DEVELOPMENT OF NUCLEAR RESEARCHES AND PERSPECTIVES OF PEACEFUL USE OF NUCLEAR ENERGY IN AZERBAIJAN

A.A. Garibov
Institute of radiation problems, ANAS, Baku, Azerbaijan
nukl@box.az

1. The fields of nuclear physics, nuclear chemistry, physics of high energies in Azerbaijan have begun since implementation of Union-scale scientific-technical programs of former USSR.
   - Institute of Physics of ANAS -nuclear physics
   - Baku State University - physics of high energy particles
   - Institute of Radiation Problems of ANAS nuclear chemistry
     -radiochemistry
     -radiation technology
     -radiative study of materials
2. Scientific-research works in these directions were carried out together with the leading scientific and educational institutions of the former USSR.
   1. I.V.Kurchatov Institute of Atomic Energy (Kurchatov centre)
   2. Dubna International Nuclear Research Centre
   3. Moscow State University named after M.V.Lomonosov (MSU)
   4. Moscow Engineering Physics Institute
   5. Ukraine, Kazakhstan, Belorus Nuclear Physics Institutes
   6. Novosibirsk etc.
3. After gaining sovereignty besides preserving traditional relationships, it was established relations with new international institutions and foreign nuclear states.
   1. CERN
   2. IAEA
   3. Italia Abdus Salam International Centre for Theoretical Physics
   4. South Korea KAERI (Korea Atomic Energy Research Institute)
   5. France CEA and AREVA
   6. Argentina
   7. Russia etc.
4. Using these relations in Azerbaijan it has been established an initial staff potential in the field of practical and theoretical nuclear researches.

   IRP ANAS
   Institute of Physics of ANAS
   Baku State University
   Azerbaijan State Pedagogical University
5. Azerbaijan participated in the international projects carried out by Dubna International Centre and CERN in the directions of physics of high energy particles and physics of high energy nuclear collision. Azerbaijani scientists are involved in scientific processing of the obtained results within the framework of ATLAS program. The obtained results were widely discussed at the last forum and interpreted in joint publications.
6. The main practical significance of nuclear researches is the use of nuclear energy, application of nuclear and radiation technologies in various fields.
7. Let us take schematically the process of decomposition of uranium - one of the main nuclear fuels – as follows:

$$\mathbf{U + n \rightarrow \sum X_i + \alpha,\beta,\gamma + 2 \div 3\ n}$$

In nuclear power plants the energy of fragments appeared after uranium decomposition is given to the conversion-to-heat energy system in heat separation element and then to the system of conversion-to-electric energy via heat carrier. Typically, the fragments reatin 60-70% of fission energy. The obtained neutrons are used in contuniuing the chain. 20-25% of fission energy is separated in the form of various rays and used inefficiently in energy reactors. Efficiency of conversion processes of fragment energy into electric energy is within the range of 37-40%. Here in fuel combustion degree also there are losses. Thus, together with I.V.Kurchatov Institute, we have developed a new process based on hydrogen energy carrier for increasing the efficiency of conversion-use processes of nuclear energy.

To put uranium isotopes (U^{235} enrichment $\leq$ 1-2%)into the form of the system which is radiation resistant and has a radiation catalytic influence in water decomposition

- UO_2-SiO_2
- $(UO_2)_x$-$(BeO)_y$ -$(SiO_2)_2$
- $(UO_2)_x$-$(SiO_2$-$B_2O_3)$

Giving water vapor on the obtained system within the irradiation by neutron flux (thermal and fast) the fragment energy conducts the system temperature and the rays – the process.

Under radiation catalytic influence of SiO_2, BeO, B_2O_3 system the energy yield of hydrogen equals $G(H_1) \geq 8$ molecule/100 eV. The obtained hydrogen is easily separated from water vapor + O_2 in nanosize and its energy is converted into the energy of heat carrier in a special cell. As well as the energy of HO_2 + O_2system obtained in the result of the process, is converted into electric energy. Developed schematic processes enables the conversion of nuclear energy into electric energy with high efficiency.

For transforming the developed scheme into real installations, it is required the safety of the process and optimization of energy conversion processes.

8. Efficiently use of the energy of the rays obtained from nuclear fuel fission consists of several components.

Conversion of beam energy into an efficient form for decomposition of the substances containing energy carrier. For this purpose, it has been taken semiconductive and dielectric oxides and metals for its composition, dispersion ability, structure order and band gap width.

$$M \rightarrow e + p + e_x + S^*$$

It has been determined that in the studied systems the energy of high-energy initial rays is converted into efficient, relatively low energy-electron, hole, structure defects and exitons for decomposition of the substances containing energy carrier.

Threshold energy of (e+p) pair formation in semiconductors

$$Eh=(3ç4)\ E_d$$

and in dielectrics

$$Eh=(2ç3)\ E_d$$

On the other hand the energy of the formed particles must be more than dissociation energy.

$$E_i \geq E_D$$

Within irradiation of metal systems, it is formed mainly structure defects and second electron irradiation emited from metal.

Theoretically, we have determined energy distribution and energy yield of the particles in various systems.

As the formation of energy carrier occurs on surface level, the obtained particles have to migrate to the surface.

The other case

$$\lambda \geq R_{\text{solid material}}$$

λ – free migration distance of energy carriers (e, p, ex), R – size of solid material.

This effect is characterized as a size effect in radiation catalysis. The values of λ have been defined theoretically and practically for various materials. If the particle energy is $E_i=10^2$ eV in metal-semiconductor-dielectric chain, then the value of λ changes within 10ç1000nm .

So, depending on E_D, for each process it can be selected an optimal energy converter and radiation catalyst and their size must be as $R \leq 10^3$ nm. The result that was theoretically achieved, has been practically tested in the sample of n-SiO_2, n-Al_2O_3, n-ZrO_2 in the process of hydrogen obtain from water and it has become possible to increase the hydrogen yield in the order 10-10^2.

This result is recommended for the following fields for usage:

- Atom-hydrogen energy;
- Development of new type of energy reactors;
- Radiation technologies;
- In the field of atom-hydrogen energy

Obtain of energy carrier through heat potential and radiation control of high temperature reactor of new generation and production of electric energy on its base. We have developed obtain processes of hydrogen from water, hydrocarbon, hydrocarbon-H_2O systems with high energy yield.

Radiation technologies:

- Radiation and radiation-catalytic transformation processes of oil and oil products
- Radiation-chemical synthesis
- Radiation polymerization
- Control of the physical properties of semiconductive, dielectric-type substances and increasing their radiation resistance
- Obtain of new type of materials (sorbent, catalyst, composite materials etc.)
- Application of radiation technologies in environmental problem solution (oil contamination of fume and gases)

9. Safety of water cooled nuclear reactor

Economic efficiency of nuclear energy is higher than all other types of alternative energy (IAEA reports).After the Chernobyl accident, ensuring the safety of the nuclear energy system has emerge das a main duty. Safety of nuclear power systems has become more urgent after the Fukusimia accident and new tasks have been set out on nuclear safety in the documents of the three summit held in this direction.

Nuclear explosions did not occur in any of the nuclear reactor accidents; the events happened due to the radiation thermal processes occurring in contact of heat carrier materials under the influence of temperature, radiation. Unfortunately, in the documents it is reflected only the thermal processes and radiolysis processes of pure water in normal operating conditions. Since1986, we have studied the obtain of hydrogen from radiation-heterogeneous processes in contact of heat separate elements (zirconium, sircolay alloys, stainless steel, aluminum), which are used in the existing thermal power reactors, with water and the regularities of oxidation of the materials. In figure 1 and 2 it is given the oxidation kinetic field of H_2 and metal in the result of radiation- heterogeneous processes in the sample of zirconium.

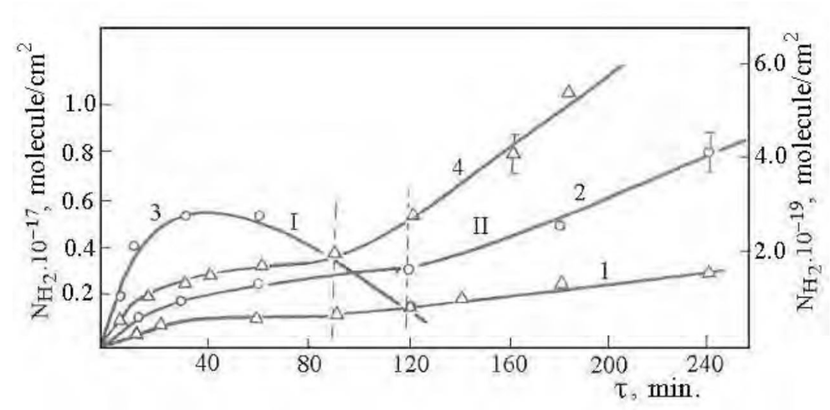


Figure 1. Kinetic curves of hydrogen obtain in heterogeneous processes occurring in contact of Zr(1-3) and (4) Zr+1%Nb with water:

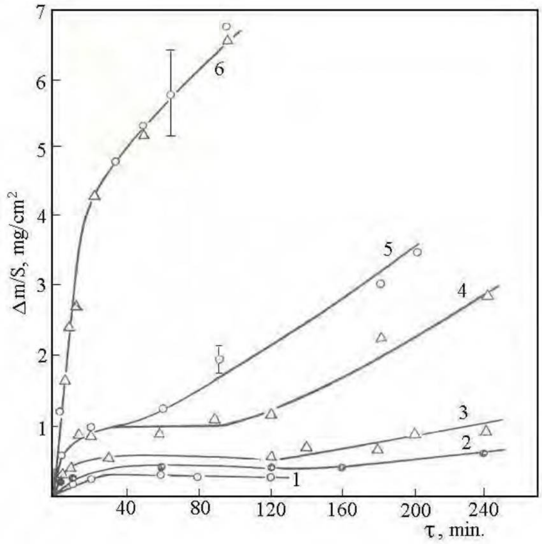


Figure 2. Kinetic curves of oxidation of Zr+1%Nb alloy in the result of radiation-thermal and thermal processes occurring in contact with

It has been determined that hydrogen obtain in contact of the metal materials with water and metal oxidation has the same natural phenomenon, and consists of three parts:

1. Kinetic field of the formation of protective oxide layer
2. Formation of protective oxide layer
3. Catastrophic oxidation field of the metal

$$Zr + 2\,H_2O \xrightarrow[T>473K]{\gamma,\ n} Zr - ZrO_2 + 2\,H_2$$

$$\text{Stainless Steel} + H_2O \xrightarrow[T>373K]{\gamma,\ n} SS - Fe_xO_y + H_2$$

$$Al + H_2O \xrightarrow[T>300K]{\gamma,\ n} Al - Al_xO_y + H_2$$

Stainless steel (SS)

The obtained Me-MeO system accelerates water decomposition.

Under the influence the electrons emited from metal at initial states at 1st and 2nd phase shifts from $\lambda_e > R_{oxide}$oxide layer to contact environment and homogeneous radiolysis of water occurs. At the end of the 2nd phase density of O oxygen holes and structure defect of Me-MeO layer increase. Due to these processes the specific surface of Me-MeO increase.

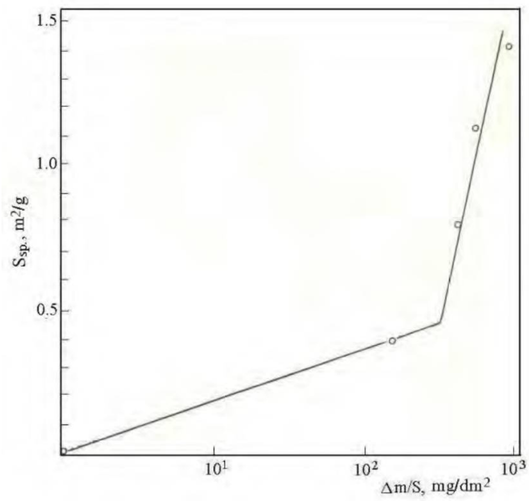


Figure 3. *dependence of specific surface of Zr-ZrO2system on the amount of oxide phase on zirconium surface within radiation-thermal oxidation of Zr in contact with water*

At the new phase the catastrophicoxidationstate of the metal occurs and as a result of the fast metal-water reaction, the density of hydrogen in reactor environment sharplyrises.

Within accident modes as a result of catastrophic radiation-heterogeneous processeshydrogensharply rises.

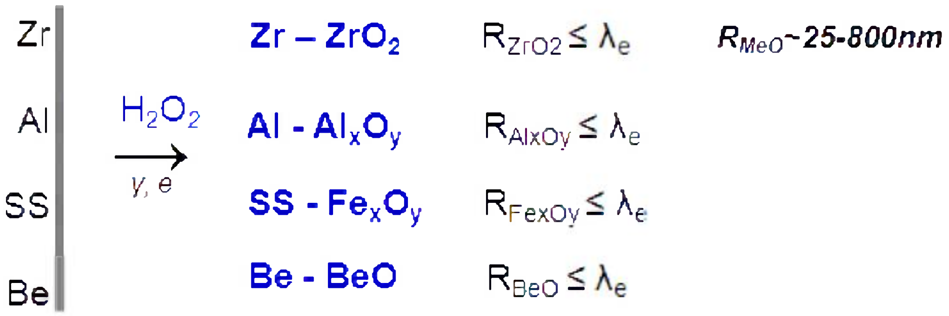
Based on the achieved resultsit has been estimated the share of radiation- heterogeneous processes, occurring in contactof zirconium material with water at real operating mode of water-cooled nuclear reactors, in hydrogen production.

The amount of hydrogen obtained in 1kg of heat carrier as a result of radiation-heterogeneous processes in contact of zirconium with water

Table 1. *Water density, power of gamma irradiation, speed of hydrogen accumulation*

T, K	g, мг/см^3	D, Вт·кг$^{-1}$	W(H_2), г·кг$^{-1}$·ч$^{-1}$
300	$1 \cdot 10^3$	125	0.05
473	5		0.05
573	5		0.39
773	5		39.21
923	5		54.13

1. Increasing the resistivity of construction materials to the influence of agressive environment by the radiation-oxidation methods on the contacts with H_2O_2.



11. In nuclear research reactors of nuclear states it has been studied change regularities of composition, properties under the influence of various-energy neutrons on n-SiO_2, n-Si and other materials
12. For separation of natural uranium and radium from aqueous solutions by sorption method, it has been obtained new polymer-based sorbents, studied its properties at real environment and created new technology
Azerbaijan government pays attention to nuclear sciences, nuclear technology, nuclear energy, and the creation of human potential in these directions as an actual and perspective scientific and technical direction.

By the decree №442 of the President of Azerbaijan Republic, I.Aliyev, dated May 8, 2014 it was established "National Nuclear Research Centre" Closed Joint-Stock Company under the Ministry of Communications and High Technologies of Azerbaijan Republic with the purpose of formation of nuclear sciences, nuclear technology, nuclear energy, and the creation of human potential in these directions. Nuclear Program of Azerbaijan is reflected in this document which is a historical decree.The followings will be carried out within this decree:

- Establishment of Nuclear Research Reactor which is important for nuclear researches
- Electron, proton accelerators
- Research facilities and equipment
- Establishment of modern complex for radiation technological sterilization and other processes
- Estimation of natural resources of nuclear materials
- Formation of staff potential
- Preparing proposals on energy application of nuclear energy in Azerbaijan

Implementation of the above-shown and other projects will allow realization of peaceful large-scale scientific and practical works in the field of nuclear research and nuclear technologies besides other fields of scientific technology and Azerbaijan Republic will be more powerful as a Nuclear State.