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CHEMI-IONIZATION – EXPERIMENT, THEORIES, GEOCOSMICAL PERSPECTIVES

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Abstract. A systematic presentation is given of the current state of experimental and theoretical studies of elementary chemi-ionization processes with Rydberg atoms participation. General conclusions are presented about their effect on the macroscopic properties of the geocosmical plasmas. The considered processes are interesting since they may be regarded as prototype of the elementary processes of the light excitation energy transformation into electric one.

1. INTRODUCTION

Elementary ionization processes involving highly excited Rydberg atoms (RA) in geocosmical plasmas traditionally attracts researchers attention (see, for example, Mihajlov et al. 2003, Klyucharev et al. 2007). In the first place it may be connected with the plasma characteristics of many types of astrophysical objects. Such plasma parameters evolve with the universe evolution. Due to the interest in chemi-ionization processes with the RA participation several methods of rate constants calculation were elaborated. The systematic experimental (Devdariani et al. 1978) and theoretical (Mihajlov and Janev, 1980; Duman and Shmatov, 1980) studies of the RA chemi-ionization were started relatively recently. The theoretical approaches were later complicated taking into account effect of the Rydberg electron (RE) stochastic instability during one collision (Bezuglov et al., 2003). The studies of nonlinear mechanisms have shown that the so called regime of dynamic chaos should be considered as typical, rather than exceptional, situation (Zaslavsky 1988). Obtained results show that the resonant mechanism of the chemi-

ionization (Mihajlov and Janev, 1980) and stochastic approach (Bezuglov et al., 2003) are adequate in a wide range of the RA principal quantum numbers and temperatures (Klyucharev et al., 2007). Note that the theoretical studies were stimulated as a rule by the experiments started in 1978 (Devdariani et al., 1978). Such type of chemi-ionization processes with appreciable rate constants k are being incorporated in an increasing by rigorous manner in kinetic equations for low temperature plasmas. This refers in the first instance to studies involving inert gas and alkali metal atoms in the lowest of all the possible excited states X*. Two possibilities are then found to arise. They are:

1. Total excitation energy greater than the ionization potential of an individual atom ($\sum U^* > U_i$)

2. Total excitation energy smaller than the ionization potential ($\sum U^* < U_i$)

Case (1) includes the ionization of the atoms of hydrogen, inert gases, the halogens, nitrogen and oxygen, whereas case (2) includes the ionization of alkali metals, rare-earth elements, uranium and most atoms. In addition to ionization (1a) we can have transitions (1b) in which the upper highly excited (Rydberg) states become populated:

$$X^* + X^* \rightarrow X_2^+ + e \quad (1a)$$

$$X^* + X^* \rightarrow RX + X \quad (1b)$$

These states takes part in associative and Penning-type ionization processes (1), (2)

$$RX + X \rightarrow X_2^+ + e \quad \text{AI} \quad (2a)$$

$$RX + X \rightarrow X^+ + X + e \quad \text{PI} \quad (2b)$$

$$\rightarrow X^+ + X^-$$

Optical excitation of gas media has special features in an intermediate range of radiation field intensities. On one hand, intensities in this range are too small for processes of multi-photon atomic ionization or ionization stimulated by radiation to take place. On the other hand, secondary processes involving excited atoms (molecules) substantially affect properties of the medium even at these intensities. From the expression for the Debye radius of charge screen in plasma it follows that electron concentration N_e must be more than 10^7 cm^{-3} for an excited medium with a typical dimension of 1 cm and $T_e \approx 10^3$K. Fig. 1 illustrates the range of plasma parameters at which the ratio of ionization processes rate in pair collisions of cesium atoms in lower excited states to the rate of standard electronic radiative-collisional ionization is equal to unity (Bezuglov et al. 1994). It's seen that it exist a wide range of parameters of low-temperature plasma in which the collisions of the heavy particles make the dominant contribution to ionization.

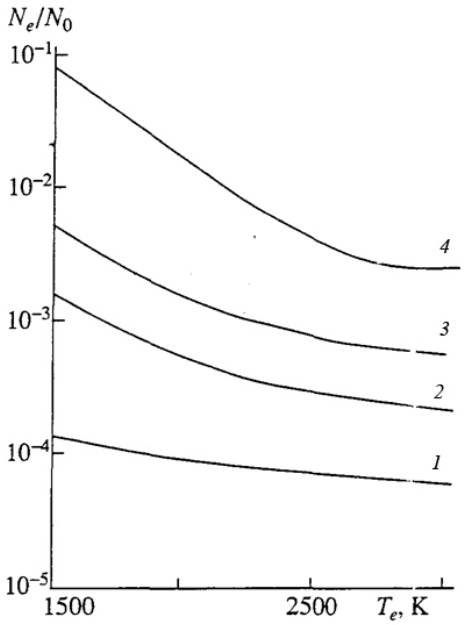
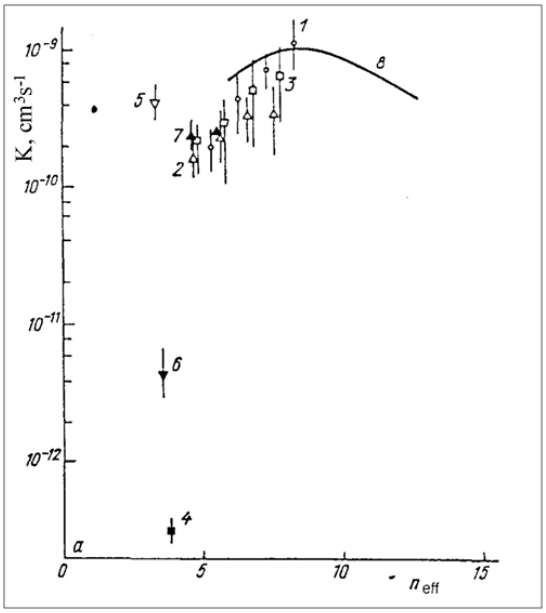


Figure 1: Concurrence between AI and radiative-collisional ionization in Cs plasmas.

Today alkali-metal plasmas became the subject of direct geocosmical investigation. For instance, sodium clouds are found in the atmosphere of Io (Klyucharev et al. 2007). If an absorbing medium is irradiated with light, an ansamble of excited particles is formed in it. In the general case it means the creation of the ionized source. These processes relate to the category of photochemical (chemi-ionization) reactions and cannot be considered in isolation from the stage of light excitation. At the transition to optically thick case the role of collsional processes involving excited atoms and molecules increase. Chemi-ionization assumes the formation of an intermediate quasi-molecular complex. That complex stabilization or its decay with formation of charged fragments is determined by a set of parameters, such as the nature of colliding particles and peculiarities of their interaction potentials. AI processes with the participation of alkali atoms in the resonant excited states in this case must be treated above all as a process with the energy threshold and depends significantly on the particle relative velocity distribution. Fig. 2 shows experimental data for the reaction (2) in the mercury, cadmium and rubidium cases (Klyucharev et al. 2007). The effective quantum number n_{eff} was determined by the expression $n_{eff} = (2(U_i - \sum U_n))^{-1/2}$. Where U_i is the ionization energy of atom and $\sum U_n$ is the sum of the atom excitation energy.



1 – Rb(n P)+Rb(5 S) (520 K)

2 – Rb(n D)+Rb(5 S) (470 K)

3 – Rb(n S)+Rb(5 S) (470 K)

4 – Rb(5 P) +Rb(5 P) (470 K)

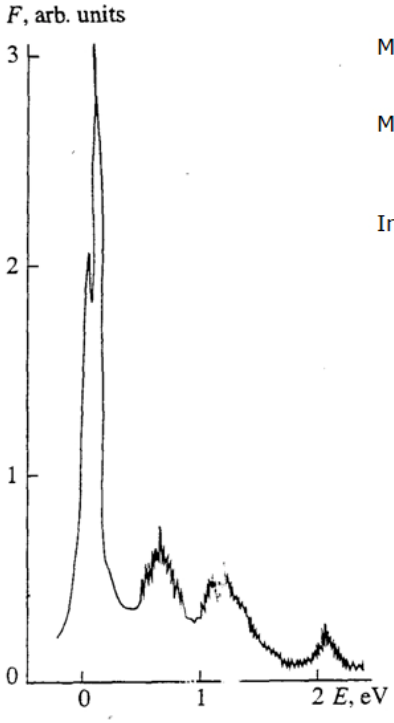
5 – Hg (300 K)

6 – Cd (575 K)

7 – Rb(n²D)+K(4 S) (440 K)

8 – DSMY model calculations for Rb (520 K)

Figure 2: Chemi-ionization rate constant for as a function of the n_{eff} for Rb, Hg, and Cd.



Main peak – primary electrons produced in AI

Maximum at E=2.1 eV is caused by collisions of the second kind

Intermedia maxima results from the photo- and collisional ionization RA via pooling processes

Figure 3: Energy spectrum of electrons with an energy from 0 to 2.1 eV formed during resonance Na vapor excitation.

Fig. 3 illustrates the energy spectrum of electron produced on (1a) channel (sodium) obtained by method of electron spectroscopy (Bezuglov et al., 1994). In addition to the main peak of the primary electrons near the zero energy we can see the maximum at E_a=2,1 eV which is caused by collisions of the second kind

$$Na^* + e \rightarrow Na + e^*, \quad (3)$$

and intermediate maxima from the photo and collisional ionization of highly excited sodium states populated via the energy pooling collisions between two $Na(3^2P)$ atoms

$$Na(3^2P) + Na(3^2P) \rightarrow Na(n^2L) + Na(3^2S) \quad (4)$$
$$Na(n^2L) + Na(3^2S) \rightarrow Na_2^+ + e$$

For example that case at the density of sodium normal atoms $N_0 \approx 10^{13}$ cm^{-3} photoplasma ($N_e > 10^{13}$ cm^{-3}) is formed at a radiation power density as small as $I \approx 10^2$ W/cm^2. Another effective channel leading to excited atoms creation is the ion-electron recombination processes in low temperature weakly ionized layers of helium-rich DB white dwarfs and solar photosphere (Mihajlov et al. 2003). In those conditions the direct chemi-ionization and opposite to its chemi-recombination processes

$$He^*(n) + He \leftrightarrow He_2^+ + e, \quad (5)$$
$$He^*(n) + He \leftrightarrow He^+ + He + e, \quad (6)$$

are absolutely dominant over another ionization an recombination processes for the lower effective temperature T_{eff} as in hydrogen case. With the increase of temperature the influence of processes (5,6) decrease. For instance, in white dwarf atmospheres their contribution are reducing from 100 for T_{eff}=12000K and 10 for T_{eff}=16000K down to 0,1 for T_{eff}=20000K and 0,01 for T_{eff}=24000K. Regarding the relative importance of the (5,6) reactions in comparison with photorecombination

$$He^+ + e \rightarrow He^*(n) + e \quad (7)$$

leading to the lower excited states population, the theoretical results (Mihajlov et al. 2003) show that the processes (5, 6) may to prevail within the effective temperature range $12000 \leq T_{eff} \leq 30000$K. About 100% of the full photorecombination flux in hydrogen leads to the population states with $1 \leq n \leq 7$ for $T_e \geq 3500$K, 80% for $T_e \approx 1150$K and 68% for T_e=350K (Massey and Buzhop 1952). For T_e>24000K electron impact excitation and ionization, as well as three particles recombination resulting in high excited states population are dominant. Note, that dissociative recombination (5) leads to Rydberg atom excitation with the baunding energies of the order of about the dissociative energy of the molecular ions.

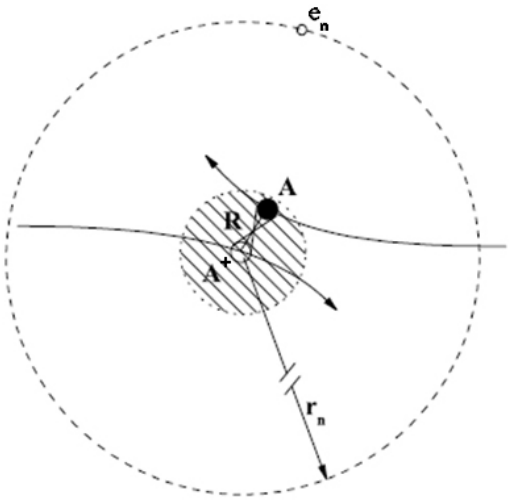


Figure 4: Schematic illustration of RA+A collision (the region of R where the outer electron is collectivized is shaded).

The influence of the processes (5) and (6) on the population of highly excited atomic states in the case of a helium-rich atmosphere is considerably larger than in the solar hydrogen one. The reason for this is much higher ionization potential of helium atoms in comparison with hydrogen so that for the same pressures and temperatures the ionization degree of the helium plasma is several orders of magnitude lower than that of the hydrogen case.

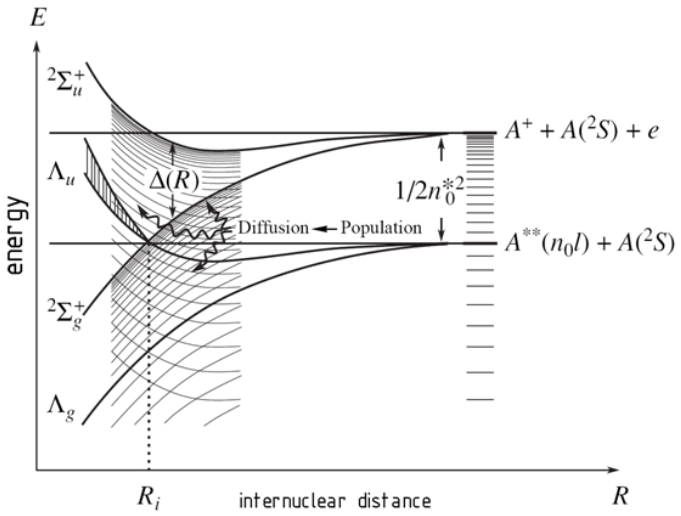


Figure 5: Illustration of the mechanism of the RA + A collision process.

In the white dwarfs atmosphere conditions the ratios of the corresponding fluxes the full (5) + (6) and dissociative (5) recombinations decrease from 0,6 (7000K) to 0,16 (30000K) for n=3 and from 0,12 (7000K) to 0,03 (30000K) for n=10. Obtained in (Mihajlov et al. 1997) results show that chemi-recombination processes in hydrogen have an important role in the large region of the T_{eff} around the temperature minimum T≈4000K in the solar atmosphere. Fig. 6 show the theoretically obtained results for total chemi-ionization rate constants in hydrogen with 1000K ≤ T ≤ 6000K and for principal quantum numbers n=4÷25 (Mihajlov et al. 1997).

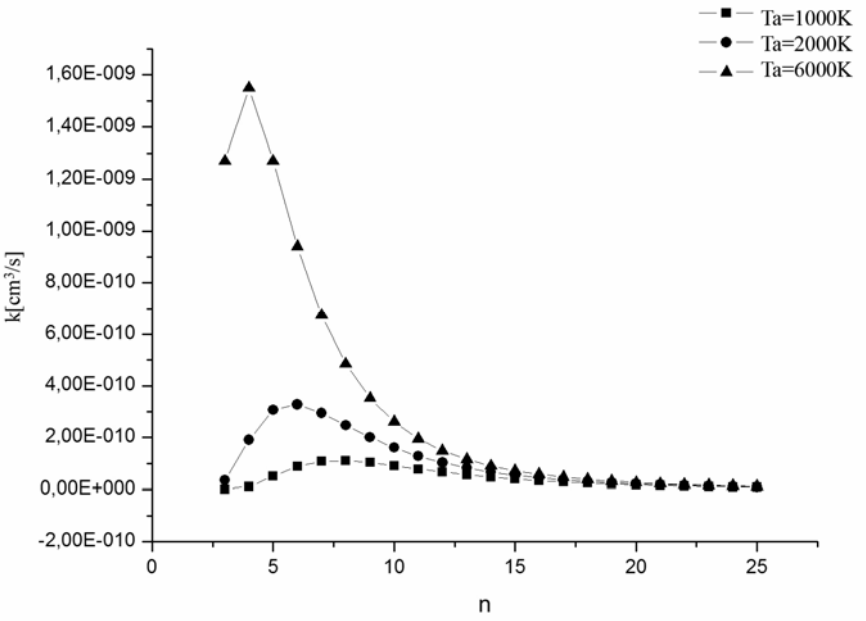


Figure 6: Theoretically obtained results for total chemi-ionization rate constants in hydrogen.

Fig. 7 presents the results obtained within the frame of the theoretical resonant-ionization model – the AI rate constants for chemi-ionization in Na (n_{eff}^2P)+Na collisions; dotes: cb (crossed beam) - experiment, T=600K, (Boulmer et al. 1983), the full curve: cb(T=600K), c (cell),T=720K, theory (Ignjatović and Mihajlov, 2005).

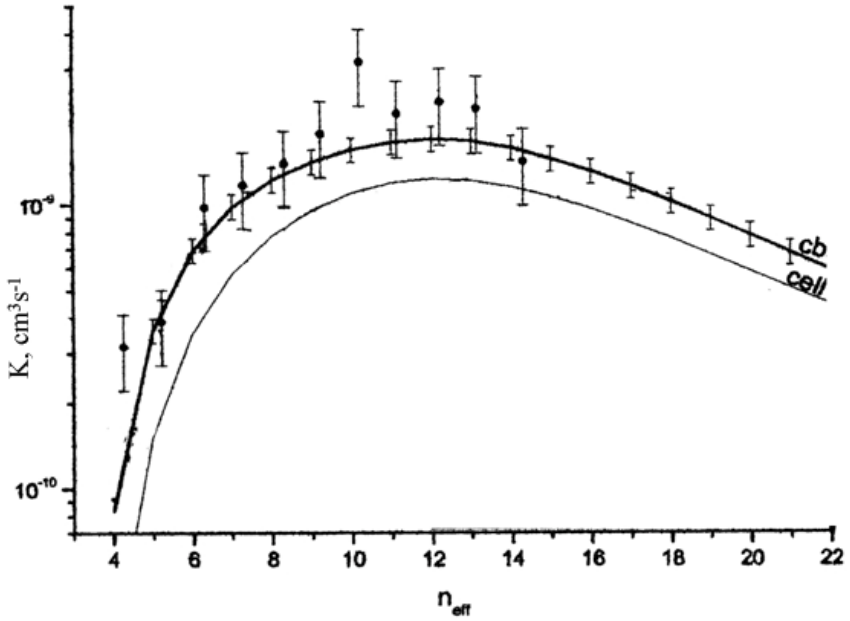


Figure 7: The rate constants for chemi-ionization in Na collisions.

Known are the analogies between the cosmical and earth's laboratory plasma conditions. For instance, between processes in laser induced hydrogen plasma and atmospheres of cool white dwarfs G 226-229 (Kielkopf et al., 2004).

2. RESONANT MECHANISM OF THE COLLISIONAL IONIZATION

Collisions leading to the ionization are realized for the internuclear distances R, $r_0<R<r^*$, see Fig. 4. Where r_0 and r^* are the classical radii of the excited and unexcited atoms correspondingly. For the small internuclear distances the repulsive quasi-molecular (A*+A) curve conforms to U_2 potential curve of the molecular ion and (A*+A) attractive potential to the U_1 one. Well-known method of AI and PI calculation using so-called "resonant mechanism" (RM) is effective for the internuclear distances region $R \leq r^* \sim n^2$ (a.u.) (Smirnov and Mihajlov, 1971). In literature RM was used for the different approximations for symmetrical cases: three semiclassical and one quantum mechanical. It was shown in (Mihailov and Janev, 1980; Smirnov and Mihajlov, 1971) that in some average potentials along the unique trajectory the dipole moment D(R) of $(A^+ + A)$ system can be represented as a function of the time and ΔR, namely D(R(t)) = F(R(t), ΔR), were R(t) is the internuclear distance in the moment of the time t and ΔR is the splitting between U_1 and U_2 terms (see Fig. 5).

$$\Delta R(R) = U_2(R) - U_1(R) \qquad (8)$$

According to (Devdariani et al. 1978) the cross-section σ_{ci} of the processes (1) within the framework of the charge-exchange hydrogen model for n>4

$$\sigma_{ci} \sim \sigma_{RCE}/n^5 \quad (9)$$

where σ_{RCE} is the resonant charge-exchange cross-section (a.u.). The cross-section decreases as n^{-5} (the photoionization cross-section's dependence is proportional to n). In (Duman and Shmatov, 1980) was proposed a model, which makes it possible to obtain analytic expressions for the cross section and for the rate constant of the RA in their own gas. The rate constant of the ionization assumes a maximum value in the region $n_{max} \sim \frac{1}{2}T^{-\frac{1}{2}}$. At sufficiently small n ($n<n_{max}$) the rate constant $k(n) \sim \exp(n)$ increases exponentially with increasing n and ionization proceeds via the AI mainly. At large n ($n>>\frac{1}{2}T^{-\frac{1}{2}}$), $k(n) \sim n^{-3}$ and AI can be neglected. Recently, the RM (deterministic approach) method was used for the investigation of processes in slow non-symmetric atom-Rydberg atom collision (Ignjatović et al., 2008).

3. THE STOCHASTIC DYNAMIC APPROACH

Existing to that time DSMJ theory (Mihajlov and Janev, 1980; Duman and Shmatov, 1980) treats the chemi-ionization processes (2a, 2b) deterministically as the interaction of an unique covalent bound Rydberg quasi-molecular state with the ionization continuum. The stochastic model (SM) takes into account diffusion like migration of RE in the energy space prior ionization.

The first results on the investigation of chemi-ionization in RA-atom collisions have been summarized in (Klyucharev and Lazarenko 1980). The more substantial disadvantage of the previous works was the neglecting of the large number of crossings of the initial covalent term Λ_u with ion term $^2\Sigma_g^+$ (see Fig. 5). In the case of multiple crossing of terms, the attempt to take into account each particular crossing in theoretical approaches traditional for atom collision physics does not lead to any kind of general results. Namely, the Rydberg electron energy change occurring for each of the multiple crossing of the terms is $\delta E \leq 1/n^3$, so that $\delta E/E_n \sim 1/n \ll 1$, where $E_n = 0.5/n^2$ is the binding energy of RA. This lead to the idea of the possibility of a diffusion approach to solution of the atomic collisions problem with RA participation, having in mind diffusion over the energy states of the quasi-molecule in one collision event (Devdariani et al. 1988).

The first obtained results give the reasons to believe that, during a single slow collision, the motion of the *RE* experiences the action of internal nonlinear dynamic resonances that arise due to the coincidence of the overtones of the *RE* motion over the Keplerian orbit with the frequency of the inner electron transfer. As a result, the motion of the *RE* becomes unstable. In this case, the transitions of the *RE* acquire the character of random walks over the network of crossing potential energy curves, thereby admitting a kinetic description of the time evolution of the distribution *f(n, t)* of the *RE.*

The latest stochastic version of chemi-ionization on *RA*-atom collisions extends the treatments of the DSMJ model by taking into account redistribution of population over a range of Rydberg states prior to ionization. That redistribution is modelled as diffusion of the *RE* in the Rydberg energy spectrum using a Fokker-Plank-

Kolmogorov type equation (FPK). Stochastic dynamics describe the random walk of *RE* within the hydrogen like discrete energy spectrum caused by the coupling of *RE* with internal electrical field *(E(t))*. The initial covalent Λ_u state crosses the ionic $^2\Sigma_g^+$ state at $R = R_n$, becoming auto-ionizing, see Fig. 5.

Note that the idea that the *RE* diffuses over the discrete energy spectrum of *RA* was successfully used earlier in Delone et al. (Delone et al. 1983) to interpret anomalously high photo-ionization cross sections in experiments on laser irradiation of gases. This logically suggests that for the ionization of the considered *RA,* the quasi-monochromatic electric field formed by charge transfer can also cause *RE* to diffuse over the discrete electronic spectrum, a process that can result in the displacement of the position of point R_i.

4. MODEL OF STOCHASTIC DIFFUSION

Characteristic times

(1) Inter-nuclear distance *R(t)* depends on time according to collision dynamics of the system.

(2) Factorization of FPK (with respect to *R* and *n)* means introduction of an "effective time" t_{eff}.

(3) Total effective time t_{tot} for the collision event with fixed impact parameter q means time spent while *R(t)* goes from $R = \infty$ to turning point R_{turn}.

(4) Average effective diffusion time $\langle t_{eff} \rangle$*:* the average time $t_{diff}(n^*_0,q)$ for the *RE* to diffuse from n_0^* level to the ionization limit determined from steady-state solution of FPK.

Diffusion equation. *RE* perturbation by internal electrical field *E(t)* causes appearance of auto-ionization width $W(n_{eff},R)$ of terms and can lead to dynamics chaos regime of classic trajectories. Stochastic motion of RE in energy space is described by (FPK) diffusion equation for the distribution function $f(n_{eff},t)$*:*

Area of dynamics chaos regime. Stochastic diffusion of RE in energy space is based on Chirikov criteria (Chiricov 1979) with Kepler mapping.

(1) Restrictions on the random motion ("lower limit"): The diffusion is forbidden in the energy region $n_{eff}<N_{min}(R)$, because energy difference between the neighboring levels becomes too large.

(2) Restriction on random motion ("upper limit"): Chirikov criteria for global chaos onset breaks down.

The ionization occurs whenever *RE* enters levels $n_{eff}> N_{max}(R)$ where the direct quantum photo-ionization channel becomes open and the corresponding auto-ionization width $W(n_{eff},R)$ is expressed via the photo-ionization cross-section σ_{ph}. Important key-point for the stochastic diffusion processes: long collision times. It makes the model suitable for future application to slow collisions. The most important part of AI processes with RA participatipation occurs at atomic internuclear distances about 10-15 au i.e. more smaller than the typical orbit size of RE with $n_{eff}>5$.

The series of the test experiments for to quantitative examination of the stochastic model application to chemi-ionization of sodium atoms recently have been

performed within the frame of INTAS and Russian Foundation for Basic Research projects (Ryabtsev et al., 2005; Beterov et al., 2005; Michulis et al., 2005, see Fig. 8). The absolute AI rate constants in sodium have been determined earlier in single beam conditions (Weiner and Boulmer, 1986) – n^2P states, crossed beams (cb) experiment $17 \leq n_{eff} \leq 27$, n^2P states (Boulmer et al., 1983). If was found that the atomic ions at the standard experimental conditions are created mainly due to blackbody radiation (BBR) at the ambient temperature of 300K i.e. the room's temperature. In (Michulis et al., 2005) the new method of the AI processes investigation based on relative measurements of A_2^+ and A^+ signal has been used having in mind the BBR – induced mixing of Rydberg states and phenomenon of ionization RA by the extractive field puls. Note that range of n_{eff} 5÷20 is of particular interest, since this is where the maximum in the AI rate constants is expected (see for example in Klyucharev, 1993). The using of the approximation assumes that RE motion adiabatically adjusts to the comparatively slow variation of the nuclear motion during collisions, namely the negligible RE stochastic dynamic on this effects will be assumed in the future. Today is actual the perturbation of the nuclear motion in quasi-molecule by the stochastic behavior of RE during one collision.

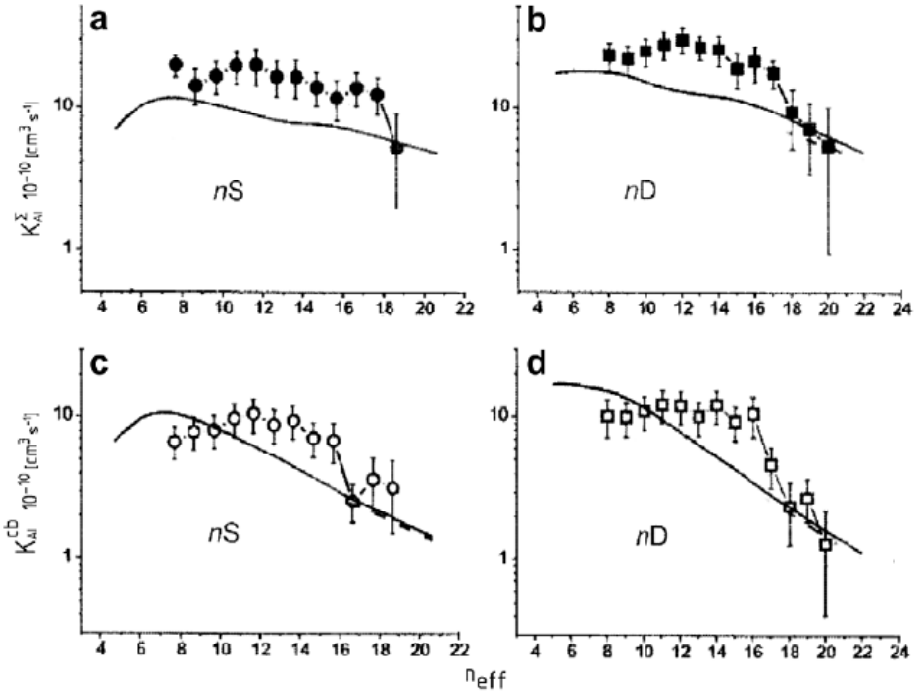


Figure 8: Experimental and theoretical $Na^*(n_{eff},l)$ + Na AI rate coefficients $8 < n_{eff} < 18$ for cb conditions, T = 600 K. dotes – cb conditions, *l*=1 (600K) open circle, sb – conditions *l*=1 (1000K), open triangle, sb-conditions *l*=2 (1000K), open square, sb-conditions, *l*=0 (1000K). full curves – theory, stochastic theory results.

Another limitations to use the model are:

1. The average relative velocities of the colliding atoms must be small compared to the mean velocity of the RE, $\bar{V}_{RE} = n_{eff}^{-1}\ a.u.$ It's fulfilled for states with $n_{eff}<10^3$ in single and crossed beams experiments
2. Massey parameter $\xi = \frac{\Delta E R_i}{\bar{V}_c}$ must be larger than one. Here $\Delta E=n^{-3}_{eff}$, $R_i\approx$10-15 a.u. and $\xi>1$ for $n_{eff}<30$
3. Relative atom kinetic energy E exceeds the energy separation of RA excited states, $E>\Delta E n_{eff}$. In cb-collisions that leads to correlation, $n_{eff\ min}>7$ (The approximation of a common trajectory for the internuclear motion). In the single beam case model it correspond to $n_{min}>15$. Michulis et al. (2005) present the stochastic calculation results for *nl* states of the excited sodium atom states (l=0,1,2) for sb conditions ($16\leq n_{eff}\leq 26$) and cb-condition ($4\leq n_{eff}\leq 14$) with experimental ones (Boulmer et al. 1983, Weiner and Boulmer 1986).

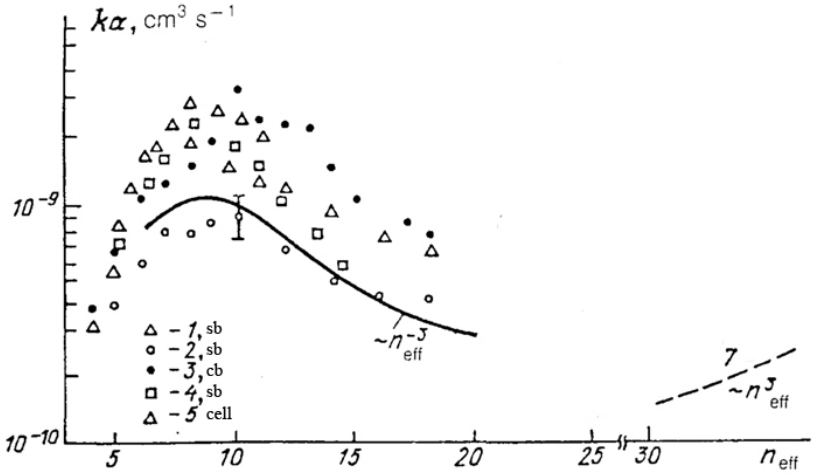


Figure 9: *1*—Li (1100 K), 2—Na (720 K), *3*—Na (600 K), *4*—K (660 K), 5—Cs (560K),6—calculated using the model relying on electron capture to an autoionizing state of a negative ion (Na,500 K), *7*—qualitative form of *k(neff)* according to the model relying on the scattering of a quasi-free weakly-bound electron in the sodium atom; solid curve—DSMY model (Na, effusive beam, *700* K). The rate constants are given in units of ka, where $a^{-1}=(T_{Na}M_A/\ T_AM_{Na})^{1/2}$, where T_A in the temperatures of the alkali metals sources< and $M_{A,Na}$ is the mass of the atoms of the elements under investigation (Klyucharev 1993).

Note, that in these experiments liquid nitrogen cooled screens have been used to prevent BBT effect manifestation. As expected, the results of stochastic and deterministic theories practically coincide for $n\geq 7$ in the crossed beam conditions. The observed discrepancies for atomic states with orbital moment value $l\neq 1$ may be connected with non-considered possible correlation effect between electronic and nuclear degrees of freedom in slow collisions. Fig. 9 demonstrates that within

the experimental error that dependences of the AI rate-constants in the hydrogen-like atomic systems may resemble each other.

The chemi-ionization processes have two ionization channels (2a, 2b). Their correlation dependences on the relative kinetic energy E of the colliding atoms. Really AI and PI processes take place in two separated regions of internucleonic (interatomic) distances R: $R \geq R_1$ – Penning type ionization $R < R_1$ – associative ionization. The PI and AI chemi-ionization branches may be received from the total rate constants, see Fig.10 (Ignjatović and Mihajlov, 2005).

In the cross-beam experiments the resulting molecular ion signal has been determined by the three rate constants: k_{cb}^{Σ}, k^{sb}, k^{cb}, where k_{cb}^{Σ} describes the total ion flood from the reaction zone, k^{sb} and k^{cb} – collisions in the each of crossing beams and collisions between atoms of two different beams (Beterov et al. 2005). As stated above the deterministic DSMJ approach threats the molecular ions creation via chemi-ionization processes as a result of the evolution of a Rydberg quasi-molecule formed in atom-atom collisions.

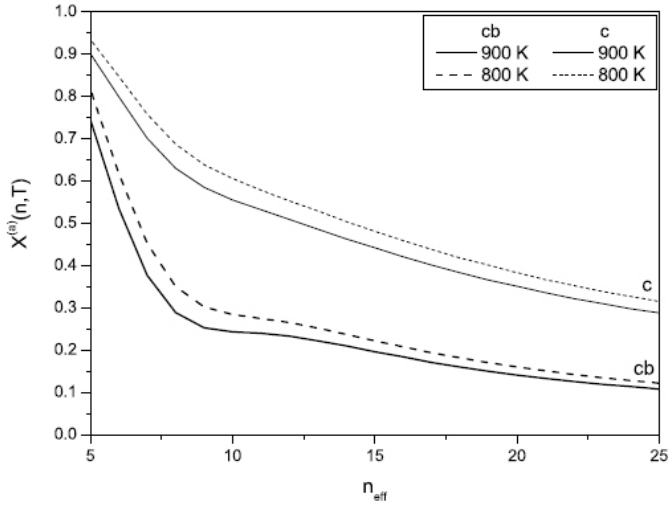


Figure 10: The branch coefficients $X^{(a)}(n_{eff},T)$ for chemi-ionization in $Na^*(n_{eff}{}^2P)+Na$ collisions. The main designations are the same as on the previous figure, T=900K, the dotted line, T=800K (Ignjatović and Mihajlov, 2005).

For alkali atoms, an interesting situation with stochastic regime may arise under the presence of Foster resonance when the so called dipole blockade effect may take place (Gontis, Kaulakys 1987). Importantly, the microwave field intensity F directly relates to the threshold boundary value $n_0^* = n_0 - \mu_0$ via radial dipole matrix elements $S_{\pm}(\varepsilon_0 l_0) = S(\varepsilon_0, l_0 \longrightarrow \varepsilon_0 + \omega, l_0 \pm 1)$ between the Rydberg states with quantum numbers $q = \{\varepsilon = 1/(2n^{*2}), l\}$: $F = (12\pi\omega n_0^{*5}\sqrt{2\pi n_0^{*3}(D_\varepsilon/F^2)})^{-1}$. The parameter $D_\varepsilon = \frac{\pi}{12}F^2\omega^2 n_0^{*3}\sum_{\pm}S_{\pm}^2(\varepsilon_0 l_0)$ plays the role of a diffusion coefficient describing stochastic migration of RE through energy levels ε in the region

$n^*>n^*_0$. Due to such migration, RE diffusion ionization in the microwave field occurs.

Foster resonance corresponds to the double photon resonance, i.e. a Rydberg l-state should be situated exactly in the middle between two neighbor l'=l+1-states (or l-l-states). Quantitatively, this situation occurs when the difference $\Delta\mu=\mu_l-\mu_l$ between quantum defects of the states involved in the microwave coupling is equal to 1/2. The magical half-integer value plays an important role in formation of the Cooper minimum in atomic photoionization cross sections.

The performed calculations justify the mentioned above theoretical expectations on the dynamic chaos control and a curious method based on Stark shift of levels may be suggested for manipulation of the output in the ionization channel during a single collision.

5. CONCLUSION

The main result obtained recently is the understanding of experimental results, namely that on chemi-ionization relate to the group of the mixed RA states close to the primarily excited one. Under experimental conditions three mixing processes occure l-mixing at large interatomic distances with cross sections having strong dependences on collision velocity, blackbody radiation BBR leading to BBR-mixing and photoionization, and RE diffusion in the frame of stochastic dynamic approach. Two first may be diminished at lowest normal (nonexcited) screens cooled by liquid nitrogen or helium. At the same time the RE stochastic diffusion always must be taken into account. It is a nontrivial task because the efficace of Landau-Zener like transitions occur in the region of multiple crossing of the quasimolecular terms so that it is not possible to assume that all crossing points are isolated from eachother. For RA states with high densites of the energy levels that assumption is not valid. Note, that under some conditions such kind of processes may be controlled to separate the ionization channels in crossed beams experiments. The RA chemi-ionization investigation and theory remains today its in leading positions and the common analysis of the results obtained within the framework of the deterministic and the stochastic theories is very useful for their future developement.

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