Radiative electron capture

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1 Radiative electron capture

Radiative electron capture is a time-reversed process of photoelectric e ect. When a high speed charged ion collides with a neutral target atom, the charged ion can capture an electron from the target atom. During this process, a photon may be emitted. Such a process of emission of a photon by absorbing an electron is called as radiative electron capture. The energy of the emitted photon is calculated as the sum of the kinetic energy of electron and the binding energy of the shell in which the electron is captured. The energy of emitted photon is independent of target material [1]. The phenomenon is observed for various materials such as sulfur, chlorine, bromine, etc which have energy range between 10 MeV and 140 MeV. The target material can ranges from boron to uranium and tungsten .

If the target charge is small when compare with the colliding ions and the binding energy is small in comparison with the kinetic energy of electrons, then the following assumption can be made: the collision can be considered between a free electron and a highly accelerated ion.

2 Experiment

The rst step in the process of inverse photoelectric e ect is to produce charged ions. This can be achieved by colliding stationary ions with highly accelerated electrons in specialized accelerators. For example, Super-EBIT at Livermore can produce ions with di erent ionization charges [2]. In the experimental setup, a storage unit is used which is called as experimental storage ring. It is a circularly shaped part which consists of several number of devices such as cooler, rf cavities, gasjet target, etc. The purpose of this storage unit is to accumulate the ions and keep them cool and maintain them in a constant velocity.

In radiative recombination, a moving ion capture an electron from an stationary atom. If the ions are highly energetic and their charge is very high comparing with the target photon, then we can realize radiative electron capture.

A gas is expanded through a nozzle to produce a gasjet. Gases such as hydrogen, nitrogen, argon, krypton, xenon can be used as targets [4]. Due to the interaction between the Coulomb capture and radiative emission capture, we have di erent e ects for di erent energies of ion beams. While K shell radiative emission capture dominates in the high energy region of ion beam, Lyman transition happens in the low energy regime. An radiative electron capture can be given by the following equation:

$$P^{q+} + T \rightarrow P^{q-1} + T^{+} + \text{photon}; \qquad (1)$$

where P^{q+} is a positive ion and T is the target atom. $P^{q\,1}$ says that the positive ion looses one electron and T^{+} says that the target gains that electron. The equation says that a photon is created.

3 Theory

The electron capture cross section is given by

$$= \frac{N_{U^{91+}}}{\quad} \; Z \; \frac{d^{REC}_{K}}{\quad} \tag{2}$$

where $N^{U_{91+}}$ is the number of uranium atoms. $N^{K\ REC}$ is the number of emitted photons. The expression inside the integral gives the di erential cross section. The time dependent Hamiltonian for an electron involved in the collision is given by

$$H(t) = \frac{p^2}{2m_e} + V_T(r) + V_P(r \quad R(t)); \tag{3}$$

where V_T stands for potential for the target and V_P stands for potential for the moving ion. The cross section for K electron is obtained as [5]

$$=2^{\,6}Z^5 \quad \frac{m_e c^2}{h!} \quad {}^5 \quad c_0 2\,{}^3 \quad {}^3 \quad \frac{4(2)}{3} \quad + \quad \frac{}{+1} \quad 1 \quad \frac{1}{2^{\,2}} \quad \ln \quad \frac{1+}{1} \quad : \tag{4}$$

The di erential cross section for radiative recombination is given by

$$d = \frac{(2\,)^4}{v_i} \; j\,j^2 \; (\,{}_a + k_f^0 \quad p_i^0)dk_f \tag{5}$$

References

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