Theory of Energy

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Learning Objectives

1. Discovering the nature and atomic structure of matter.
2. Investigating the energy level of the atom.
3. Understanding the meaning of an electrical potential and electrostatic fields.

Early trends

The early caveman probably concealed himself on a rock ledge and hurled a stone at a wandering animal. Although a crude method of conversion of energy, it did provide food and clothing for his family. Unaware of the principles of science, the caveman bound a stone to the end of a stick to give the world its first hammer.

Since the beginning of time man has searched for ways to convert energy into useful work. Only in recent years has man emerged from the dark ages of mystery and superstition and made intelligent investigations into the sources and uses of energy. There is indeed a great expanse of time between the crude inventions of early man and the now sophisticated age of orbiting satellites, hydrogen bombs and computerized machinery. More has been learned and recorded in the field of science during the last one hundred years than in all the previous years of man's existence on earth

Probes to the surface of the moon have disclosed the moon to be a cold and barren outpost. Can you imagine the life, if any, on EARTH if it were not for the sun and its continuous supply of light and heat energy? Energy is our life. It grows our food and supplies our water. It is harnessed to manufacture our homes, our clothes and many conveniences. Its conversion to transportation has provided high powered automobiles and supersonic jets; energy conversion has joined remote world locations within a world community by communications.

Electronics is a study of energy conversion; it is a study of man's discovery of the development of an electrical potential, its transfer and conversion into work. The structure of all matter is a combination of atoms in elementary form or in combinations with others. Each atom is a source of energy.

The structure of Matter

Anything which occupies space and has mass is called "matter.” Matter may be composed of any number of elementary substances found in nature. Matter may be a compound or mixture of elements or elements in their pure form. The ELEMENT is the basic building block of nature. The element was originally defined as a substance which could not be divided or decomposed into simpler substances. In recent years, scientists have divided some of the heavier elements and found the source of atomic energy• Familiar examples of ELEMENTS which you use daily are Iron (Fe), Copper (Cu), Aluminum (Al), Carbon (C), Gold (Au) and Silver (Ag). There are over one hundred of these elements which have been identified in nature and in the laboratory. It would be a revealing experience to study the Periodic Table of Elements and identify those elements which are familiar

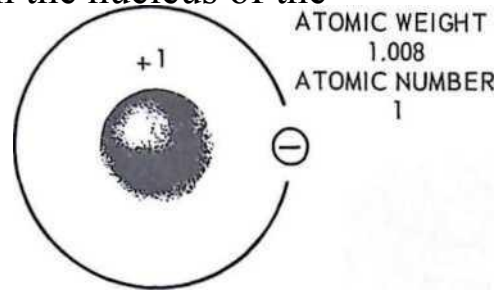
Atoms and Molecules

Just as the element is the building block of nature, the element is composed of small particles called ATOMS. An atom is defined as the smallest particle of an element that retains all the properties of the elements. DALTON'S* conception of the atom was, aU materials are composed of minute indestructible particles" and "the smallest component part of an element that enters into a chemical reaction."

Combinations of two or more atoms, either of the same kind or different, are called MOLECULES and constitute matter. The molecule may be defined as the smallest particle of a compound. If further subdivision is made, the molecule will not be the same substance. For example: a grain of salt (NaCl) is a chemical combination of Sodium (Na) and Chlorine (Cl). If you could divide the grain.of salt an infinite number of times, you would still have salt. In spite of the infinite division you would still have an atom of Sodium and an atom of Chlorine. If the smallest division or molecule were chemically divided, it would no longer be salt. It is possible also, to have molecules made up of atoms of the same kind.

Atomic Structure

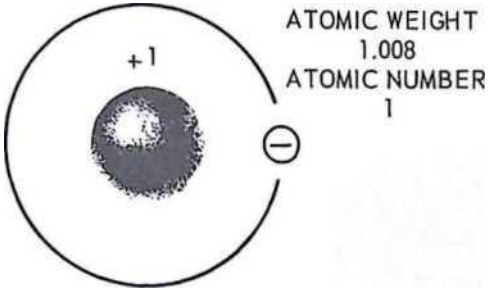
Atoms of all elements are composed of minute particles of electrical charges. Elements differ only in the number of particles and their arrangement. THOMPSON ** proposed a theory that an atom was a small ball containing an equal amount of positive and negative charges of electricity. Its overall charge was neutral. Further experimentation by RUTHERFORD who proved that the POSITIVE charges were concentrated at the center or NUCLEUS of the atom and the NEGATIVE charges rotated in specific orbits around the nucleus. These negative particles of electricity or charges are called ELECTRONS; the positive particles are called PROTONS. A third particle which is neither positive or negative, but neutral is called a NEUTRON These neutrons are found in the nucleus of the atom. Thus emerges our present concept of the structure of an atom

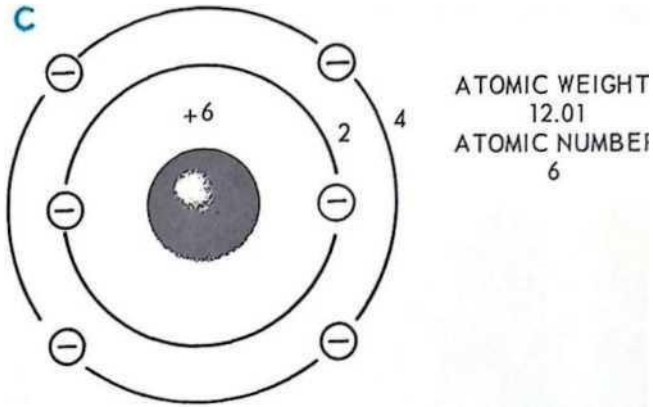


ATOMIC ENERGY LEVELS

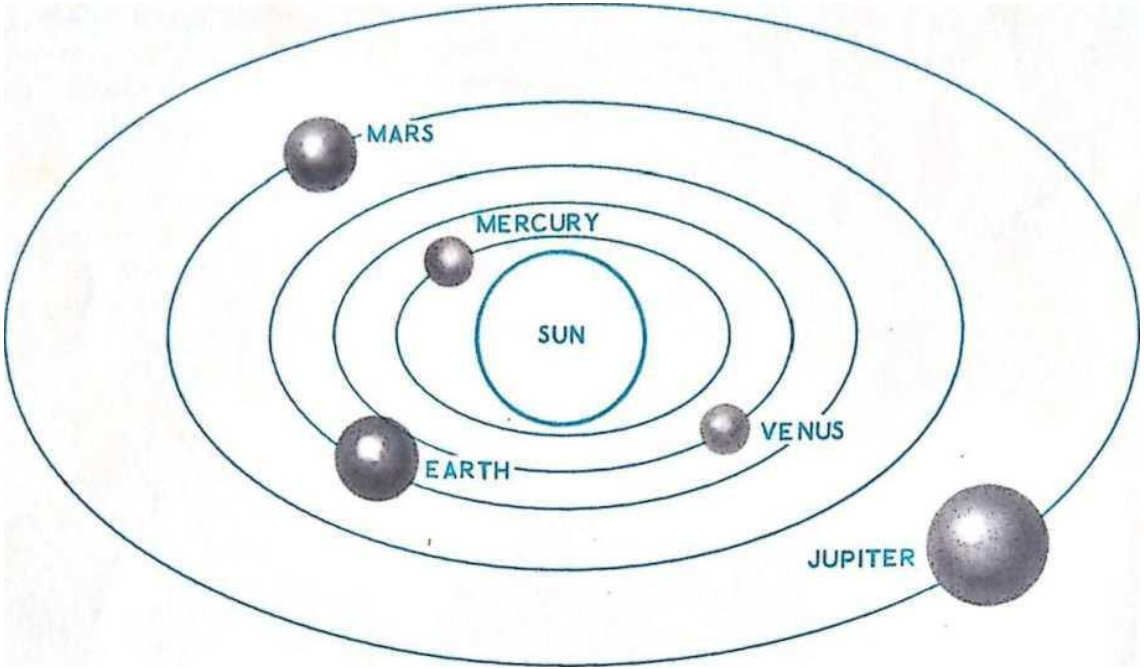
electrons are truly in motion in an apparently solid material such as a piece of copper

THE HYDROGEN ATOM *ONE ELECTRON IN ORBIT *ONE PROTON IN NUCLEUS
THE CARBON ATOM
*SIX ELECTRONS IN ORBIT *SIX PROTONS IN NUCLEUS





Correlation to our solar system



Explanation.

The orbiting electron is held a specific distance from the nucleus by two counteractive forces. The first is CENTRIFUGAL
force which tends to cause the electron to fly outward into space. Secondly is CENTRIPETAL force, which is the attractive force between the protons in the nucleus and the electrons. At some definite diameter of the orbit these forces are in balance. The atom contains both mass and motion, and therefore two kinds of energy, Kinetic and Potential

In the atom the sum of the potential and kinetic energy determines the energy level of the atom and the radii of the orbiting electrons.

ENERGY SHELLS

The concept of energy levels in an atom is most important in the study of solid state electronics. This concept suggests that electrons orbit in specified shells or layers around the nucleus. Each shell corresponds to a fixed energy level. The number of electrons in each shell may be predicted by the formula, $2N^2$, where N is the number of the shell. See Fig. 1-4.

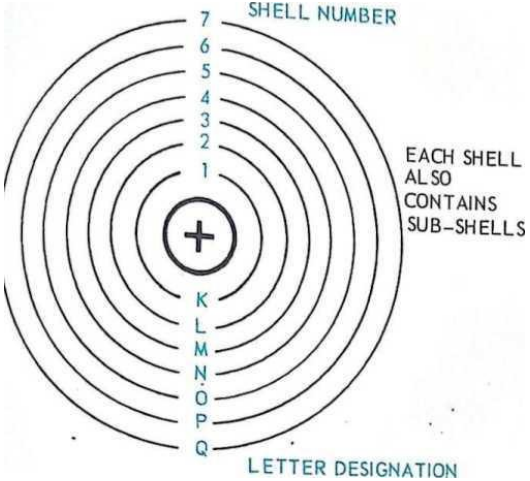


Fig. 1-4. Electrons are contained in shells of specified energy levels around the nucleus. Shell letter and number designations **are** *shown.*

PHOTONS AND PHONONS

The interesting study of energy shells of an atom would not be complete without mention of EXCITATION. The addition of energy to an atom by means of heat, light or an electric field will cause electrons to jump outward into the next energy shell.

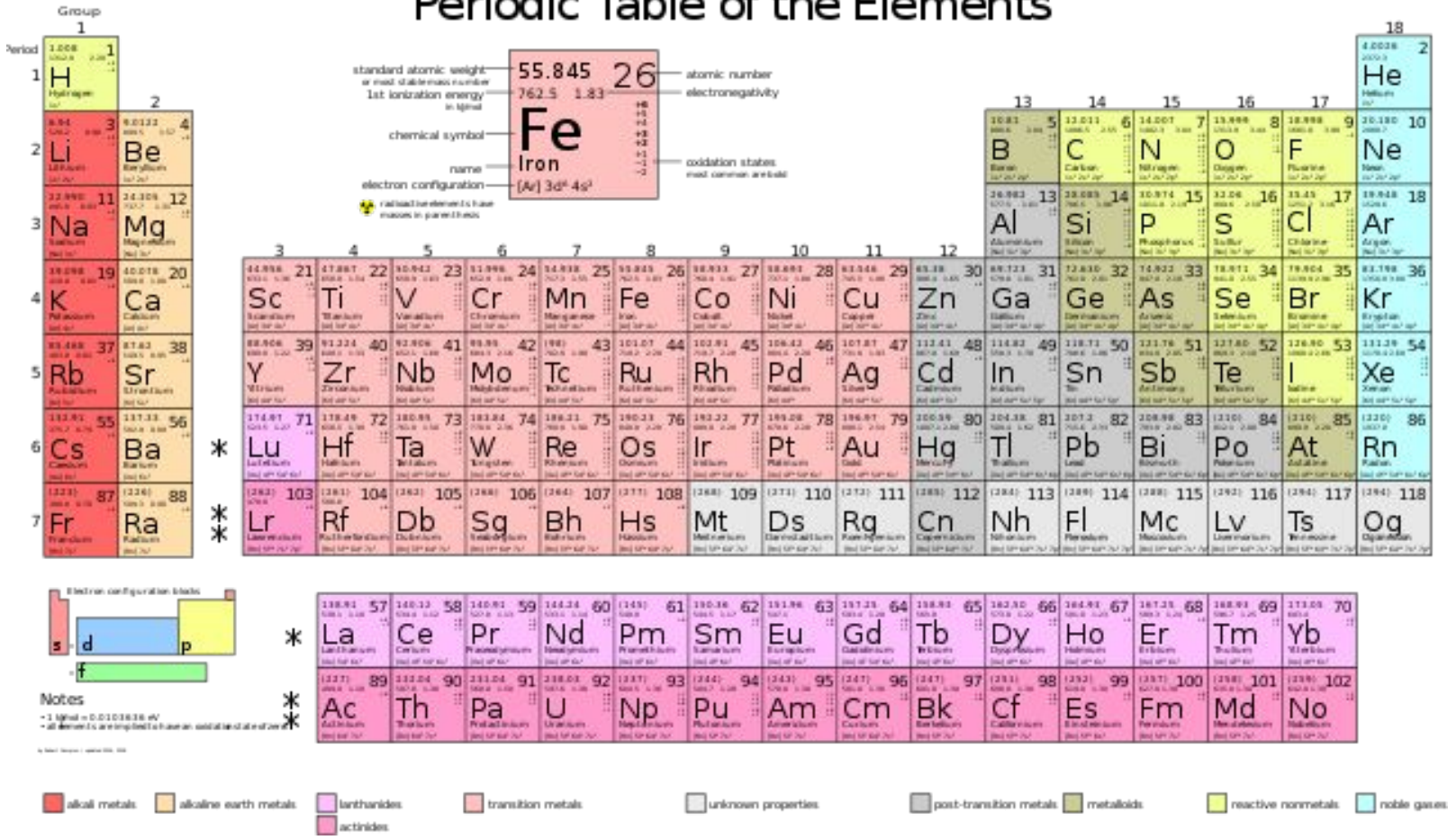
A discrete quantity of heat energy is called a PHONON and a discrete quantity of light energy is a PHOTON. When these discrete quantities of energy are accepted by the atom, the electrons move outward from their subshell to the next higher energy subshell. They can also move from one major shell to the next higher major shell.

Also, if electrons move to the next lower shell, energy is given off. Example: As a warm object cools, it gives off heat. Conversely, to heat an object requires the addition of heat.

VALENCE

The number of electrons in the outer shell, less than the permitted number, is the VALENCE of the atom. The outer shell, therefore, is called the VALENCE SHELL. The valence of an atom is an indication of its ability to gain or lose electrons and determines the electrical and chemical properties of the atom. An atom which has almost its full complement of electrons in the valence shell will easily gain electrons to complete its shell, but a relatively large amount of energy is required to free any of its electrons. Conversely, an atom which has only a small number of electrons in the valence shell compared to its permitted amount will lose these electrons quite easily.

Periodic Table of the Elements



Elements are arranged in groups on the periodic Table according to their valence. Those in Group IV have four valence electrons, Group III are trivalents meaning three and Group V are pentavalents meaning five valence electrons.

IONIZATION

Up to this point in our discussion, we have assumed an equal number of protons and electrons in the atom. The electric charge is neutral. It is possible by adding external energy to the atom to upset this balance or neutrality. If electrons are driven out of an atom, by adding energy, the protons and electrons are out of balance. The protons being in a majority, the atom becomes a POSITIVE ION. On the other hand, if an atom with an incomplete shell accepts an electron from some source, the electrons are in the majority and the atom becomes a NEGATIVE ION

The process is called IONIZATION.

To remove an electron from an atom, energy levels must be raised. As stated earlier, this may be accomplished by heat, light or an electric field. The energy required to do this is called the IONIZATION POTENTIAL.

BONDING IN ELEMENTS

Basic types of bonding include Covalent bonds and Ionic Bonds. Meanwhile Metallic Bond also exist in elements such as copper

Metallic Bond

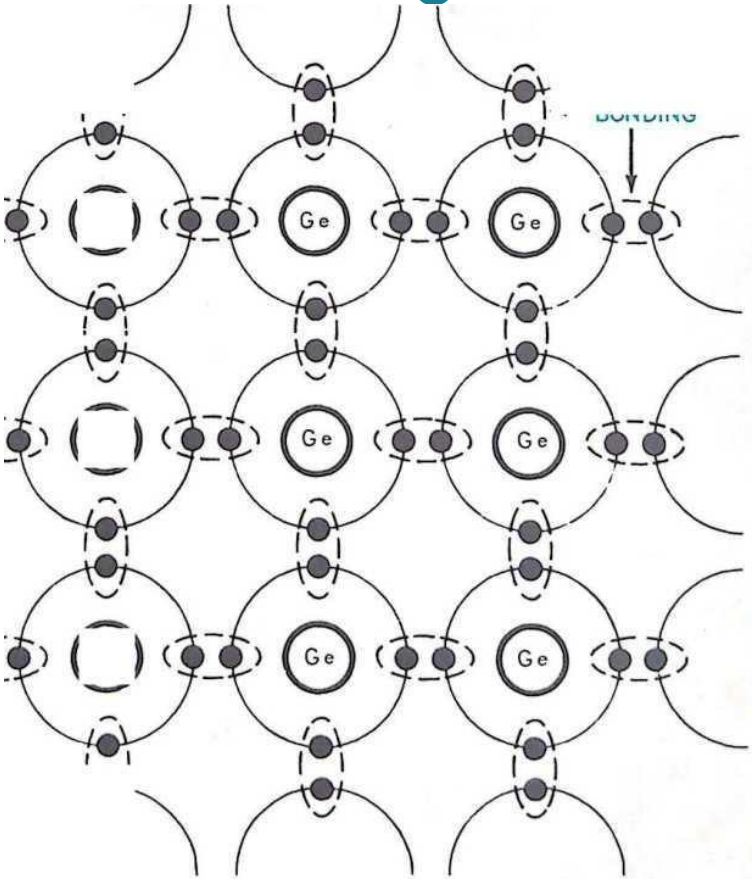
Metallic bonding is a type of chemical bonding that arises from the electrostatic attractive force between conduction electrons and positively charged metal ions. It may be described as the sharing of free electrons among a structure of positively charged ions

COVALENT BONDING

Covalent bonding is the sharing of electrons between atoms. This type of bonding occurs between two atoms of the same element or of elements close to each other in the periodic table. This bonding occurs primarily between nonmetals; however, it can also be observed between nonmetals and metals.

Most inorganic materials have their atoms arranged in crystalline structure. A substance may have its crystals arranged in random fashion; others may assume a LATTICE formation. Every crystal will be like its adjacent neighbor and arranged in a precise manner. The lattice formation for a Germanium crystal is illustrated in figure below

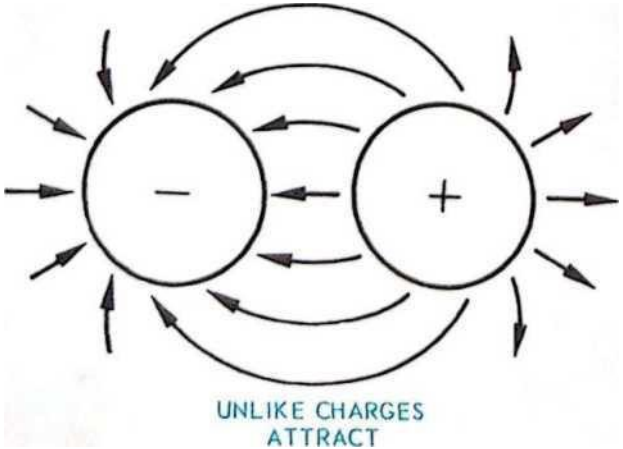
Covalent bonds in atoms of germanium



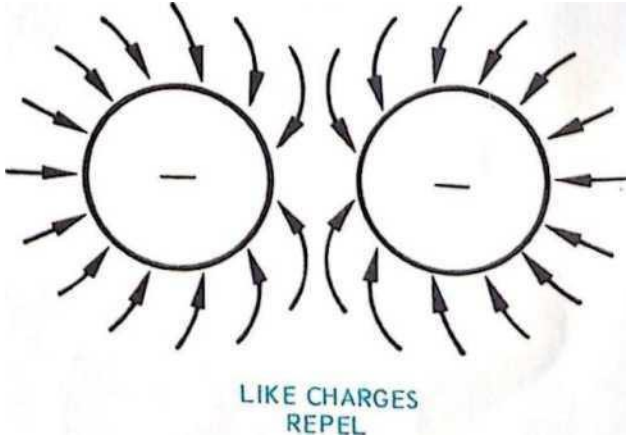
Only the valence electrons are shown for simplicity. Please note that the valence of Germanium is 4 and it has four valence electrons. To complete the valence band of Germanium, eight electrons are required. Since no free electrons are available, each atom shares its valence electrons with the other. The atoms are firmly attached in a crystal-lattice structure by COVALENT BONDING. If an electrical potential was applied to a crystal of this type, no electric current would flow through the crystal since there would be no "free electrons" to transfer the energy.

LAW OF CHARGES

In the discussion of ionization, it was pointed out that under certain conditions atoms could lose or gain electrons. When such is the case, a material or body which has gained electrons is charged NEGATIVELY, Existing in space around such a charged body is an invisible ELECTROSTATIC FIELD. By convention, the their fields will interact, an attractive force will appear which tends to bring the bodies together. Refer to Figures below



UNLIKE CHARGES ATTRACT



LIKE CHARGES REPEL

If the two bodies possess the same charge, either positive or negative, a repulsive force would tend to hold the bodies apart. This introduces one of the more important laws in the study of electricity.

LIKE charges REPEL each other,

UNLIKE charges ATTRACT each other.

This law will be applied to explain the theory and operation of many components, circuits and devices.

THE COULOMB

The atom is an infinitesimally small particle of matter. In fact, several billion and more atoms would be required to make up the "head of a pin." The electron is even smaller. In order to have a quantity of electrons of sufficient size to use, the term COULOMB is used as a quantitative measure of electrical charges. It represents a charge of $6.28gx10^{18}$ electrons. The letter symbol Q has been assigned to the coulomb. Coulomb's Law states that the force between two charges is directly proportional to the product of the charges and inversely proportional to the square of the distance between the charges.

THE ELECTROSCOPE

An instrument used in the laboratory to detect a charge and determine its polarity is the ELECTROSCOPE, Fig. 1-9. It consists of a glass jar with a center rod and ball. Two gold leaves hang on the rod a.t the center of the jar. If the two sections of gold leaf become charged alike, either negatively or positively, they will expand because like charges on both leaves will repel each other.

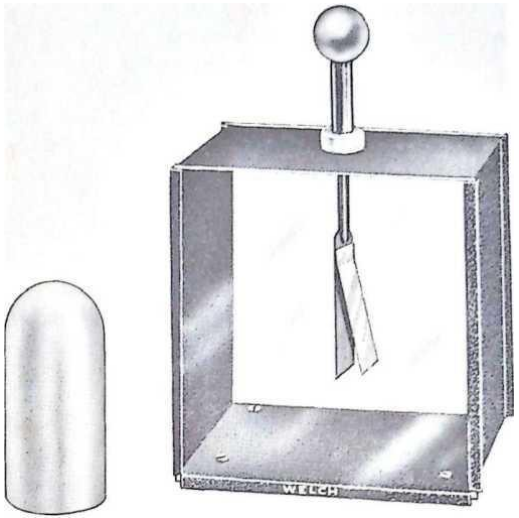


Fig: An electroscope. (Welch Scientific Co.)

To demonstrate this phenomenon, a vulcanite rod is vigorously rubbed with a piece of wool or cat's fur. This action places a negative charge on the rod. As the rod is brought close to the ball on top of the electroscope, but not touching the ball, the gold leaves expand. See Figure below

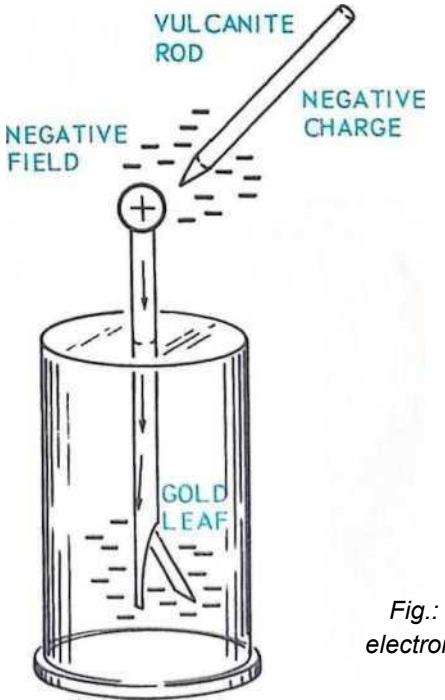


Fig.: The negative electrostatic field around the rod drives the electrons down into the jar and causes the gold leaves to expand.

The negative electrostatic field around the rod repelled the electrons from the ball down to the gold leaves. Both leaves then having a negative charge would repel each other.

While the rod is in position and the leaves expanded, touch the ball with your finger. Remove your finger and remove the rod. The leaves remain expanded. What happened? When you touched the ball, electrons escaped through your finger and into your body. When the finger and rod were removed, the electroscope had no chance to regain its lost electrons. It therefore became charged positively and the leaves expanded. This is charging an electroscope by INDUCTION since only the electric fields were used.

Touching the electroscope will permit it to regain its lost electrons and become neutral with its leaves collapsed.

Rub the vulcanite rod again and then touch the ball of the electroscope with the rod. Remove the rod and the electroscope remains charged NEGATIVELY. The rod shared its electrons with the electroscope.

This is charging by CONTACT.

These experiments may be repeated using a glass rod and a piece of silk. Rubbing will place a positive charge on the glass rod. A positive rod will charge the electroscope negatively by induction and positively by contact

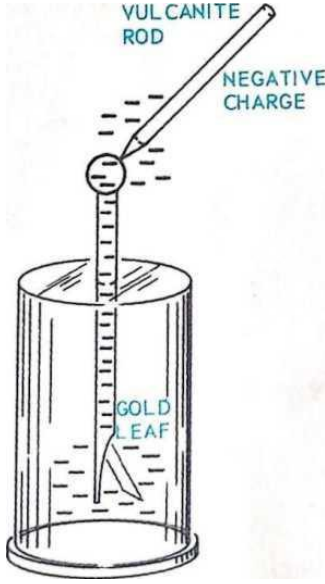
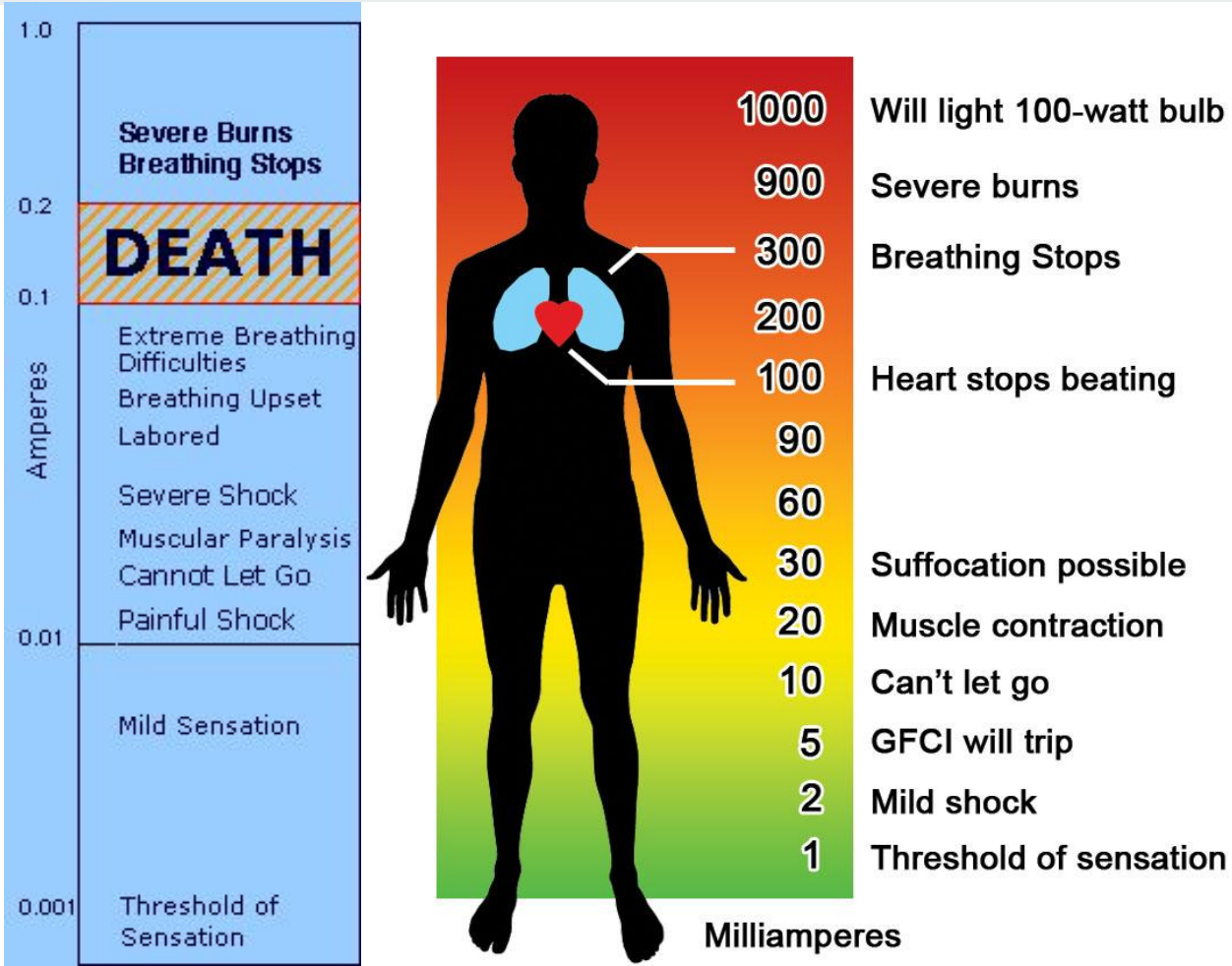


Fig. The electroscope is charged by contact with a negatively charged rod.

SAFETY LESSON: When working with electricity as well as with all kinds of machinery, never permit yourself to be distracted. And equally important do not distract your fellow worker. Don't be a clown! Jokes have no place in the electrical shop. Your seemingly harmless interruption may cause a serious accident and also damage to expensive equipment.

Physiological Effects of Electric Currents



Be curious, be creative, work safe!