This thesis describes the experimental study of fast electron and ion impact ionization studies of atoms, small molecules and large biomolecules alongwith comparison with different state-of-the-art theoretical models. In the first part, keV energy electrons were used to carry out the electron impact ionization studies of diatomic molecules N_2 and O_2. The incident electron impact energies were varied between 2 and 8 keV. The keV energy electrons were generated from an electron gun and further focussed with sets of Einzel lenses, electrostatic deflectors and several apertures of varying dimensions. In the second part, the highly charged heavy ions were used for the collisional experiments of various gaseous targets and biomolecules. For this purpose, two different accelerators i.e., the Pelletron accelerator and the electron cyclotron resonance (ECR) ion accelerator were used. The MeV C^{6+} ions were obtained from the 14 MV Pelletron accelerator and the hundreds of keV energy protons were extracted from the 14.5 GHz ECR ion accelerator at TIFR, Mumbai. The ECR ion accelerator machine has a maximum extraction voltage of 30 kV. The plasma chamber, Einzel lens and the bending magnet are all placed together on an isolated high voltage (HV) deck which can be raised upto 400 kV. The experiments are performed under high vacuum conditions. Electrostatic quadrupole triplet lenses and deflectors are used for steering and focussing of the ion beam. All the experiments were carried out using ejected electron spectroscopy technique involving hemispherical electrostatic analyzer. The double differential cross section (DDCS) of the electrons emitted from the different targets in collision with the projectile beam (electrons/ions) were measured. The DDCS were obtained as a function of ejection angle and emission energy of the electrons. Integrating the DDCS over the emission angle or energy provided the single differential cross section (SDCS) and further integration yielded the total ionization cross section (TCS). An effusive vapour source was used for carrying out the experiments with the biomolecular targets which are otherwise obtained in powder form commercially. A oven assembly was prepared for this purpose. The powder of uracil and bromouracil was placed inside a metallic oven and heated gradually to produce a vapour of the target and a thickness monitor was placed above the jet nozzle to monitor the density of the vapour effusing out of the jet nozzle. Various theoretical models were also used to compare the experimentally obtained DDCS. In case of electron impact ionization studies, the DDCS were compared with the CTMC (classical trajectory Monte Carlo) calculations and the CB1 (First Born approximation with correct boundary condition) calculations. Further, the CSP-ic (complex scattering potential - ionization contribution) approximation was used to deduce the total ionization cross section which were compared with the experimentally obtained total ionization cross section results. In case of keV energy proton impact and MeV energy bare C ions impacting on gaseous targets (He, CH_4, O_2) and biomolecules (uracil and bromouracil) the data were compared with the CDW-EIS (continuum distorted wave – eikonal initial state) approximation.

The Young type interference effect obtained from the ejected electron spectrum for multi-electronic diatomic molecules, N_2 and O_2 under fast electron impact were investigated in the present experiments. A clear signature of the interference oscillation was observed for both the molecules. The DDCS ratios i.e. the ratio of DDCS for molecular -to- atomic target clearly reveal the oscillations for each emission angle. In addition, the forward-backward angular asymmetry provided a convincing evidence of the interference mechanism. The signature of second order interference was also seen through a oscillatory structure with double frequency in the asymmetry parameter. The angular dependence of the frequency of oscillation under electron impact showed marked difference from that for heavy ion induced ionization. Further, detailed measurements of the DDCS, SDCS and TCS for e-impact ionization of N_2 are studied over the incident electron energy range from 3 to 8 keV.

In the second part, the collision dynamics for keV and MeV energy ion impact ionization of different atomic and molecular targets were studied. The absolute DDCS for electrons emitted from atomic target He and molecular targets CH_4 and O_2 were measured in collisions with 200 keV/u protons. Further for O_2, measurements were also performed by changing the projectile to 5.5 MeV/u C^{6+} ions. These two projectiles were chosen such that they had large difference in velocity (v_p) and charge state (q_p), but their perturbation strength (q_p/v_p) were nearly the same. The angular distribution showed a distinctly different character for the two different projectiles. In case of 200 keV/u protons, the asymmetry between the extreme forward and backward angles were much larger compared to that obtained for 5.5 MeV/u C^{6+} ions. The large asymmetry provided signature of the fact that post collision interaction and two center effect play a dominant role in case of 200 keV/u protons. Further, a quantitative measurement of the angular asymmetry parameter for the three different targets He, CH_4 and O_2 impacted by the same projectile showed signature of saturation effect at high velocity of the emitted electrons. From the study of the angularasymmetry parameter it was found the perturbation strength q_p/v_p (charge state/ velocity ofprojectile) alone cannot characterize completely the asymmetry and two-center effect. The comparison of the e-DDCS with the CDW-EIS calculations showed an excellent agreement for 5.5 MeV/u C^{6+} ions impacting on O_2 whereas in the intermediate energy range (i.e., 200 keV/u protons), the calculations provided a qualitative agreement with deviations existing quantitatively.

Further measurements were carried out for the ion impact ionization of uracil, a nucleobase of RNA and bromouracil, a halouracil. The double differential cross section for electron emission from uracil and bromouracil were measured in case of 42 and 66 MeV C^{6+} ions obtained from the 14 MV Pelletron accelerator. This study was further extended for 200 keV protons obtained from the ECR ion accelerator. The low energy electrons emitted from the biomolecules can damage the DNA/RNA of the malignant cells by causing strand breaks. Several strand breaks within a localized region can result to cell death which can prevent the malignant cells from multiplying further in human body. Thus the amount of production of low energy electrons is extremely important in hadron therapy. From the present series of DDCS measurements, a quantitative estimate of the enhancement in electron emission from bromouracil compared to uracil has been presented in this thesis. For either projectiles at different energy range, a substantial enhancement in low energy electron emission from bromouracil have been obtained. The present results clearly indicate the radiosensitive property of bromouracil which can be used for modelling doses in hadron therapy.