### CHAPTER \_ I

#### INTRODUCTION AND EXPERIMENTAL BACKGROUND

### 1.1 Introduction :

''Scattering Theory'' is one of the recent and interesting topics. It is related to the Quantum mechanics, which is an important branch of Physics. The present study deals with the interaction of an electron with an atom. When an electron collides with atom then the questions were raised such as, what were the collision cross sections ? What were the mechanisms for the different collision processes ? and in what way answers to these questions are useful ? The answers to these questions are still being searched with more and more precision and sophistication by the experimentalists as well as theorists. These informations are needed in the study of atmosphere, ionosphere, planetary and stellar atmosphere, laser plasmas, electrical discharges radio-chemistry and health physics etc. The passage of electrons through atmospheric gas would be an important process in the Aeronomy. Apart from this the subject is playing a leading part in the establishment of quantum theory and including many aspects of fundamental importance in the theory of atomic structure. Thus the phenomenon of the electron scattering by the atoms seems to have important bearing on many branches of the science and engineering. Many experimentalists and theorists are

attracted by this ''Scattering theory'' because of its importance not only in the subject of physics but also in Biology and Engineering.

The answers to the above mentioned questions were given in two correlated different ways, one was from classical and the other from the quantum mechanical treatments.

### 1.2 <u>Collision processes</u> :

A collision is said to have taken place between two particles when they collide with each other, if and only if any physical change occurs, which can be detected.

Consider the Fig. 1.1 which is a schematic representation of a typical collision experiment. A beam of projectiles ( electrons )  $\overline{e}$ , from a source is well collimated and directed towards target, which are essentially at rest in the laboratory frame of reference. The projectiles are assumed to be sufficiently monochromatic and collimated so that one ion assign a single wave number to the incident beam and that the slight angular divergence from the collimator can be ignored. The target usually consists of a macroscopic sample containing a large number of scatters ( atoms )A. The distances between these scatterers are in general quite large with respect to the de Broglie wave length of the incident particle, in which case one can neglect coherence effects between the waves scattered by each of the scattering centre.

In addition, if the target is sufficiently thin, multiple scattering by several scatterers can be neglected. One may then consider that each scatterer acts as if it were alone and focus one's attention on the study of a typical collision between a particle  $\overline{e}$  of the incident beam and a scatterer A of the target. After the collision, some or all out going particles are registered by detectors which count the number of particles of a given kind which arrive there. The principle role of the collimator is to shield the detector from the incident particles comging directly from the source without having been scattered there by the target particles. The more perfect the collimation, the better approximation. It is to assume that all the incident projectiles e travel barallel to the Z - axis, indeed they define a Z - axis. In most of the scattering experiments great care is taken to ensure that all the projectiles have the same initial energy when they leave the source. Suppose that with the help of a counter placed at a large distance from the target, one can measure the number of particles of a certain kind which emerge in a collision region in the different directions. Several collision processes can occur from the encounter of an electron with a gas atom. These may first be distinguished as elastic, inelastic, superelastic, or radiative. These collision processes are explained below. Elastic Scattering : In this process two bombarding particles electron  $(\overline{e})$  and atom (A) are simply scattered without

any change in their internal structure i.e.

4

In this collision e losses that amount of energy which is necessary for the conservation of the momentum in the collision process. In such a collision, only the kinetic energy between the impinging e and the target A is exchanged, so the internal state of the target particles A remaining unchanged. The average energy transferred to the target atom A in an elastic scattering is small. However e may transfer considerable momentum in making large angle scattering. The transfer of momentum, then is the focal point when considering the elastic collision.

In elastic scattering : In this process the projectile particle e remains unchanged, but the target particle A undergoes a change of its internal quantum state during the collision process

 $\overline{\mathbf{e}} + \mathbf{A} \longrightarrow \overline{\mathbf{e}} + \mathbf{A}^*$  (1.2)

In inelastic collision process the target A gains internal energy at the expense of the kinetic energy of the colliding particles  $\overline{e}$ . The impact results in the excitation or the ionization of the target. There may be even formation of compound negative ion state. If in a collision process, whole or part of the energy lost by the  $\overline{e}$  is emitted as electro magnetic radiation. This process is also called an inelastic collision.

Superelastic scattering : In this collision process the target particle is initially in an excited state, denoting this by  $A^*$ 

This process can occur only between the projectile particles  $\overline{e}$  and  $A^*$ .  $A^*$  of the target states are such that the A gains energy from the internal motion of the target A. This is possible only if the energy of the internal motion of A before the impact is not already a minimum. The collisions of this type are important at low  $\overline{e}$  energies and in collistions with metastable target particles A. This collision process, particularly for the elastic scattering from long lived metastable states is of special interest in astrophysics and plasma physics.

In the preceding heads the basic requirements of a typical collision experiment, as well as the physical requirements of the incident beam of particles  $\overline{e}$  and the target particles A in a collision process are described. And the types of collision processes are also explained. The next important task ''Collision Cross Sections'', which are created by the collision processes, are naratjed in the following way.

### Collision Cross Sections

The previous results obtained by the collision experiments are usually expressed in terms characteristic quantaties called '' Cross Sections ''. These are basically, differential, total, total elastic and momentum transfer, cross sections respectively. These are defined as below :

> The cross section of a certain type of event in a given collision process is the ratio of the number of events of this type per unit time and per unit scatterer, to the relative flux of the incident particles with respect to the target.

Consider a beam of incident particles which satisfies the physical requirements is fixed in to the target which consists of a large number of gas atoms, and let a parallel flux of Ne particles per unit area per unit time strikes the target gas containing Ne - atoms. Let us denote N, the total number of incident particles, which have interacted in unit time with the target atoms. This quantity N is proportional to the product of Ne and Nt, and expressed as

 $N = Ne Nt \sigma_{tot} \qquad (1.4)$ 

where  $\sigma_{tot}$  is called the total cross sections for scattering of an incident particle  $\overline{e}$  by the target atom A.

Total cross section has the dimension of an area. The quantity  $\sigma_{tot}$  depends only on the collision energy and refers to an intrinsic, microscopic property of the quantum system ( $\overline{e} + A$ ). It gives a measure of the tendency of the particles  $\overline{e}$  and A to interact at a given energy. The equation (1.1) could be extended to different types of collision processes. In the case of elastic scattering it becomes

 $N^{el} = Ne Nt \sigma_{el}$  (1.5)

here N <sup>el</sup> is the total number of particles which have been scattered elastically per unit time and  $\sigma_{el}$  is the total elastic cross section. The total cross sections give informations about the interactions experienced by the colliding particles. More details can be obtained about these interactions from the differential scattering cross sections.

## Differential Scattering Cross Sections ( DCS )

Let d N be the number of incident electrons that emerge in unit time with in a solid angle d S centered about a direction which has scattering angles  $\Theta$  and  $\phi$ with respect to the direction of parallel flux as polar axis. Because of the interaction of electron and atom, the atom may be excited from the initial state n to the final state n<sup>t</sup> By analogy of the equation (1.4) d N can be expressed as

 $dN = NeNt\sigma(\Theta, \phi) dS$  (1.6)

The proportionality factor  $\sigma (\Theta, \phi)$  is called the DCS It defines the angular distribution of scattered electrons ( elastically or inelastically ). DCS is useful in defining the total and momentum cross sections. These are defined as follows .

## Total Cross Section ( TCS )

The integral of the DCS ,  $\sigma$  (  $\Theta$  ,  $\varphi$  ) over the sphere of unit radius gives the total cross section  $\sigma_{tot}$  is expressed as

 $\sigma_{tot} = \int \sigma (\Theta, \phi) dS$ 

=  $\int \sigma(\Theta, \phi) \sin \Theta d\Theta d\phi$  ..... (1.7)

## Momentum Transfer Cross Section (MTCS )

- --

The momentum transfer cross section  $\sigma_m$ , for the transfer of momentum to a target by an electron scattered at the polar angles  $\Theta$  and  $\varphi$ , having excited the target atom from initial state n to final state n' is formulated as

 $\sigma_{\rm m} = \int \sigma (\Theta, \phi) \sin \Theta \, d\Theta \, d\phi \, (1 - \cos \Theta) \quad \dots \quad (1.8)$ 

 $\sigma_{\rm m}$  is also called as diffusion cross section. This type of cross section is useful in discussions of diffusion of newtral and charged particles in gases, and the mobility of gaseous ions. The difference between  $\sigma_{\rm tot}$  and  $\sigma_{\rm m}$  is a weighting factor (1 - cos  $\Theta$ ).

8 /

The cross sections discribed above are correspond to the inelastic collision process. The equations for elastic and superelastic processes can be obtained easily from the equations ( 1.1 ), ( 1.3 ) and ( 1.4 ) to ( 1.7 ) respectively.

These are the informations delivered by the ''Scattering theory'' acting as a bridge between experimentist and theorist. The différence do exist to obtain the accurate results because of the approximations made by these two correlated approaches.

Basically there were two conv**tant** frame of references for the description of collision cross sections. One was centre of mass system in which the centre of mass of the two colliding particles (A + B) is at rest during the collision process. Second frame of reference was laboratory system in which the bombarded particle (B) is initially at rest. For the collision of a particle with a fixed scattering center the definition of the differential scattering cross(equ. 1.6) section is equally valid in both the frames of references. For a collision between two particles of finite mass, however the equation (1.6) applies in general only to the laboratory co-ordinate system and to the observation of the scattered incident particle. In the centre of mass system the differential cross section may be defined in analogy with equation (1.6).

#### 1.3 Experimental Background :

In this section I shall describe the experimental methods which are used to study the electron - atom scattering. Numerous experiments were performed to measure the collision cross sections, with increasing accuracies. All these experiments were folded in between three types of experimental techniques : the electron Swarm, the electron beam and the combination of these two techniques. These three techniques were generally used to study electron - atom ( molecule ) interactions.

The Swarm technique included the drift velocity, the diffusion, and the microwave methods. In this types of experiments the distribution of energies was wider, and certain desirable quantaties were not obtained directly but have to be deduced from the measured parameters through elobrate and not straight forward procedures. In Swarm experiments the gas was studied under conditions and under the influence of a uniform electric field. These experiments were performed at low energies, i.e. below 1 eV. Swarm experiments Yield certain parameters absolutely which can be used to normalize relative beam data.

The beam technique included the single - beam methods and yielded directly the total scattering cross section, single - beam methods for the direct determination of the differential scattering cross section, and crossed - beam methods for the study of unstable species. These electron beam experiments were more direct, they dealt with nearly mono energetic electrons and were quite generally, performed under single collision conditions. They were difficult to perform at low energies ( $\leq 1 \text{ eV}$ ), due principally to contact potentials, stray fields, and mutual electrostatic repulsion, and yield in most cases was relative rather than absolute values of the measured quantaties. In beam experiments the gas was as a rule, studied under dynamic and field free conditions.

Thus the advantage of Swarm technique was in obtaining transport co-efficients over a vide energy range and particularly at very low energies. But the beam experiments were diffécult to perform at low energies. The main advantage of the beam technique was in obtaining the cross sectional results directly. In the case of Swarm technique the cross sectional results were deduced after extremely complex calculations.

The basic principles involved under each of the three techniques and the experimental procedures to calculate collision cross sections are outlined below.

#### 1.4 Beam Technique :

The experiments fall under this technique give direct

results of collision cross sections. Since these experiments are single - collision experiments utilizing mono energetic electron beam, these are divided in to three groups : those which yield the total cross sections, those which allow determination of the differential scattering cross sections, and those employed for the study of unstable species. The main problems faced by the beam technique are of making low energy mono - energetic beam, making line target and detecting scattered electrons at even some finite angular resolution. These problems are solved by the modern equipments. Experiments under each group are discussed as follows :

<u>Total Cross Section Measurements</u> : First (Experiment) to measure total cross sections was based upon the principle of Ramsauer's (1921 a, b) method. The principle of this method is illustrated in Fig. (1.2). Electrons from a source F were accelerated to the desired velocity before passing through the slit  $S_1$ . By means of a magnetic field perpendicular to the plane of the paper, those electrons that suffered no collision described a circular path through the slits  $S_1 - S_7$  and entered a collector C. Electrons that were elastically scattered from the beam failed to pass through the slits, while those that suffered inelastic collisions, even without deflection, moved in a new circular path of smaller radius in the magnetic field and so failed to pass through the succeding slits. The procedure adopted for

the total cross section was as follows. With a pressure P1 torr in the apparatus the current, I1 to C alone and J1 to B and C together were measured by an electrometer. Similarly I2 and J2 are currents when the pressure is P2 torr. Then using the following expressions the total collisional cross section Q can be calculated.

and

$$(P1 - P2) \alpha x = \log \frac{J1 I2}{J2 I1} \qquad (1.9)$$
$$Q = \frac{\alpha}{N} = 2.81 \times 10^{-17} \alpha/P \text{ cm}^2$$

where P is the gas pressure in torr  $\alpha$  is the absorption coefficient at pressure of 1 torr, x is the length of the path between slits  $S_6$  and  $S_7$ . Provided the slits are narrow this method should give the true total cross section, as no encounter fails to be detected, except for the small of elastic collisions through very small angles. If the electron energy is lower than the energy for excitation of any of the levels of the target gas, the measured cross section is equal to  $\sigma$  el other wise inelastic collisions contribute to the cross section. If the scattered electrons are energy analysed by retarding potential technique or deflection in an electric or magnetic field, the elastically scattered electrons can be separated and collected, and  $\sigma_{el}$  and  $\sigma_{in}$  can be determined. Ramsauer's apparatus has not only been used for measuring the total absorption cross - section for electrons in gases and vapours but has also been adopted by Brode (1929.) for measurements in metal vapours. There is no difficulty in principle in employing Ramsauers method with an electron Source that provides a beam of much greater homogeneity in energy so as to investigate the fine structure in the cross section energy variation.

Investigations of fine structure in the energy variation of the total cross section required a the development of electron beams. Electrons emitted from a hot filament had an energy spredd of several tenths of an! electron, volt due to the temperature and the effect of the drop of potential along the filament it was essential to an energy monochromator to select electrons of a use narrow band of energies before they enter the collision. Keeping all these points in mind Golden and Bandel (1965) improved the resolution in a Ramsauer experiment so that the electron energy spread, between, half maxima was about O.l eV at 20 eV . Cylindrical electrostatic monochromators ( c.e.m ). spherical energy analyser ( s.e.a ) and retarding potential difference method ( r.p.d ) were used by several workers to obtaim the electron beams and to improve the energy resolution. Some investigators used c.e.m. to obtain beams monochromatic to 0.06 to 0.10 eV. Simpson (1963) developed an apparatus for studying total collision cross - sections of electrons in gases in which

both monochromator and analyser were identical and consisted of concentric spherical electrostatic deflectors as described by Purcell ( 1938 ). Withethis method Simpson found that the width of the beam at half the maximum energy was = 0.038 eV and the collected current  $3 \times 10^{-10} \text{ A}$ . This apparatus was used to detect fine structure in the variation of total cross - section with electron energy rather than the accurate absolute measurement of cross sections. The r.p.d technique was used by Schulz (1964) to investigate fine - structure effects in the total cross section of atomic hydrogen. The main interest in s.e.a and r. p. d was to find accurately the energies at which rapid variations of the scattering cross - sections occured. This was done by comparing these energies with other well known atomic excitation energies. The informations comping out of these were useful both from the point of view of theoretical interpretation and the design of experiments.

In the next group of experiments in the beam technique we had Crossed - beam methods for the study of collisions between electrons and chemically unstable species. In recent years methods were developed in which the scattering atoms from an atomic beam that crosses the electron beam. The products of the collisions were then detected and analysed. In these experiments, which were of importance in the measurement of many types of collision cross - sections, the number density of particles in the beam was

frequently considerably less than the molecules of residual or recombined gas. To pick out the wanted signal due to collisions with atoms in the beam, either >> the atomic or electron beam was chopped mechanically at an audio - frequency. The wanted signal was amplified by a narrow band amplifier tuned to the modulation frequency of the atomic beam and measured by a phase - sensitive detector. Three different techniques were developed to study the collisions in monetomic gases and vapours. First technique, which was of wider application to the study of the cross - sections for different types of collision, depends on the measurement of the current of scattered electrons! Brackman et al (1958) applied this method to measure the total cross section of atomic hydrogen. Since in their experiment scattered electrons were collected over an angular range around  $90^{\circ}$ , the estimate of the total cross section required a knowledge of the angular distribution of the scattered electrons. In the second technique, which concerned with the measurement of total cross sections, depends on the 'measurement of attenuation of the atomic beam ' due to collisions with other crossed beam. Using this method Perel et al ( 1962 ) measured the total collision cross section for lithium, sodium and potassium atoms. Later Sunshine et al (1967 ) applied the same method to measure the total cross section for atomic oxygen . The last was similar to the second. This technique technique depended in the 'attenuation of electron beam' instead

of atomic beam. Total cross sections for hydrogen and oxygen were measured by Neynaber, et al (1961 a, b ) using this method. This method was also applied for atomic nitrogen

<u>Angular Distribution Measurements</u>: These were the third group of experiments under the head of the beam technique, to measure angular distributions of the scattered electrons. Very extensive measurements were made of the angular distribution function  $\sigma$  ( $\Theta$ ,  $\phi$ ) both for elastically scattered electrons and electrons scattered in specific in elastic impacts. Again these experiments were classified as energy - loss and thresold - electron excitation. The general principle of most of these experiments used is illustrated in Fig. (1.3)

A beam of electrons of definite energy emerged through the slit S into the gas contained in a region free from electrostatic fields. Those electrons scattered from the area ABCD of the beam through angles in the small range between  $\Theta_1$  and  $\Theta_2$  ( $\simeq \Theta_1$ ) and passed through the entrance slit L of a collector. This collector includes  $\varepsilon$ some analysing device to ensure that only scattered electrons with renergies in the required range are measured. Either the source S or the collector C may be rotated about an axis perpendicular to the plane of the paper Lat E, so that the variation of the collected current with the

angle  $\Theta$  may be measured. The volume of the region from which the scattered current is observed increases as Cosec $\Theta$ so that the observed current at an angle  $\Theta$  must be multiplied by sin  $\Theta$  in order to obtain the true relative scattered intensity per unit solid angle.

ີ່

To ensure that the observations refer only to single scattering it is necessary to work with a sufficiently low gas pressure and beam current. When working at energies above the ionization energy of the gas the restriction to small beam currents must also be adhered to in order to prevent the setting up of a positive ion space charge large enough to distumb the path of the scattered electrons -It is also important that no stray fields should be present due to charging up of the bounding walls of the scattering chamber. To avoid this the wall is bounded by a metal enclosure, usually cylindrical in form. To avoid effects due to presence of impurities, it is necessary to design apparatus so that it can be throughly outg\_assed by baking.

The basic components in these experiments are, the electron source the monochromator and the analyser and collector. In most recent angular distribution experiments an electron multiplier detector has been used for the scattered electrons. Various workers have studied the angular distribution of electrons by atoms at small and large angles

using some special conditions in the components. Crossed beam method was also applied by various investigators to study the angular distribution of electrons by atoms. The pulsed crossed - beam method using a phase sensitive detector was applied by Bederson et al (1957), and by Gilbody et al (1961) to measure the elastic scattering of electrons from hydrogen atom. The apparatus used was similar to that used by Brackmann et al (1958), only the difference was electron multiplier instead of electron collector.

Using these beam - technique an extensive work was been done bfor elastic and inelastic scattering of electrons by atoms. Angular distributions of elastically scattered electrons from the rawe gas atoms are of extreme interest ( Massey and Burhop ( 1952 ). Some distinct features in the data of rare gases are worth noting given as

- The maxima and minima in the differential scattering cross section which arise from the differaction of the electron waves by the target atom.
- The trease in complexity of the angular pattern with increasing atomic number of the scattering atom.
- 3. The variation of the differential scatter ging cross section with electron energy. At low energies large angle scattering becomes very probable , while at high electron energies forward scattering predominates.

1.5 <u>Swarm Technique</u>: The experiments fall under the head of this technique do not given direct results of collision cross sections. They are to be deduced from the measured parameters of the Swarm experiments. Again these Swarm experiments are divided in to two groups. First group of experiments concern with measurements of the drift velocity of electrons in the direction of a uniform external field ( electric or magnetic ). And the second group of experiments produce the diffusion coefficient. Experiments under each group are discussed as follows.

In Swarm technique electrons undergo many collisions and diffuse in the gaseous medium through which they drift under the influence of an externally applied electric field. An equilibrium energy distribution is attained where the gain from the field is balanced by the numerous but small fractional energy losses due to the dominant elastic collisions. Large angle scattering as well as low energy inelastic scattering an important effect on the distance travelled by an electron in a given swarm. If d is the drift distance and x' is the actual distance travelled by an electron in the Swarm usually x' >> d . Further if  $\mu$ is the random velocity and  $\omega$  is the average velocity in the field direction called the electron Swarm drift velocity in the field direction, then usually  $\mu >> \omega$  . Thus if

$$t = \frac{a}{\omega}$$

is the time required for the swarm to drift the distance d, the actual distance travelled x' is equal to

 $\mu t = (\frac{\mu}{\omega}) d$ 

where the ratio is typically  $\geq 10^2$ .

When conducting electron swarm experiments, the electron swarm or pulse should reach a steady - state condition and attain an equilibrium energy distribution quickly, that is from the beginning of the drift space. This introduces some problems as to the backscattering of electrons and the effects of boundaries in solving the Boltzmann transport equation. The relaxation time t' i.e. the time it takes for an electron swarm to reach a steady - state condition in a gas must be t' << t. In the absence of inelastic collisions the relaxation time is

$$t' \approx \frac{M}{2m \nabla_c}$$

where  $\overline{V}_{c}$  is the average electron collision frequency (Mc Daniel, 1964), M and m are the masses of the gas and electron.

Fig. (1.4) represent schematizally the drift and diffusion of an electron swarm which is produced by an ultraviolet pulsed at the plane x = 0 (at t = 0) and drifts along the x direction under the influence of a uniform external electric field. As the electrons drift towards the collector located at x = d, the swarm remains well - defined in space about its center of mass (dense line) but it spreads out due to diffusion. The velocity of the centre of mass in the

field direction has been referred to the drift velocity  $\omega$ . From the spreading, dx, of the electron Swarm the diffusion coefficient D<sub>c</sub> can be determined.

The energy E' of the electrons in the Swarm has a considerable spreading which is characterized by a function

f ( $E', \frac{E}{P}$ ) at defined by f ( $E', \frac{E}{P}$ ) dE' = fraction of electrons in an energy range dE' about E'; E/P is the 'Pressure reduced electric field' commonly expressed in volts/cm torr at a specified temperature (T) usually indicated as a subscript to the pressure P. In Swarm experiments, the measured quantities are overaged over f(E', E/P) and are recorded as functions of E/P.

As it was mentioned in the beginning of this technique, there are two basic parameters measured in the Swarm experiments given as

- (1) The drift velocity  $\omega$  ( cm/sec ) or(the electron mobility  $\mu$ ' which is related to  $\omega$  by  $\omega = \mu$ 'E ).
- (2) The diffusion coefficient D (  $cm^2/sec$  ) lateral  $D_1$ , or longitudinal  $D_1$ .

The lateral diffusion coefficient  $D_{\rm L}$  ( diffusion at right, angles) to the direction of the drift) cannot be measured alone, but as the ratio  $\omega/D_{\rm L}$ . An independent measurement of  $\omega$  at the same E/P yields  $D_{\rm L}$ . The longitudinal diffusion coefficient ( diffusion in the direction of the drift ) can be

measured directly by the time of flight method. From these measured basic quantaties as a function of E/P, the following Physical parameters were derived through computional techniques

- Mean free path of the electrons L at unit pressure.
- (2) Mean electron energy of the Swarm  $\langle E' \rangle$  as a function of E/P .
- (3) Mean energy loss per collision n as a function of E/P or other convenient parameter such as the mean electron energy.

Using all the above quantaties the following collision cross sections were obtained as functions of the mean energy.

(1) Momentum transfer cross section .

- (2) Inelastic scattering cross section.
- (3) Electron attachment cross section.

As it was mentioned first group of Swarm technique to measure the drift velocity, again divided in to three methods ( Loeb, 1955 ). They are given as

(1) The Townsend method ( Townsend, 1947 ).

- (2) The Electrical Shutter method
- (3) The pulse method ( Christophrous, et al 1966 ).

The drift velocities measured by the use of these methods are generally in satisfactory agreement, the greatest discrepancies occurring in short drift chambers and small values of E/P. It might be pointed out that the errors in the pressure measurement and gas purity account for a substantial portion of the existing inaccuracies. Latger on workers ( Lowke , 1963 ; Grunberg, 1967 ; Frommhold, 1968 ) have measured the drift velocities very accurately. Finally it was concluded by the workers that the drift velocities is sensitive to gas temperature, T and the variation of  $\omega$ with T is useful for obtaining information on the velocity dependence of the cross section for momentum transfer.

Now the second group of experiments in Swarm technique are basically two methods for the measurement of electron diffusion coefficients in gases which are given as

- (1) The Townsend method which allows determination of  $\omega/D_T$  (Humpley et al. 1962).
- (2) The time of flight method which yields  $D_L$ (Hurst et al 1963, Wanyer et al 1967).

The principle of the two methods is shown in the Fig. (1.5). The Townsend method uses at steady - state point source and a plane detector. In constrast, the time of flight method utilizes a pulsed plane source and a point detector. Further in the Townsend method one measures  $\omega/D_L$  while in the time of flight method  $D_L$ . The time of flight method offers some advantage over the Townsend method in that it requires solution of Boltzmann transport equation in one dimension

rather than in three dimensions as in the Townsend method, and in that it measures the distribution in time of arrival of the electron Swarm at a point - this time distribution can be measured with an arbitrarily large number of points with modern multichannel analysers - in contrast to the Townsend method where only two currents are measured.

There is another group of experiments known as Microwave methods. These methods have been developed for the study of electron collision processes in the energy range extending from thermal to several electron volts. These methods require the equilibrium conditions. Various microwave methods have been summarized, discussed, and applied by the old workers ( Brown, 1959; Biondi, 1963; McDanial, 1964; Hasted, 1964; Phelps, Fundingsland and Brown, 1951; Chen and Raether, 1962). Momentum transfer cross sections, electron attachment cross sections are obtained by these technique.

As it was mentions that the Swarm technique provides two basic transport coefficients which are, the electron Swarm drift velocity  $\omega$  and the electron diffusion coefficient D. These two coefficients have been used to obtain the collision cross sections. A number of determinations of  $\sigma_m$  for He, Ar, Kw and Xe from analyses of transport coefficients and data obtained from microwave and total scattering beam experiments have been surved by Frost and Phelps (1964). Elastic scattering of electrons by helium atom has been by the workers ( Crompton , Elfordaol Tory, 1967 ;Golden, 1966 b ), and similar studies for helium and argon have been obtained by the workers ( Golden and Bandee , 1965a, 1966 ).

# 1.6 <u>Recent Experimental Developments in Electron Atom</u> <u>Scattering Measurements</u> :

Since 1970, considerable measurements have been done by the experimentalists for the collision cross sections of electron - atom interactions. Out of these measurements, a large attention was paid by the workers for the differential scattering cross sections of hydrogen, helium and lithium atoms. The measurements of these atoms have been attracted by a number of theorists, because of their import-Justifying the theoritical approximations. in ance These three atoms are the testing problems in the theoretical approaches. During the last 10 years a large variety of differential cross sections of hydrogen, helium and lithium atoms have been reported with increasing accuracies. The experimental methods used for these cross sections have fallen under the beam techniques. Recent measurements of collision cross section for hydrogen, helium and lithium atoms, and the experiments performed for these cross sections are outlined as follows .

The elastic scattering of electrons by atomic hydrogen is the simplest non-trivial atomic elastic scattering process,

and it has therefore attracted a great deal of theoretical attention. Since the difficulty of producing pure ground state atomic hydrogen beams, there have been only two experimental investigations of the elastic scattering of electrons by atomic hydrogen in the intermediate - energy range, both using a modulated atom beam in their crossed beam techn ique. Lloyed et al ( 1974 ) measured the differential elastic scattering cross sections for H and H<sub>o</sub> over the angular range  $15 - 130^{\circ}$  at a number of energies. They also obtained the ratios of the total cross sections for elastic scattering of electrons from H and H<sub>2</sub> . Immediate to these measurements, absolute differential cross sections were obtained by Williams ( 1975 ) using a quite different procedure. Firstly, absolute cross sections values in THe were calculated by making a phaseshift analysis of the elastic scattering from He around the ls  $2s^2$  s resonance. From measurements of relative beam flux densities for He and molecular H beams, and of the dissociation fraction of 3000°C molecular H beams, absolute cross section values in atomic H were then determined. The experimental technique used for these measurements was similar to those techniques of earlier workers ( Fite and Brackman, 1958; Turner et al 1965; McGowan and Clarke, 1968 and M.Gowan et al 1969 ), with improvement in the electron beam optics, angular resolution and momentum selection of both the incident and scattered electrons, single

pulse counting, digital recording and automatic operation of the apparatus. With this refined technique Williams and Wills (1975) have obtained the absolute differential cross sections for electrons losing 10.2 eV in-exciting the n = 2 state of atomic H, over the angular range 20 to  $140^{\circ}$  for the incident energies of 54 to 680 eV. Afterwords Williams (1975) has measured elastic cross sections from atomic H over the angular range 10 to  $140^{\circ}$  for the incident energies of 20 to 680 eV. Williams claimed an accuracy of  $\pm 11$  % for his measurements. Later a Van Wingerden et al (1977) have measured absolute elastic cross sections for H at incident energies 100 and 200 eV over the angular range 20 to  $130^{\circ}$ . The experimental apparatus, method and procedure for these measurements are identical to those discussed by Jonsen et al (1976).

In the experimental findings of collision cross sections for electron - helium interaction, there have been considerable data reported by the workers. Setturaman et al (1974) have measured differential elastic cross sections for helium at the incident energies 100 to 500 eV, over the angular range between 30 and  $150^{\circ}$ . The data have been normalized to Brokergs (1969) measured cross sections for 500 eV electrons at  $60^{\circ}$ . Bromberg (1974) measured elastic cross sections for helium atom at the incident energies between 200 and 700 eV over the angular range 2 to  $30^{\circ}$ . Afterwords Mc Conkey and Preston (1975) measured elastic cross section for helium in the angular range 20 - 90° and the energy range 1.5 -100 eV. The spectrometer used in these measurements was similar to Preston et al (1973). Absolute elastic differential cross sections have been measured by Kurepa and Vuskovic (1975) for helium atoms, at incident energies 100, 150 and 200 eV, over the angular range between 5 and 150°. These values have been determined from experimentally, measured quantities without normalization to other results. Jansen et al (1976) have constructed an electron spectrometer for the study of elastic and inelastic processes. Using this spectrometer they measured absolute differential cross sections for Helium at impact energies between 100 and 300 eV and scattering angles between 5 and 55°.

Out of all these measurements for hydrogen and helium, the most recent measurements have been done by Registar et al ( 1980 ) for the differential, integral and momentum, transfer cross sections. They have reported the results for the impact energies 5 to 200 eV. Angular distributions for elastically scattered electrons were measured in a crossed - beam geometry using a collimated differentially pumped atomic - beam source which requires no effective path - length correction. Below the first inelastic thresold the angular distributions were placed on an absolute scale by use of a phase - shift analysis. Above this thresold the angular distributions from 10 to 140° were fitted using the phase shift technique and the resulting integral

cross sections were normalized to a semiempirically derived integral elastic cross section. Depending on the impact energy the data were estimated to be accurate to with in 5 to 9 % . Before Register et al (1980) measurements, Dalba et al (1979) have measured absolute total cross sections for electron - helium elastic scattering in the energy range 100 - 1400 eV. In the year of 1980 Blaauw et al have carried out accurate measurements of the total cross sections for electron - helium elastic scattering in the energy range

30

Comparatively very less data have been reported for the interaction of electron - Lithium atom. No direct measurements have been reported for lithium. Perel et al ( 1962 ) and Buke et al ( 1969 ) have measured total cross section for lithium. The measurements have been refined and extended to higher energies by Kasdam et al ( 1971 ). Williams (1976.) measured differential and integral cross sections for elastic and for the excitation states of lithium. And elastic momentum transfer cross sections were obtained at incident energies range between 5 and 60 eV. The experimental method used for these measurements was similar to Chutjan et al ( 1973 ) and Williams et al ( 1974 ). An electron - impact spectrometer has been used for these measurements. The differential cross sections were extrapolated to 0 and 180° and integrated to obtain the corresponding integral cross sections.



Fig. 1.1 Schematic drawing of a collision experiment



Fig. 1.2 Ramsauer's apparatus for measurement of collision cross-sections.



Fig. 1.3 Illustrating the principle of the method of measuring angular distribution of electrons scattered in gases and vapours.



Fig. 1.4 Schematic of electron swarm at constant E/P



Fig. 1.5 The Principle of Townsend method and Time of flight methods.

• ~