LETTERS TO THE EDITOR

PROTON-INDUCED EXCITATION-AUTOIONIZATION

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ATOMS (ions) are frequently excited to certain quasi-bound states (imbedded in lower continuum) which in turn decay by electron rather than photon emission (e.g. autoionization). Excitation of a single tightly bound inner-shell electron is one of the main processes which gives rise to such states. The excitation to these autoionizing levels in atoms (ions) can be achieved by bombardment of any charged particles like electrons, protons, etc. Such studies are of great interest in studying various physical phenomena in astrophysics and plasma physics dealing with ionization equilibria.

Our previous studies[1-3] successfully considered the electron impact excitation of the autoionizing levels in alkalis which also led to good experimental understanding[4]. However, the upcoming ionization experiments[5] demand similar attention using proton as projectile to explain excitation-autoionization contributions. It was therefore considered useful to study cross-sections for proton impact excitation of the autoionizing levels in lower alkalis which could also be utilised in calculating their excitation rates, etc. In the present note, we report the total excitation cross-sections for the lowest autoionizing levels in Li, Na and K using first Born approximation[6]. The problem has been treated as a simple one-electron excitation from an initial orbital to a final orbital. The coupling of the final level to the continuum is not considered explicitly except in assuming that once the autoionizing level is excited it decays non-radiatively to the continuum and the excitation cross-section is in fact the cross-section for autoionization.

In the first Born approximation, the total cross-section σ for excitation of an atom from its initial state i to final state f due to proton impact is given by (atomic units are used)

$$\sigma(i,f) = \frac{8}{s^2} \int_{q_{min}}^{\infty} |F_{if}(\vec{q})|^2 q^{-3} dq \,(\pi a_o^2) \qquad (1)$$

where

$$F_{if}(\vec{q}) = \int \psi_f(\vec{r}) \exp(-i\vec{q}.\vec{r}) \psi_i(\vec{r}) d\vec{r} \qquad (2)$$

with

$$s^2 = \frac{m_e v_p}{2 I_H} \quad \text{and} \quad q_{min} \approx \frac{\Delta E_{if}}{2s} \left[1 + \frac{m_e \Delta E_{if}}{4 M^2 s^2} \right]$$

$\psi_i(\vec{r})$ and $\psi_f(\vec{r})$ are the wavefunctions of i and f states respectively and ΔE_{if} is the threshold energy in units

of I_H the ionization potential of hydrogen. M is the reduced mass. m_e is the electronic mass.

Similar to the approximations made earlier, we consider the excitation process as involving the transitions $1s$-$2s$ in Li, $2p$-$3s$ in Na and $3p$-$4s$ in K. We represent the radial part of the wavefunction for both s- and p-orbitals by the very accurate Hartree-Fock double ζ functions taken from the compilation of Clementi and Roetti[7]. The scattering amplitude $F_{if}(\vec{q})$ (equation (2)) for both s-s and p-s transitions have been first obtained in closed form and then the total cross-section σ in each case is obtained by numerical integrations. The values for the excitation thresholds (lowest values are taken) in Li and Na are taken from Pegg[8] and for K from Nygaard[9].

TABLE 1

Energy (keV)	Cross-section (in πa_o^2)		
	Potassium	Sodium	Lithium
0.5	2.658⁻⁴*	9.164⁻⁵	—
1	5.050⁻³	2.624⁻³	—
2	5.795⁻²	1.477⁻²	—
3	1.057⁻¹	2.444⁻²	—
4	1.289⁻¹	2.909⁻²	—
5	1.367⁻¹	3.046⁻²	4.116⁻³
10	1.168⁻¹	2.503⁻²	1.011⁻²
15	9.113⁻²	2.027⁻²	1.289⁻²
20	7.005⁻²	1.755⁻²	1.355⁻²
25	5.417⁻²	1.575⁻²	1.317⁻²
30	4.126⁻²	1.433⁻²	1.233⁻²
40	2.359⁻²	1.198⁻²	1.027⁻²
50	1.334⁻²	9.950⁻³	8.347⁻³
60	7.502⁻³	8.194⁻³	6.739⁻³
80	2.344⁻³	5.471⁻³	4.420⁻³
100	7.075⁻⁴	6.634⁻³	2.960⁻³

* The superscripts denote the power of ten by which the quantity is to be multiplied.

Our results are displayed in table 1. No comparable direct experimental results are available as yet for Li, Na and K. It is well known[6] however, that excitation cross-sections become equal for very high impact energies with equal velocities for the incident electron and proton. This could be the basis of an indirect comparison as no other theoretical results for proton impact excitation of these autoionizing levels are available in literature. Therefore, on qualitative comparison with our earlier electron[3] impact results, we find that most of the variations (structure) of cross-sections with

energies of proton have similar features except that the peaks (the maximum) of cross-section curves are larger than the corresponding electron impact case for all the atoms *e.g.* Li, Na and K, individually. Also at *very high energies in both cases (i.e. by electron and proton impact)*, the cross-sections tend to each other. We finally conclude from the present work that the proton impact autoionization contribution in lower alkalis are also of considerable significance and these cross-sections when used in collision physics could provide important changes.

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GLAUCONITE IN THE QUILON LIMESTONE (EARLY MIOCENE) OF COASTAL KERALA SEDIMENTARY BASIN

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THE fossiliferous limestones and clays, interbedded with fine to medium grained sandstones and carbonaceous clays of the Tertiary sedimentary sequence of the coastal Kerala are known as the Quilon Beds[1]. These are supposed to be overlain by the Warkalli Beds, comprising terrigenous sandstones and variegated clays that are associated with impure lignite. The fossil assemblages of the Quilon Beds indicate an Early Miocene (Aquitanian-Burdigalian) age[2].

Glauconite has been recorded within the hard and compact fossiliferous limestones of the Quilon Beds which occur as thin bands around Quilon (8° 53': 76° 35'30") and at Padappakara (8° 58': 76° 38'). Glauconite also occurs in limestones at depths of 18-20 m and 200-330 m at Mayyanad (8° 50': 76° 39') and Nirkunnam (9° 24': 76° 21'45") (near Ambalapuzha), respectively. This note is intended to report perhaps for the first time the occurrence of glauconite within these limestones.

Glauconite occurs as pellets and blebs in the micritic matrix of the limestone, and also as in-fillings of the chambers of the microfossils of foraminifera and gastropods. The limestone is a biopelmicrite. Apart from glauconite it contains fossil shells of various forms and sizes and faecal pellets in a micritic matrix. The composition of the limestone varies from CaO - 45.7%, MgO—1.3%, to CaO—16.3%, MgO—20.6%.

Grain characteristics

The body colour of glauconite is either light green or dark grass green. Both these varieties are closely associated with the filling materials of the chambers of the fossils as well as with the calcite crystals of the matrix as pellets and blebs. The shape of most of the glauconite pellets is round to oval. The fossil in-filled glauconite grains are either irregular or they take the shape of the empty chambers. Granulometric analysis indicates that the glauconite pellets range in size from less than 50 to 200 microns with a mode at 75 microns, and the glauconite filling of the fossil tests from 50 to 500 microns and above with a mode at 175 microns. The glauconite filling of the fossil tests is thus coarser than the glauconite pellets.

Mode of Formation

Glauconite within shell limestones usually forms by alteration of the filling materials of the empty fossil tests[3]. The yellowish green variety of glauconite that fills the tests of fossils of the Eocene carbonate rocks of Mikir Hills is considered to be authigenic[4], whilst a detrital derivation has been ascribed to the dark grass green variety. The intensity of the dark colouration of glauconite depends on the degree of later oxidation[4]. Under this scheme, the occurrence within the limestone under study of both the yellowish green and the dark green varieties of glauconite, indicating different oxidation conditions, is problematic. This feature may, however, be explained by the existence of a reducing micro-environment within the tests of the organisms even though the overall environment at the depositional site was oxidising during digenesis[5,6]. Glauconite requires a reducing environment for its development, but it can form even in well-oxygenated environments if there is an adequate supply of organic matter. It forms on the present-day sea floor within the tests of foraminiferids where the micro-environment