nucleus with large protons and neutrons may decay by emitting alpha radiations. . Beta radiation is a stream of high-energy electrons. An unstable nuclei with excess of neutrons may eject beta radiations. Gamma radiations are fast moving light

photons. They are electromagnetic radiations of very high frequency (short wavelength) emitted by the unstable excited nuclie.

### Ionizing Effect

The phenomenon by which radiations split matter into positive and negative ions is called ionization. All three kinds of radiations i.e., alpha, beta and gamma can ionize the matter. However, alpha particles have the greatest power of ionization as compared to beta particles and gamma rays. It is due to large positive charge and large mass of alpha particles. Beta particles ionize a gas much less than alpha particles. The ionization power of gamma rays is even less than that of beta particles. Ionization of three radiations in a gas is shown in Fig. 18.5.

### Penetrating Ability

The strength of radiations to penetrate a certain material is called penetrating power. The alpha particle has the shortest range because of its strong interacting or ionizing power. The gamma rays can penetrate a considerable thickness of concrete. It is due to their large speed and neutral nature.

The beta radiation strongly interacts with matter due to its charge and has a short range as compared to gamma radiations. Fig. 18.6 shows the relative penetrating abilities of three kinds of radiations.

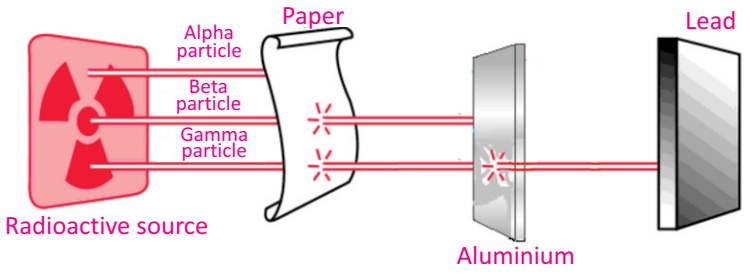



**Fig.18.6:** Penetrating power of radiations in different materials

Alpha particle has a range of only a few centimetres in air. Beta particles have range of several metres in air. However, gamma rays have a range of several hundreds metres in air.

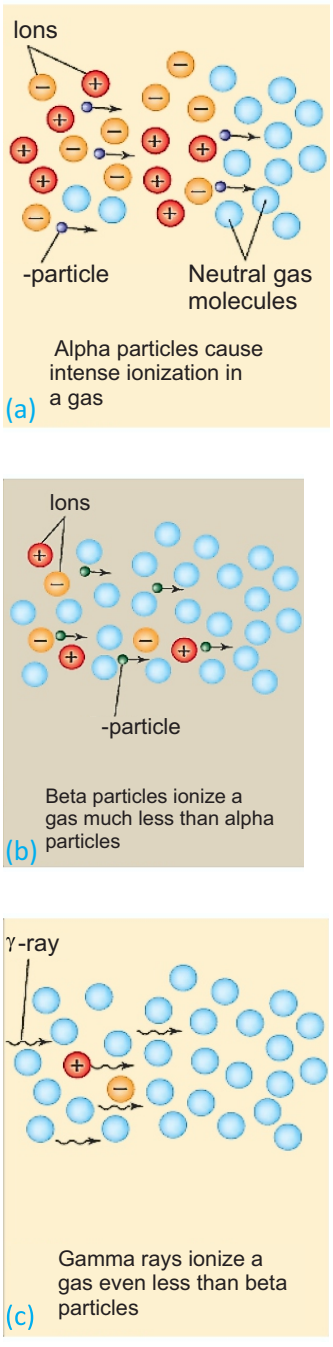



**Fig. 18.5:** Ionization effect of radiations in a gas

## 18.5 HALF-LIFE AND ITS MEASUREMENT

Process of radioactivity is random and the rate of radioactive decay is proportional to the number of unstable nuclei present. In the process, a constant fraction of large number of unstable radioactive nuclei decays in a certain time. So the life time of the unstable nuclei is unlimited and is difficult to measure. We can get the idea about decay rate by the term half-life.

| Remember | | |
|---|---|---|
| Three types of Radiations | | |
| **Alpha Particle** | **Beta Particle** | **Gamma Ray** |
| Charge +2 | Charge – 1 | No charge |
| Least penetration | Moderate penetration | Highest penetration |
| Transmutes nucleus:<br>$A \rightarrow A - 4$<br>$Z \rightarrow Z - 2$<br>$N \rightarrow N - 2$ | Transmutes nucleus:<br>$A \rightarrow A$<br>$Z \rightarrow Z + 1$<br>$N \rightarrow N - 1$ | Changes only energy<br>$A \rightarrow A$<br>$Z \rightarrow Z$<br>$N \rightarrow N$ |

### Half-Life

*The time during which half of the unstable radioactive nuclei disintegrate is called the half-life of the sample of radioactive element.*

Every radioactive element has its own characteristic half-life. For example, radium-226 has a half-life of 1620 years, which means that half of a radium-226 sample will be converted to other elements by the end of 1620 years (Fig.18.7). In the next 1620 years, half of the remaining radium will decay, leaving only one-fourth the original amount of radium, and so on.

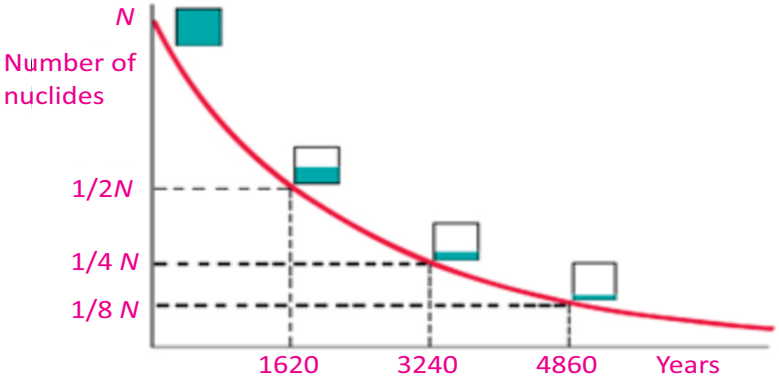



**Fig.18.7:** Radioactivity of radium

**Alpha ($\alpha$) Particles**
Positively charged particles (helium nuclei), ejected at high speed with a range of only a few centimetres in air. They can be stopped by an ordinary sheet of thin aluminium foil.

**Beta ($\beta$) Particles**
Streams of high-energy electrons, ejected at various speeds as high as close to the speed of light. Beta particles may be able to penetrate several millimetres of aluminium.

**Gamma ($\gamma$) Rays**
Electromagnetic radiation of very short wavelenght. Their wavelengths and energies can vary. High-energy gamma rays can penetrate at least 30 cm of lead or 2 km of air.

**For your information**

i. Nuclear radiation is measured in units of roentgen equivalent man (rem), a unit of equivalent dose.
ii. Patient should be exposed to X-rays with the limit of 0.1 to 1.0 rem.
iii. Safe limit of radiation exposure is 5.0 rem per year.

**Physics insight**

A half-life is the time a radioactive element takes for half of a given number of nuclei to decay. During a second half-life, half of the remaining nuclei decay, so in two half-lives, three-quarters of the original material has decayed, not all of it.

If the half-life of the radioactive element is $T_{1/2}$, then at the end of this time the number of atoms in the sample will become half i.e., 1/2. After a time $2T_{1/2}$, i.e., after second half-life period, the number of remaining atoms will become $1/2.1/2 = 1/2^2 = 1/4$, after a time $3\ T_{1/2}$, the number of remaining atoms left will be $1/2.1/2.1/2 = 1/2^3 = 1/8$ , and at the end of '*t*' half lives number of atoms that remain will be $1/2^t$. It means that if $N_o$ is the original number of atoms in the sample of radioactive element, then after '*t*' half-lives number of atoms left in the sample can be determined by using the relation,

$$\text{Remaining atoms} = \text{Original atoms } 1/2^t$$

$$\text{or} \quad N = N_o \times 1/2^t$$

The process of radioactivity does not depend upon the chemical combinations or reactions. It is also not affected by any change in physical conditions like temperature, pressure, electric or magnetic fields.

**Example 18.2:** The activity of a sample of a radioactive bismuth decreases to one-eight of its original activity in 15 days. Calculate the half-life of the sample.

**Solution:** Let $T_{½}$ is the half-life and $A_o$ is the original activity of the sample. After time $T_{½}$ activity will be $A_o/2$. After $2T_{½}$ activity will become $1/2.\ A_o/2 = A_o/4$. While after time $3T_{½}$, i.e., after three half-lives, the activity will drop to $A_o/8$. It means activity drops to one-eighth of original activity in a time of $3T_{½}$.

Therefore, $3T_{½} = 15$. This means half-life $T_{½}$ of the sample will be 5 days.

**Example 18.3:** A radioactive element has a half-life of 40 minutes. The initial count rate was 1000 per minute. How long will it take for the count rate to drop to (a) 250 per minutes (b) 125 per minutes (c) Plot a graph of the radioactive decay of the element.

**Solution:** The initial count rate is 1000, therefore,

$$1000 \xrightarrow{40\ \text{min.}} 500 \xrightarrow{40\ \text{min.}} 250 \xrightarrow{40\ \text{min.}} 125$$

(a) As clear from above, it takes 2 half-lives for the count rate

**Be careful !**

International symbol that indicates an area where radioactive material is being handled or produced.

**Radiation Treatment**

Gamma radiations destroy both cancerous cells and healthy cells. Therefore, the beam of radiation must be directed only at cancerous cells.

to decrease from 1000 to 250 per min, hence

Time taken = 2 × 40 min. = 80 min.

(b) It takes 3 half-lives for the count rate to decrease from 1000 to 125 per min, hence

Time taken = 3 × 40 min. = 120 min = 2 h

(c) Graph is shown in Fig 18.8.

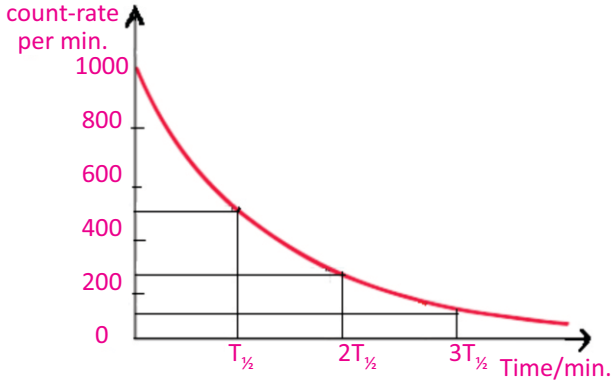



Fig. 18.8: Decay of unstable element

**For your information**

During brain radiotherapy, patient is carefully positioned in the helmet to ensure that the *gamma* rays converge at the desired point in the brain. A lead apron protects the body from exposure to radiation.

## 18.6 RADIOISOTOPES AND THEIR USES

Nuclei which do not emit radiations naturally are called stable nuclei. In general, most of the nuclei with atomic number 1 to 82 are stable nuclei. While the elements whose atomic number is greater than 82 are naturally unstable. They emit different types of radiations, all the time, and hence continuously change from one type of element to another.

The stable and non-radioactive elements can also be changed into radioactive elements by bombarding them with protons, neutrons or alpha particles. Such artificially produced radioactive elements are called radioactive isotopes or radioisotopes. Here are some examples of the production of radioisotopes:

1. $^{1}_{0}n$ + $^{23}_{11}Na$ ⟶ $^{24}_{11}Na$ + gamma ($\gamma$)-rays

neutron — stable sodium nuclide — a sodium radioisotope

2. $^{4}_{2}He$ + $^{27}_{13}Al$ ⟶ $^{30}_{15}P$ + $^{1}_{0}n$

alpha particle — stable aluminium nuclide — a phosphorous radioisotope

## Uses of Radioisotopes

Radioisotopes are frequently used in medicine, industry and agriculture for variety of useful purposes. Following are few applications of radioisotopes in different fields.

### 1. Tracers

Radioactive tracers are chemical compounds containing some quantity of radioisotope. They can be used to explore the metabolism of chemical reactions inside the human body, animals or plants. Radioisotopes are used as tracers in medicine, industry and agriculture. For example, radio iodine-131 readily accumulates in the thyroid gland and can be used for the monitoring of thyroid functioning. For the diagnosis of brain tumor phosphorous-32 is used. The malignant part of the body absorbs more quantity of isotopes, and this helps in tracing the affected part of the body.

In industry tracers can be used to locate the wear and tear of the moving parts of the machinery. They can be used for the location of leaks in underground pipes. By introducing a suitable radioactive tracer into the pipe, the leak can be conveniently traced from higher activity in the region of crack in the pipe.

In agriculture, radio phosphorous-32 is used as a tracer to find out how well the plants are absorbing the phosphate fertilizer which are crucial to their growth (Fig.18.9).

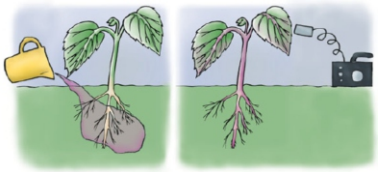


**Fig.18.9:** To check the action of a fertilizer, researchers combine a small amount of radioactive material with the fertilizer and then apply the combination to a few plants. The amount of radioactive fertilizer taken up by the plants can be easily measured with radiation detectors.

### 2. Medical Treatment

Radioisotopes are also used in nuclear medicines for curing various diseases. For example, radioactive cobalt-60 is used for curing cancerous tumors and cells. The radiations kill the cells of the malignant tumor in the patient.

### 3. Carbon Dating

Radioactive carbon-14 is present in small amount in the atmosphere. Live plants use carbon dioxide and therefore become slightly radioactive (Fig. 18.10).

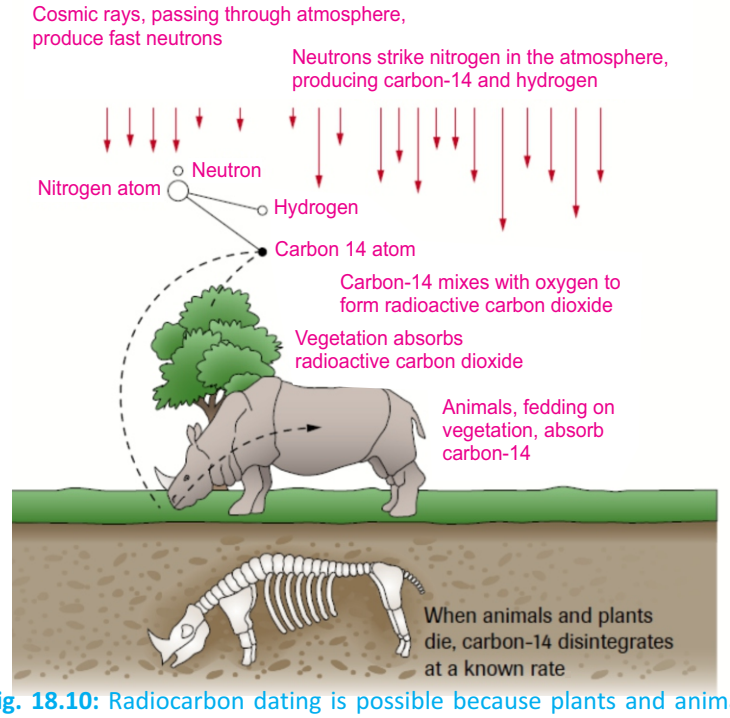



**Fig. 18.10:** Radiocarbon dating is possible because plants and animals absorb radioactive carbon-14 through their intake of $Co_2$

When a tree dies, the radio carbon-14 present inside the plant starts decaying. Since the half-life of carbon-14 is 5730 years, the age of a dead tree can be calculated by comparing the activity of carbon-14 in the live and dead tree. The activity of the live tree remains almost constant as the carbon-14 is being replenished while the carbon-14 in the dead tree is no more replenished. Therefore, by measuring the activity in the ancient relic, scientists can estimate its age.

Other radioisotopes are also used to estimate the age of geological specimens. For example, some rocks contain the unstable potassium isotope *K*-40. This decays to the stable argon nuclide *Ar*-40 with half-life of $2.4 \times 10^8$ years. The age of rock sample can be estimated by comparing the concentrations of *K*-40 and *Ar*-40.

**Example 18.4:** The *C*-14: *C*-12 ratio in a fossil bone is found to be $1/4^{th}$ that of the ratio in the bone of a living animal. The half- life of *C*-14 is 5730 years what is the approximate age of the fossil?

**Solution:** Since the ratio has been reduced by factor of 4 therefore, two half-lives have passed.

Therefore age of the fossil is given by: 2 x 5730 = 11460 years

## 18.7 FISSION REACTION

Nuclear fission takes place when a heavy nucleus, such as *U*-235, splits, or fissions, into two smaller nuclei by absorbing a slow moving (low-energy) neutron (Fig. 18.11) as represented by the equation:

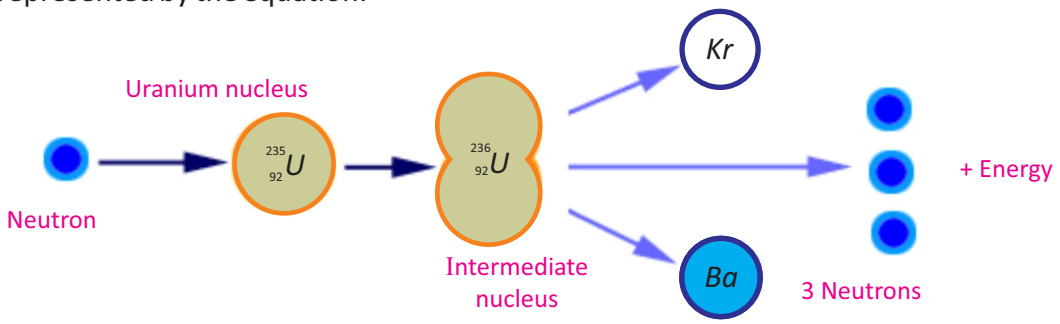



Fig. 18.11: Nuclear fission reaction

$$^{1}_{0}n + {}^{235}_{92}U \longrightarrow {}^{236}_{92}U^{*} \longrightarrow X + Y + neutron$$

where *U**-236 is an intermediate state that lasts only for a fraction of second before splitting into nuclei *X* and *Y*, called **fission fragments**. Nuclear fission was first observed in 1939 by Otto Hahn and Fritz Strassman. The uranium nucleus was split into two nearly equal fragments after absorbing a slow moving (low-energy) neutron. The process also resulted in the production of typically two or three neutrons per fission event. On the average, 2.47 neutrons are released per event as represented by the expression

$$^{1}_{0}n + {}^{235}_{92}U \longrightarrow {}^{141}_{56}Ba \longrightarrow {}^{92}_{36}Kr + 3\,{}^{1}_{0}n$$

In nuclear fission, the total mass of the products is less than the original mass of the heavy nucleus. Measurements showed that about 200 MeV of energy is released in each fission event. This is a large amount of energy relative to the amount released in chemical processes. For example, If we burn 1 tonne of coal, then about $3.6 \times 10^{10}$ J of energy is released. But, during the fission of 1 kg of Uranium-235 about $6.7 \times 10^{11}$ J of energy is released.

We have seen that neutrons are emitted when *U*-235 undergoes fission. These neutrons can in turn trigger other nuclei to undergo fission with the possibility of a chain reaction (Fig.18.12). Calculations show that if the chain

**For your information**

Electron volt is also a unit of energy used in atomic and nearly physics:

$1eV = 1.6 \times 10^{-19}$ J

reaction is not controlled, it will proceed too rapidly and possibly results in the sudden release of an enormous amount of energy (an explosion).

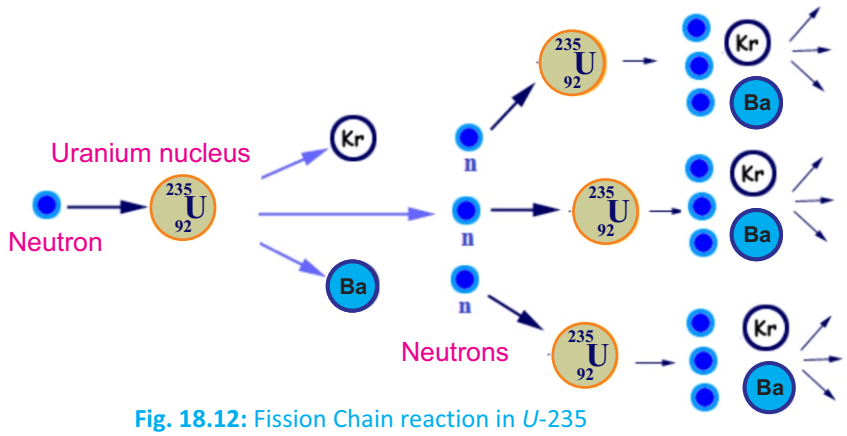



**Fig. 18.12:** Fission Chain reaction in *U*-235

This fission chain reaction is controlled in nuclear reactors. A nuclear reactor provides energy for useful purposes. In this sort of self sustained reaction, extra neutrons liberated in fission reactions are absorbed using some material to slow down the chain reaction.

## Half-lives of Selected Isotopes

| Element | Isotope | Half-Life | Radiation Produced |
|---|---|---|---|
| Hydrogen | ${}^{1}_{0}H$ | 12.3 years | β |
| Carbon | ${}^{14}_{6}C$ | 5730 years | β |
| Cobalt | ${}^{14}_{6}Co$ | 30 years | β, γ |
| Lodine | ${}^{131}_{53}I$ | 8.07 days | β, γ |
| Lead | ${}^{212}_{82}Pb$ | 10.6 hours | β |
| Polonium | ${}^{194}_{84}Po$ | 0.7 seconds | α |
| Polonium | ${}^{210}_{84}Po$ | 138 days | α, γ |
| Uranium | ${}^{235}_{92}U$ | $7.1 \times 10^{8}$ years | α, γ |
| Uranium | ${}^{238}_{92}U$ | $4.51 \times 10^{9}$ years | α, γ |
| Plutonium | ${}^{236}_{94}Pu$ | 2.85 years | α |
| Plutonium | ${}^{242}_{94}Pu$ | $3.79 \times 10^{5}$ years | α, γ |

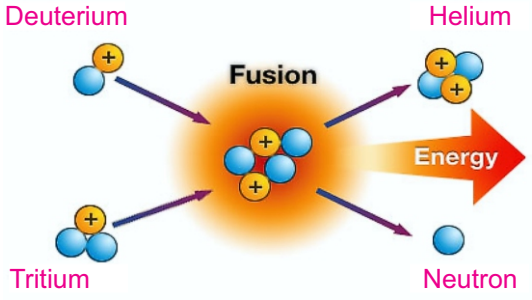
## 18.8 NUCLEAR FUSION

***When two light nuclei combine to form a heavier nucleus, the process is called nuclear fusion.***

The mass of the final nucleus is always less than the masses of the original nuclei. According to mass-energy relation this loss of mass converts into energy. If an atom of Deuterium is fused with an atom of Tritium, then a Helium nucleus or alpha particle is formed as given by

$$ {}_{1}^{2}H + {}_{1}^{3}H \longrightarrow {}_{2}^{4}He + {}_{0}^{1}n + energy $$

Pictorally fusion reaction is shown in the following figure:




Energy coming from the Sun and stars is supposed to be the result of fusion of hydrogen nuclei into Helium nucleus with release of energy. The temperature at the centre of the Sun is nearly 20 million kelvin which makes the fusion favourable. According to this reaction, four hydrogen nuclei fuse together to form a helium nucleus alongwith 25.7 MeV of energy.

## 18.9 HAZARDS OF RADIATIONS AND SAFETY MEASURES

Although, radiations are very useful in medicine, agriculture and industry, they can also cause considerable damage if not used with precautions. Radioactive, nuclear materials are now widely used in nuclear power plants, nuclear-powered submarines, intercontinental ballistic missiles etc. Some of the harmful effects on human beings due to large doses or prolonged small doses of radiations are:

1. Radiation burns, mainly due to beta and gamma radiations, which may cause redness and sores on the skin.
2. Sterility ( i.e., inability to produce children).

3. Genetic mutations in both human and plants. Some children are born with serious deformities.
4. Leukemia (cancer of the blood cells).
5. Blindness or formation of cataract in the eye.

During the nuclear accident at Chernobyl, Russia, the explosion of the nuclear reactors melted through a few metres thick concrete housing. This caused a massive destruction of local community and also contaminated vegetation and livestock in the large surrounding area. Millions of dollars were lost as the contaminated vegetable and livestock had to be destroyed.

Because we cannot detect radiations directly, we should strictly follow safety precautions, even when the radioactive sources are very weak.

1. The sources should only be handled with tongs and forceps.
2. The user should use rubber gloves and hands should be washed carefully after the experiment.
3. All radioactive sources should be stored in thick lead containers.
4. Never point a radioactive source towards a person.
5. Frequent visits to the radiation sensitive areas should be avoided.

## SUMMARY

- There are two parts of an atom. Its central part is called the nucleus which contains neutrons and protons called nucleons. The nucleus is positively charged and electrons revolve around it in nearly circular orbits.
- The number of protons present inside a nucleus is called the charge number or the atomic number and is denoted by the letter *Z*.
- The sum of neutrons and protons present in a nucleus is called its atomic mass number. It is denoted by the letter *A*.
- The atoms of same element with same atomic number but different atomic mass number are called isotopes.
- The elements whose atomic number is greater than 82 are unstable. The process of decaying such elements into daughter elements is called natural radioactivity and such elements are called radioactive elements.
- Radioactivity is a random process which does not depend on space and time.

- The time during which the atoms of a radioactive element are reduced to one half is called the half-life of that element.
- Background radiations are caused by some radioactive elements present in rocks, soil and water.
- A process in which nucleus of an unstable heavy element breaks into two nuclei of lighter elements with the emission of radiation is called nuclear transmutation.
- The isotopes which emit radiations are called radioactive isotopes. They are used in medicine, agriculture and industry for a variety of purposes.
- The age of a dead human, animal or tree can be estimated by comparing the activity of carbon-14 in the live and dead tree. The technique is called carbon dating.
- A process in which a heavy nucleus breaks into two nearly equal parts with the release of large energy is called nuclear fission.
- A process in which two light nuclei diffuse to form a heavier nucleus with release of enormous amount of energy is called fusion reaction.

## MULTIPLE CHOICE QUESTIONS

**Choose the correct answer from the following choices:**

i. Isotopes are atoms of same element with different
   (a) atomic mass (b) atomic number
   (c) number of protons (d) number of electrons

ii. One of the isotopes of uranium is $^{238}_{92}U$. The number of neutrons in this isotope is
   (a) 92 (b) 146
   © 238 (d) 330

iii. Which among the following radiations has more penetrating power?
   (a) a beta particle (b) a gamma ray
   (c) an alpha particle (d) all have the same penetrating ability

iv. What happens to the atomic number of an element which emits one alpha particle?
   (a) increases by 1 (b) stays the same
   (c) decreases by 2 (d) decreases by 1

v. The half-life of a certain isotope is 1 day. What is the quantity of the isotope after 2 days?
   (a) one-half (b) one-quarter
   (c) one-eighth (d) none of these

vi. When Uranium (92 protons) ejects a beta particle, how many protons will be in the remaining nucleus?
   (a) 89 protons (b) 90 protons
   © 91 protons (d) 93 protons

vii. Release of energy by the Sun is due to
(a) nuclear fission (b) nuclear fusion
(c) burning of gases (d) chemical reaction

viii. When a heavy nucleus splits into two lighter nuclei, the process would
(a) release nuclear energy (b) absorb nuclear energy
(c) release chemical energy (d) absorb chemical energy

ix. The reason carbon-dating works is that
(a) plants and animals are such strong emitters of carbon-14
(b) after a plant or animal dies, it stops taking in fresh carbon-14
(c) there is so much non-radioactive carbon dioxide in the air
(d) when plants or animals die. they absorb fresh carbon -14

## REVIEW QUESTIONS

18.1. What is difference between atomic number and atomic mass number? Give a symbolical representation of a nuclide.

18.2. What do you mean by the term radioactivity? Why some elements are radioactive but some are not?

18.3. How can we make radioactive elements artificially? Describe with a suitable example.

18.4. What are the three basic radioactive decay processes and how do they differ from each other?

18.5. Write the alpha decay process for $^{234}_{91}Pa$. Identify the parent and daughter nuclei in this decay.

18.6. Explain whether the atomic number can increase during nuclear decay. Support your answer with an example.

18.7. What do you understand by half-life of a radioactive element?

18.8. Is radioactivity a spontaneous process? Elaborate your answer with a simple experiment.

18.9. What is meant by background radiations? Enlist some sources of background radiations.

18.10. Describe two uses of radioisotopes in medicine, industry or research.

18.11. What are two common radiation hazards? Briefly describe the precautions that are taken against them.

18.12. Complete this nuclear reaction: $^{235}_{92}U \longrightarrow {}^{140}_{54}X + ? + 2\ {}^{1}_{0}n$. Does this reaction involve fission or fusion? Justify your answer.

18.13. Nuclear fusion reaction is more reliable and sustainable source of energy than nuclear fission chain reaction. Justify this statement with plausible arguments.

18.14. A nitrogen nuclide $^{14}_{7}N$ decays to become an oxygen nuclide by emitting an electron. Show this process with an equation.

18.15. Determine which of these radioactive decay processes are possible:

(a) $^{214}_{84}Po \longrightarrow {}^{214}_{84}Po + {}^{4}_{2}He$ (b) $^{230}_{90}Th \longrightarrow {}^{226}_{88}Ra + {}^{4}_{2}He$

(c) $^{233}_{91}Pa \longrightarrow {}^{233}_{92}U + {}^{0}_{-1}\beta$ (d) $^{12}_{6}C \longrightarrow {}^{14}_{7}N + {}^{0}_{-1}\beta$

## CONCEPTUAL QUESTIONS

18.1. Is it possible for an element to have different types of atoms? Explain.

18.2. What nuclear reaction would release more energy, the fission reaction or the fusion reaction? Explain.

18.3. Which has more penetrating power, an alpha particle or a gamma ray photon?

18.4. What is the difference between natural and artificial radioactivity?

18.5. How long would you likely have to wait to watch any sample of radioactive atoms completely decay?

18.6. Which type of natural radioactivity leaves the number of protons and the number of neutrons in the nucleus unchanged?

18.7. How much of a 1 g sample of pure radioactive substance would be left undecayed after four half-lives?

18.8. Tritium, $^{3}_{1}H$ is radioactive isotope of hydrogen. It decays by emitting an electron. What is the daughter nucleus?

18.9. What information about the structure of the nitrogen atom can be obtained from its nuclide $^{14}_{7}N$ ? In what way atom in $^{14}_{7}N$ is different from the atom in $^{16}_{7}N$ ?

## NUMERICAL PROBLEMS

18.1. The half-life of $^{16}_{7}N$ is 7.3 s. A sample of this nuclide of nitrogen is observed for 29.2 s. Calculate the fraction of the original radioactive isotope remaining after this time.

**Ans. (1/16)**

18.2. Cobalt-60 is a radioactive element with half-life of 5.25 years. What fraction of the original sample will be left after 26 years? **Ans. (1/32)**

18.3. Carbon-14 has a half-life of 5730 years. How long will it take for the quantity of carbon-14 in a sample to drop to one-eighth of the initial quantity?

**Ans. ($1.72 \times 10^4$ years)**

18.4. Technetium-99 m is a radioactive element and is used to diagnose brain, thyroid, liver and kidney diseases. This element has half-life of 6 hours. If there is 200 mg of this technetium present, how much will be left in 36 hours. **Ans.(3.12 mg)**

18.5. Half-life of a radioactive element is 10 minutes. If the initial count rate is 368 counts per minute, find the time for which count rates reaches 23 counts per minute.

**Ans. (40 minutes)**

18.6. In an experiment to measure the half-life of a radioactive element, the following results were obtained:

| | | | | | |
|---|---|---|---|---|---|
| Count rate / minute | 400 | 200 | 100 | 50 | 25 |
| Time (in minutes) | 0 | 2 | 4 | 6 | 8 |

Plot a graph between the count rate and time in minutes. Measure the value for the half-life of the element from the graph. **Ans. (half-life is 2 minutes)**

18.7. A sample of certain radioactive element has a half-life of 1500 years. If it has an activity of 32000 counts per hour at the present time, then plot a graph of the activity of this sample over the period in which it will reduce to 1/16 of its present value.

18.8. Half-life of a radioactive element was found to be 4000 years. The count rates per minute for 8 successive hours were found to be 270, 280, 300, 310, 285, 290, 305, 312. What does the variation in count rates show? Plot a graph between the count rates and time in hours. Why the graph is a straight line rather than an exponential?

**Ans. (Variation in count rate shows the random nature of radiactive decay, graph is almost horizontal line rather than exponential curve which is due to long half-life as compared to period of 8 hours)**

18.9. Ashes from a campfire deep in a cave show carbon-14 activity of only one-eighth the activity of fresh wood. How long ago was that campfire made?

**Ans. (17190 years)**

# GLOSSARY

**AMMETER:** An instrument which measures larger current.
**AMPERE:** If one coulomb of charge passes through any cross section in one second, then current will be equal to one ampere.
**AMPLITUDE:** The maximum displacement below or above the mean position of a vibrating body.
**ANALOGUE ELECTRONICS:** The branch of electronics which processes in the form of analogue quantities.
**ANALOGUE QUANTITIES:** Those quantities which change continuously with time or remain constant.
**APERTURE:** The line joining the end points of a spherical mirror.
**ATOMIC MASS NUMBER:** The sum of neutrons and protons present in a nucleus.
**BOOLEAN ALGEBRA:** The branch of mathematics which deals with the relationships of logic variables.
**BOOLEAN VARIABLES:** Such things which have only two possible states.
**CAPACITANCE:** The ability of the capacitor to store charge.
**CAPACITOR:** A device used to store electric charge.
**CAPACITORS IN SERIES:** In this combination, the capacitors are connected side by side.
**CATHODE-RAY OSCILLOSCOPE:** An instrument be used to display the magnitudes of rapidly changing electric current or potential as a function of time.
**CATHODE-RAY TUBE:** A vacuum tube used to accelerate electrons which emit from the cathode by applying high voltage between cathode and anode.
**CENTRE OF CURVATURE:** The centre of the hollow sphere of which a spherical mirror is a part.
**ATOMIC Number:** The number of protons present in a nucleus.
**CLADDING:** The inner part of the fibre optics.
**COMMUNICATION TECHNOLOGY:** An electronic based system of information transmission, reception, processing and retrieval.
**COMPACT DISC:** A molded plastic disc containing digital data that is scanned by a laser beam for the reproduction of recorded sound or other information.
**COMPOUND MICROSCOPE:** A light microscope used to investigate small objetcs.
**COMPRESSIONAL WAVES:** The longitudinal waves comprising series of compressions and rarefactions.
**COMPUTER:** An electronic device used to perform mathematical and logical operations at high speed.
**CONCAVE MIRROR:** A spherical mirror whose inner curved surface is reflecting.
**CONVEX MIRROR:** A spherical mirror whose outer curved surface is reflecting.
**CONVEX LENS:** A lens that causes incident parallel rays to converge at the focal point.
**CONCAVE LENS:** A Lens which diverges the parallel rays of light from its surface.
**COULOMB'S LAW:** The force of attraction or repulsion between two charged bodies is

directly proportional to the product of the quantity of charges and inversely proportional to the square of the distance between their centres.

**CRESTS AND TROUGHS:** In transverse waves, the highest points and the lowest points of the particles of the medium from the mean position.

**CYCLE:** One complete vibration of a wave.

**DATA MANAGING:** To collect information for a special purpose and to store it in a computer in a file form.

**DATA:** Facts and figures that are used by programs to produce useful information.

**DIFFRACTION OF WAVES:** The bending of waves around obstacles or sharp edges.

**DIGITAL ELECTRONICS:** The branch of electronics which processes data in the form of digits.

**DIGITAL QUANTITIES:** The quantities which change in non continuous steps.

**ELECTRIC CURRENT:** The time rate of flow of electric charge through any cross section.

**ELECTRIC POTENTIAL:** The amount of work done in bringing a unit positive charge from infinity to a particular point in an electric field.

**ELECTRIC POWER:** The amount of energy supplied by current in a unit time.

**ELECTROMAGNET:** The type of magnet which is created when current flows through a coil.

**ELECTROMAGNETIC INDUCTION:** The production of an electric current across a conductor moving through a magnetic field.

**ELECTRON VOLT:** The kinetic energy that an electron gains when accelerated between two points with a potential difference of 1 V. $1eV = 1.6 \times 10^{-19} J$

**ELECTRONICS:** The branch of applied physics which discusses those principles and ways by means of which we control the flow of electrons using different devices.

**ELECTROSTATIC INDUCTION:** In the presence of a charged body, an insulated conductor having positive charges at one end and negative charges at the other end.

**EMF:** The total amount of energy supplied by the battery or the cell in moving one coulomb of positive charge from the positive to the negative terminal of the battery.

**ENDOSCOPE:** A medical instrument used for exploratory, diagnostic, and surgical purposes.

**FARSIGHTEDNESS (HYPERMETROPIA):** The disability of the eye to form distinct images of nearby objects on its retina.

**FAX MACHINE:** A mean to send the documents from one place to another through telephone lines.

**RIGHT HAND RULE:** Grasp a length of wire with your right hand such that your thumb points in the direction of the current. Then fingers of your right hand circling the wire will point in the direction of the magnetic field.

**FISSION REACTION:** The process of splitting up a heavy nucleus into two smaller nuclei with release of large amount energy.

**FLASH DRIVE:** A small storage device that can be used to transport files from one computer to another.

**FLEMING'S LEFT HAND RULE:** Stretch the thumb, forefinger and the middle finger of the left hand are mutually perpendicular to each other. If the forefinger points in the direction of the magnetic field, the middle finger in the direction of the current, then the thumb

would indicate the direction of the force acting on the conductor.

**FLOW OF INFORMATION:** The transfer of information from one place to another through different electronic and optical equipments.

**FOCAL LENGTH:** The distance between the principal focus and the pole.

**FREE ELECTRONS:** Loosely bound electrons in metals which can move from one point to another inside the metals.

**FREQUENCY:** The number of cycles or vibrations of a vibrating body in one second.

**FUSE:** A short piece of metal that melts when excessive current passes through it.

**FUSION REACTION:** A process in which two light nuclei diffuse to form a heavier nucleus with release of enormous amount of energy.

**GALVANOMETER:** A sensitive electrical instrument which detects current in a circuit.

**GENERATOR:** A machine that converts mechanical energy into electrical energy.

**GOLD LEAF ELECTROSCOPE:** A sensitive instrument used to detect electric charge.

**GROUNDED:** An object connected to a conducting wire or copper pipe buried in the Earth.

**HALF-LIFE:** The time during which half of the unstable radioactive nuclei disintegrate.

**HARDWARE:** The parts of a computer that we can see and touch.

**LENZ'S LAW:** The direction of the induced current is always such that it opposes the cause that produces it.

**INFORMATION AND COMMUNICATION TECHNOLOGY (ICT):** It is concerned with the scientific methods and means to store and process vast amounts of information instantly.

**INFORMATION STORING DEVICES:** Devices used to store information for later use and benefits.

**INFORMATION TECHNOLOGY:** The scientific method used to store information to arrange them for proper use and to communicate them to others.

**INTERNET:** A computer networks which spreads all across the globe.

**ISOTOPES:** The elements with same atomic number but different atomic mass number.

**KILOWATT-HOUR:** The amount of energy obtained by a power of one kilowatt in one hour.

**LIGHT PIPE:** A bundle of fibre optics bonded together.

**LOGIC GATES:** The digital circuits which implement the various logic operations.

**LONGITUDINAL WAVES:** The sound waves in which particles of the medium vibrate along the direction of propagation of the waves.

**LOUDNESS:** A feature of sound by which a loud and a faint sound can be distinguished.

**MAGNIFICATION:** The ratio of the image height to the object height.

**MECHANICAL WAVES:** Those waves which require some medium for their propagation.

**MOBILE PHONE:** An electronic device with two-way communication. It sends and receives the message in the form of radiowaves.

**MUSICAL SOUND:** Sound having pleasant effect on our ears.

**MUTUAL INDUCTION:** The phenomenon of production of induced emf in one coil due to change of current in a neighbouring coil.

**NEARSIGHTED (MYOPIA):** The defect of eye due to which people cannot see distant objects clearly without the aid of spectacles.

**OHM'S LAW:** The current passing through a conductor is directly proportional to the potential difference applied across its ends, provided the temperature and physical state of the conductor do not change.
**OPTICAL CENTRE:** A point on the principal axis at the centre of a lens.
**PARALLEL CIRCUIT:** A circuit in which voltage remains the same across each resistor.
**PERIODIC MOTION:** The regular motion of a body which repeats itself in equal intervals of time.
**PITCH:** The characteristics of sound by which a shrill sound can be distinguished from a grave one.
**POLE:** The mid-point of the aperture of the spherical mirror.
**POWER OF ACCOMMODATION:** The ability of the eye to change the focal length of its lens so as to form clear image of an object on its retina.
**PRINCIPAL AXIS:** The straight line passing through the pole and the centre of curvature of a spherical mirror.
**PRINCIPAL FOCUS:** A point on the principal axis of mirror/lens where a beam of light parallel to the principal axis converges to or appears to diverge after reflection from the spherical mirror/lens.
**PRISM:** A transparent triangular piece of glass with at least two polished plane faces inclined towards each other from which light is reflected or refracted.
**QUALITY OF SOUND:** The characteristics of sound by which two sound waves of same loudness and pitch are distinguished from each other.
**RADIOACTIVITY:** A phenomenon in which radioactive element emits radioactive rays.
**RADIUS OF CURVATURE:** The radius of the hollow sphere of which a spherical mirror is a part.
**REFLECTION OF LIGHT:** When light travelling in a certain medium falls on the surface of another medium, a part of it returns back in the same medium.
**REFRACTION:** The change of path of waves/light while passing from one medium into another medium due to change in speed.
**REFRACTIVE INDEX:** The ratio of the speed of light in air to the speed of light in a material:
**RESISTANCE:** The measure of opposition to the flow of current through a conductor.
**RIPPLE TANK:** A device used to produce and manipulate water waves.
**S.H.M:** To and fro oscillatory motion in which acceleration of the body is directly proportional to the displacement of the body from the mean position and is always directed towards the mean position.
**SERIES CIRCUIT:** A circuit in which current remains the same across each resistor.
**SIMPLE MICROSCOPE:** A convex lens of short focal length which is used to produce magnified images of small objects.
**SOFTWARE:** It refers to computer programs and the manuals that support them.
**SOLENOID:** A coil of wire consisting of many loops.
**SOUND:** A form of energy that is passed from one point to another in the form of waves.
**SPHERICAL MIRROR:** A mirror whose polished, reflecting surface is a part of a hollow

sphere of glass or plastic.

**THERMIONIC EMISSION:** The process of emitting of electrons from hot cathode.

**TRANSFORMER:** An electrical device which is used to increase or decrease the value of an alternating voltage.

**TRANSVERSE WAVES:** The mechanical waves in which particles of the medium vibrate about their mean position perpendicular to the direction of propagation of the waves.

**TRUTH TABLES:** The truth tables are tables which give the values of the inputs and outputs of the basic types of logic gates or combination of such gates.

**ULTRASONICS:** Sound waves of frequency higher than 20, 000 Hz.

**WAVE:** A disturbance in a medium which travels from one place to another.

**WAVELENGTH:** The distance between two consecutive crests or troughs.

**WORD PROCESSING:** Such a use of computer through which we can write a letter, prepare reports and books, etc.

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