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Atom Behavior During Nucleus Fission Process (Highly Ionized Atoms (HIA) Hypothesis)

Abdul-Wali Ajlouni and A.A. Mahasneh
Department of Applied Physics, Tafila Technical University, Tafila, Jordan

Abstract: During fission process, the fission atom destroys because of the large energy released during the process which occurs via three stages and the electrons binding energy difference between the initial and the final states. Because of electron inertia, the newborn atoms are highly ionized, 10-12 electrons associated with each nucleus, called Highly Ionized Atom (HIA).

Key words: Fission process, fission products, highly ionized atom hypothesis

INTRODUCTION

Physicists always separate between nucleus and atom related activities, so when discussing nucleus activities they ignore atomic electrons behavior depend on the fact of wide energy difference between the two kinds of activities. In this study we are enforced to deal with the two kinds of activities because of the importance of the atomic activities in determine the final behavior of the fission products after have been formed due to fission process. We mention first the nucleus activities, which include nuclear fission, nuclear decay and nuclear reactions to have a clear idea about the ionization state of the atom affected by its nucleus activities.

The fission fragment produced by the fission process originates as a fast moving positive ion whose flight is generally terminated through other atoms until it becomes trapped through other atoms.

During the fission process many of the orbital electrons of the atom undergoing fission are ejected, with the result that the fission fragments carry an average positive charge of about 20 units, whereas the heavy fragments carry some 22 positive charges. Such particles, moving at a speed of 10^7 m sec^{-1}, are able to produce considerable ionization in their passage through matter. Therefore, their specific ionization is high and their range which depends on the fission fragments initial energy and mass and is, therefore, relatively short. As working approximation, the range of fission fragments in any medium may be taken to be the same as that of 4 MeV alpha particles (Loveland *et al*., 2006).

For an ideal α-decay reaction the Q value is about 4.269 MeV. This total decay energy is partitioned into the kinetic energies of the daughter nucleus and the helium nucleus if the products are formed in their ground state, which is usually true for α-decay. It can be calculated that the kinetic energies of the daughter nucleus is about 0.072 MeV, while E_α is 4.197 MeV. Almost all the energy is carried away with the α-particle, because of the large mass difference between the daughter nucleus and α-particle.

Although the kinetic energies of the daughter nucleus is small in comparison with that of E_α, it is large in comparison with chemical binding energies, <5 eV. Thus the recoiling daughter easily breaks all chemical bonds by which it is bound with other atoms (Choppin *et al*., 2002).

In β-decay, if the β-particle and the anti-neutrino are emitted with the same momentum but in opposite directions, the daughter nucleus experiences no recoil. On the other hand, if they are both emitted in the same direction, or if all the energy is carried away with one of the particles, the daughter experiences maximum recoil. The daughter, therefore, recoils with kinetic energies from zero up to maximum value, when the β-particle is emitted with maximum energy. The recoil energy is usually ~ 100 eV, which is still sufficient for causing atomic rearrangements in the surrounding molecules. In the decay of ^{14}C (to ^{14}N), E_{max} = 0.155 MeV, which gives E_N^{14} = 7 eV. However, by labeling ethane, $^{14}CH_3{}^{14}CH_3$, with ^{14}C in both C positions, it was found that $^{14}CH_3\ {}^{14}NH_2$ was formed in 50% of cases, when one of the ^{14}C atoms in ethane had decayed; although the C ≡ N bound strength is 2.1 eV only. Most of the decays occur with less than the maximum recoil energy, which can be averaged over the whole molecule. However, secondary effects tend to cause the chemical bonds to break following radioactive decay (Choppin *et al*., 2002).

The decay energy in γ-emission is distributed between the γ-ray quanta (E_γ) and the kinetic energy of the recoiling product nuclei (E_d). The amount of kinetic energy of the recoiling nuclide is so trivial (<0.1% of E_γ) that it may be neglected when only the γ-ray energy is considered (Choppin *et al*., 2002).

Corresponding Author: Abdul-Wali Ajlouni, Department of Applied Physics, Tafila Technical University, Tafila, Jordan

This Internal Conversion process occurs with the atom undergoing radioactive decay. Because the wave function of an orbital electron may overlap with that of the excitation energy of the nucleus, the excitation energy of the nucleus may be transferred directly to the orbital electron, which escapes from the atom with a certain kinetic energy E_e, with no γ-ray emitted, i.e., it is an alternate mode to γ-ray emission of de-excitation of the nucleus. Part of the nuclear excitation energy is required to overcome the binding energy of the electron in its electronic orbital. The remaining excitation energy is distributed between the recoiling daughter nucleus and the ejected electron. It can be shown that the energy of the recoiling nucleus is much smaller than the kinetic energy of the ejected electron and may be ignored (Choppin *et al*., 2002).

Once an electron is ejected from an atomic orbital due to internal conversion, electron capture, or some other processes involved in radioactive decay, a vacancy is created in the electron shell which can be filled in several ways. Electrons in higher energy orbital can occupy the vacancy with fluorescent radiation emission.

If the difference in the binding energy for the transition is sufficient to exceed the binding energy of the electrons in the L -or M-levels, emission of the energy as X-ray is not the predominant mode. Instead, an internal process, similar to photoelectric effect can occur and excess binding energy results in the emission of several low energy electrons, called Auger electrons, which are much lower in energy than the internal conversion electrons, since the difference in the electronic binding energies is in eV range for Augers, while it is in the MeV range for the internal conversion electrons, so the atom may be left in a state of high ionization by Auger emission. Positive charges of (10-20) have been observed. When such high charges are neutralized, the energy liberated is sufficient to break chemical bounds (Choppin *et al*., 2002).

The momentum imparted to a nucleus in a nuclear reaction with charged particle, or fast neutron, is almost invariably sufficient to result in the rupture of chemical bonds holding the atom in the molecule, similar to the recoil energy imparted to a nucleus in radioactive decay.

These recoiling atoms are known as hot atoms since their kinetic energy is much in excess of thermal equilibrium values. A hot atom may move as much as several hundred atomic diameters after the rupture of the bond before being stopped, even though this takes only about 10^{-10} sec.

Initially the hot atom is highly ionized (e.g., for Z = 50 ionic charges up to $^{+}20$ have been observed). As the hot atom is slowed down to thermal energies, it collides with a number of other particles in its path producing radicals, ions and excited molecules and atoms. At thermal energies it may become a neutral atom, particularly, if the matrix material is metallic and an ion is possibly in a different oxidation state, common in inorganic material, or it may react to form a compound with molecules in its path, the prevalent situation in matrices of covalent material (Loveland *et al*., 2006).

Chemical effects of nuclear transformations, hot atom chemistry, have been extensively studied in connection with induced nuclear transformations, both in gas phase, in solution and in the solid state. In the latter cases the dissipation of the kinetic energy and neutralization of the charge within a small volume produce a high concentration of radicals, ions and excited molecules in the region where the recoiling (frequently radioactive) atom is slowed down to energies where it can enter into stable combination (Choppin *et al*., 2002; Loveland *et al*., 2006).

The nucleus activities affect atomic electron, as well as, the whole material, causing ionization, molecule bond damage and creation of new materials and bonds. This is the case with small amounts of energy released from these activities, comparing with amounts of energy released during fission process. This leads to conclude that the former models to describe atomic electron states, after fission process has occurred, did not give the proper description of these states and leads to introduce the following new hypothesis.

MATERIALS AND METHODS

Highly Ionized Atoms (HIA) hypothesis: According to Bohr theory of atomic structure and the Schroedinger equation solution for energy eigen values, the bound states of the atom exist when the energy E_n, as approximate values, is:

$$E_n = \frac{QZ^2}{n^2} \tag{1}$$

where

$$Q = -\frac{2\pi^2 k^2 me^4}{h^2} \tag{2}$$

E_n is the binding energy of an electron in its nth quantum state.

During the fission process, the atom will pass through three stages.

Short distance stage: Which is the stage from the beginning of the neutron-nucleus interaction, to the time of formation of the fission fragments which start to go faraway from each other. The distance between them is very short, so the atomic electrons will feel no change because of their far distance from the event ($2\times10^3-10^5$ fm) while the distance between the fission fragments is few fm. The Coulomb potential and the energy of the system will be treated as if the two new nuclei are one nucleus. This is as long as the distance between the two nuclei is small ($d<4\times10^3$ fm) in comparison with the distance between nucleus and the electrons (Fig. 1).

Comparable distance stage: Where the distance between the two fission fragments is comparable with atomic dimensions ($d>4\times10^3$ fm). During this stage, consider one of the electrons and calculate the binding energy of this electron with each newborn atom:

$$A_f = A_1' + A_2' \tag{3}$$

$$Z_f = Z_1' + Z_2' \tag{4}$$

$$E_{n1} = \frac{QZ_1'^2}{n^2} \tag{5}$$

$$E_{n2} = \frac{QZ_2'^2}{n^2} \tag{6}$$

The difference between the two energies of the two stages is:

$$\Delta E = E_n - \left[E_{n1} + E_{n2}\right] = \frac{Q\left[2Z_1'Z_2'\right]}{n^2} \tag{7}$$

This quantity of energy will be changed to kinetic energy of the electron:

$$\Delta E = \frac{Q\left[2Z_1'Z_2'\right]}{n^2} = \frac{1}{2}mv_e^2 \tag{8}$$

where v_e is the electron tangential velocity, it is $\approx 10^7$ m sec^{-1} for an n = 2 electron.

Assuming that the electrons are distributed through equal spaces in their shells and the two fission fragments move away with an average speed of $v_{ff} \approx 10^7$ m sec^{-1}. For an n = 2 shell, only one electron, out of eight electrons, will move with v_e in the same direction of velocity v_{ff}. This electron has a chance to accompany the fission fragment of velocity v_{ff}.

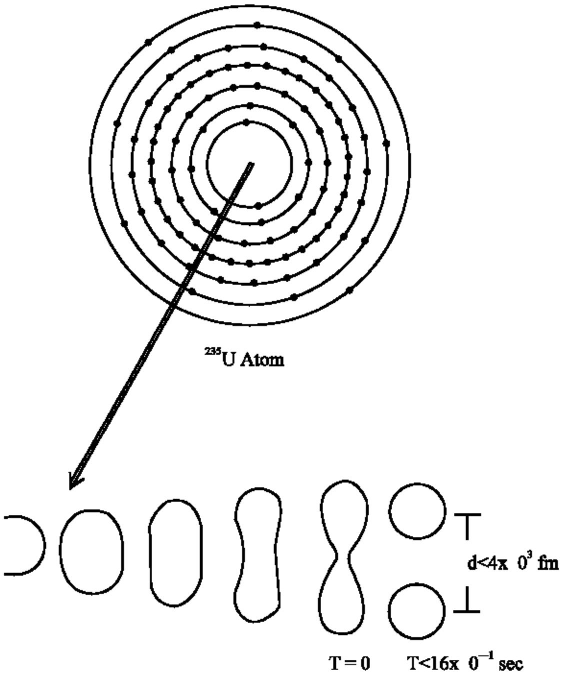

Fig. 1: Short distance stage

Table 1: ^{235}U shells, their radii r, $R_{\Delta E}$ and $T_{\Delta M}$

Shell	r ($\times10^4$ fm) r	$R_{\Delta E}$ ($\times10^4$ fm)	$T_{\Delta E}$ ($\times10^{-19}$ sec)
K	0.214	0.19	1.6
L	0.860	0.77	6.6
M	1.900	1.70	15.0
N	3.400	3.10	26.0
O	5.300	4.77	40.0
P	7.700	6.90	58.0
Q	10.500	9.45	80.0

This phenomenon occurs in each shell in different times due to the 1/r dependence of Coulomb energy that binds the electrons with the nucleus. So, it is assumed here that an electron in a shell will start affected with ΔE of Eq. 8 when each fission fragment passes 0.9 of the shell radius ($R_{\Delta E}$). Table 1 represents the seven ^{235}U shells, their radii r, $R_{\Delta E}$ and time at which fission fragment passes $R_{\Delta E}$, i.e., $T_{\Delta E}$.

It is assumed that T = 0 and $R_{\Delta E} = 0$ at the instance and position of fission respectively. This stage ends when the distance between the two nuclei become near to the diameter of the atom ($d = 10^5$ fm). Figure 2 represents this stage.

High ionized atom (HIA) stage: After the turbulence has occurred in the second stage and because of the electron

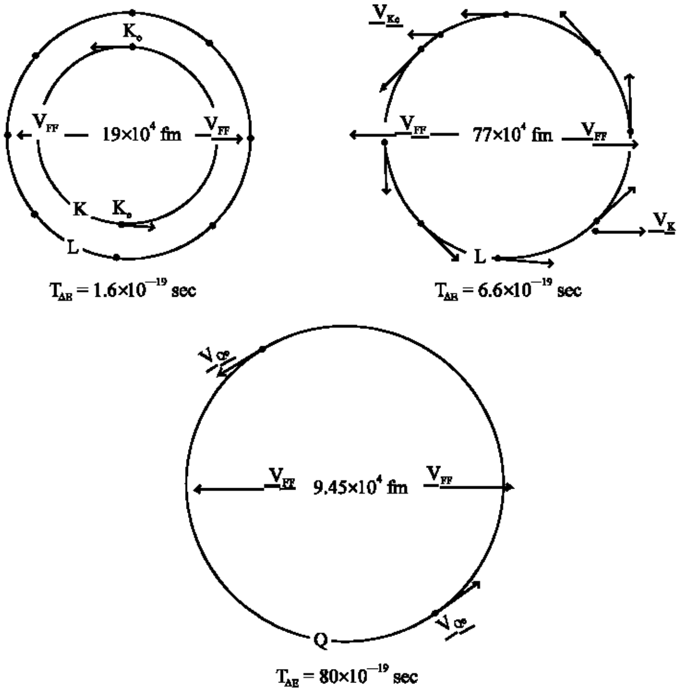

Fig. 2: Comparable distance stage

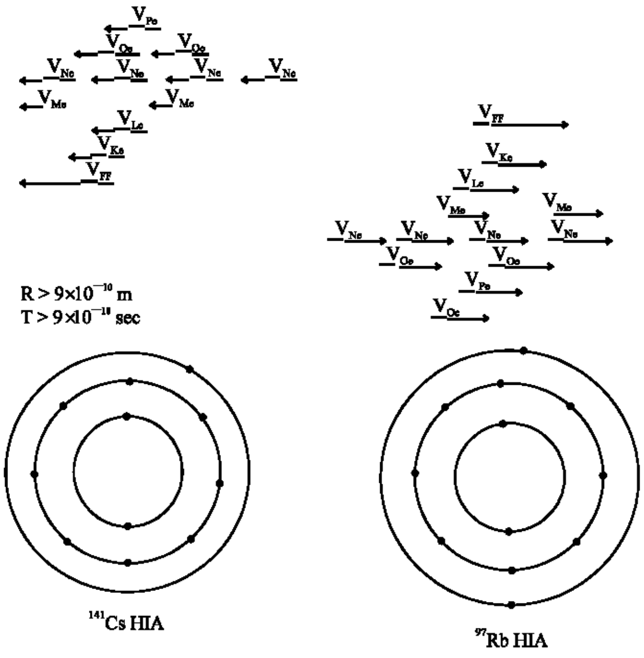

Fig. 3: HIA stage

inertia, it is expected here that no more than 1/8 of the total atom electrons follows each of the fission. In the case of ^{93}Rb and ^{141}Cs in Eq. 8, about 11-12 electrons will follow each of the two nuclei. Figure 3 represents (HIA) stage.

RESULTS AND DISCUSSION

After introducing ionization states of fission newborn atoms and make a comparison between different atom behaviors due to different nucleus activities, it is noticed that, the ionization states of fission born atoms is more near to what presented in HIA hypothesis where atom destroys completely and 10-12 electrons with each atom resulted.

According to former interpretations of electromagnetic radiation from nuclear detonations, there are three types of electromagnetic radiation (SCOPE-28, 1988):

- Soft thermal X-rays, observed within several meters of the nuclear device, $T = 10^8$ K.
- Visible light when the fireball becomes at temperatures, T = 30000 to 7500 K.
- Electromagnetic pulse (EMP) disturbing the radio-wave propagation from tens of Hz to tens of giga Hz.

The EMP produced from currents interacts with the earth magnetic field. The currents are produced from high energy Compton electrons which are in turn, produced from prompt gamma interaction with the atmosphere (SCOPE-28, 1988).

According to HIA hypothesis, there is an excess of electrons released from fissioned atoms distributed through the medium surrounding the fission process, with (keV-eV) kinetic energy. When these electrons are exposed to the very high temperature from the ambient atmosphere, originated from the detonation, it will gain more kinetic energy of about 3/2 KT in addition to that gained during fission.

From Maxwell's equations, an accelerated point charge e radiated electromagnetic radiation at a rate

$$\frac{dE}{dt} = \frac{2}{3}\frac{e^2a^3}{c^3} \quad (9)$$

where a is the acceleration of the charge. These electromagnetic radiations are emitted in quanta with frequency f (Wong, 2004).

When the ambient temperature is very high, 10^8 K, the kinetic energy will be very high and a part of the emitted radiation will be as X-rays. At intermediate temperatures 3000-7500 K, a part of the emitted radiation will be ultraviolet, visible and infrared radiation. At lower temperatures the radiation emitted will be as low frequency EMP which affects telecommunication and electronic equipment. This rapid gradient in electromagnetic radiation energies follows the rapid gradient of ambient temperatures. In case of reactor accident which stays for a long time, like Chernobyl, it is expected to have a steady level of kinetic of electron energies and radiation emission with intermediate or nearly low frequencies and this explains the red glow of Lava-like-Fuel Containing Material (LFCM) in that accident. This red glow was attributed to reactor graphite burning Sich (1995).

CONCLUSION

According to HIA hypothesis, fissioned atom destroys completely and 10-12 electrons accompanied with each new born atom. HIA hypothesis represents a new tool to understand fission product chemistry, where many issues are not clear, in a proper way.

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