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Thorium nuclear fuel – thoron aspect

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Abstract. The communication reports a serious complication connected with preparation, storage and transportation of fuel for thorium and uranium/thorium nuclear reactors. Whereas uranium fuel of any degree of enrichment is free from radium, which produces radon-222, thorium itself produces thoron (radon-220). Measurement of thoron by a routine ionization-chamber device around a small sample of 2 g thorium dioxide shows already the health endangerment situation. The presence of thoron is also confirmed by a typical solid state dosemeter (polymer CR-39), exposed to the air around ThO_2 and etched afterwards with warm NaOH solution. The unavoidable presence of thoron can cause increase of price of production of nuclear fuel, demanding special approach to the method of manufacture.

Key words: CR-39 • nuclear fuel • radon-220 • radon-222 • thorium fuel • thoron

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Introduction

One of the positive features of nuclear power stations using uranium fuel is easiness of handling the fuel in any stage of its production and storage, until the placement into the core of the reactor. Before the preparation of UF_6, natural uranium is separated from all other nuclides, especially from accumulated radium which is an uninterrupted supplier of radon-222 since the beginnings [1]. Therefore, gas bottles with uranium hexafluoride of any enrichment in uranium-235 are transported without any shield and so are subsequent chemical operations leading to UO_2 or whatever chemical uranium compound is desired. Ready fuel pellets can be touched and handgloves used for handling do not mean the protection of hands, but protection of fuel from human sweet. Easiness of handling uranium fuel does not apply in the case of thorium fuel. Thorium itself is also separated from other nuclides, but its unavoidable decay produces thoron, another isotope of radon, ^{220}Rn. It does not share popularity with radon-222 present everywhere where natural uranium is present [1]. Basic difference is in half-life time which is 55 s in the case of thoron and 3.82 days of ^{222}Rn. Alphas produced by both isotopes of radon have energies 5.59 MeV (^{222}Rn), respectively 6.40 MeV (^{220}Rn). Nevertheless, in spite of inconvenient emission, the interest in thoron is rising and a workshop on it will start in Japan soon. We have started a closer approach to thoron question in the aspect of fuel, using electronic and chemical methods to measure the extent of phenomenon.

Experimental

Thoron preparation as thorium oxide, 99.9% ThO_2, as a powder, was acquired from Koch-Light Laboratories Ltd, Colnbrook Bucks England and used without any additional processing. An amount of 2 g was placed in a container with a space of 5 ml of air over the substance, and opened when needed, in a plastic bag containing also the radon detectors.

The vicinity of the atmosphere, 10 cm over thorium oxide, was probed by a commercial radon gas detector HS71512, adapted for placing in cellars etc., where the occurrence of radon is probable, in thousands of houses in the USA. The device is simple and cheaper than apparatuses used in mines. In the last mentioned case complicated detectors do separate and concentrate radon first on chair coal trap and release it later for measurement. Our device used in the thoron research is an ionization chamber only. If we exclude a nuclear reactor with the meltdown accident in the vicinity, or the case of a nuclear war, the only radioactive gas in the air can be radon. The device used is indicating radon in pCi per liter of air. In addition, a safety siren may work in the case of level exceeding that determined by the United States Environmental Protection Agency (US EPA) which has approved the device (US EPA evaluated and recognized).

Routine CR-39 polycarbonate radon detectors were placed also 10 cm from thorium preparation, etched in warm sodium hydroxide solution and examined under a microscope for the number of alpha-traces after the decay of thoron atoms at the surface.

There was no need to use complicated arrangements developed in Japan for the unlikely case of simultaneous presence of ^{220}Rn and ^{222}Rn in a dwelling [2].

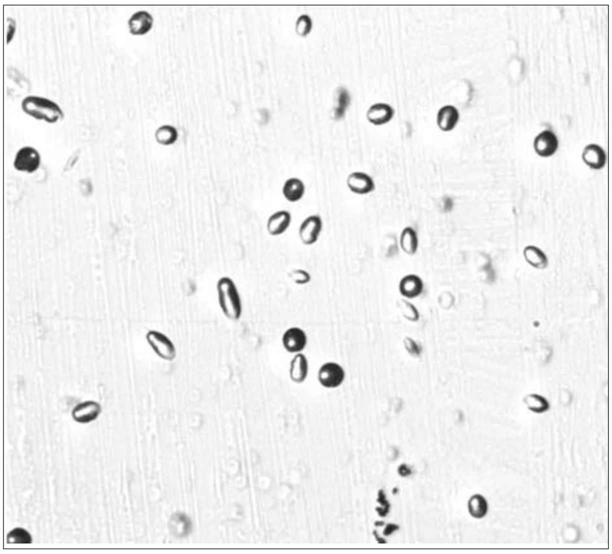

Fig. 1. Traces of thoron (^{220}Rn).

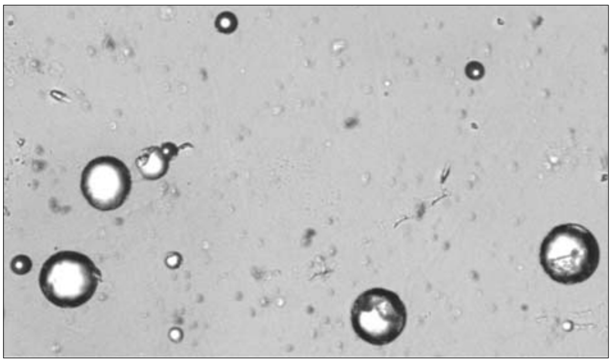

Fig. 2. Traces of radon (^{222}Rn).

Results

The display of radon detector, placed in the vicinity of thoron compound as above, was reaching rapidly the level of 4 pCi/L value, i.e. the value determined by the US EPA as the first warning to start a corrective action. The CR-39 polymer has shown traces (Fig. 1) similar to traces of radon-222 (Fig. 2). The difference is probably due to the difference of alphas energy from both isotopes. The density of traces in the case of thoron calculated per time of exposure suggest the concentration of thoron ca. 500 Bq/m^3.

Conclusions

Preliminary measurements of thoron emitted by thorium compounds, already in gram quantities indicate the existence of radioactive cloud surrounding any substances containing thorium. As the amount of thorium in nuclear energetics would be of the order of hundreds kilograms, the concentration of thoron will complicate production of reactor fuel. There will be no longer as convenient situation as in the case of uranium fuel, which does not emit neither radioactive gas, nor penetrating radiation. The production of thorium, or thorium/uranium fuel will demand either the use of special gas masks by the personnel in the existing fuel factory like by Westinghouse in Sweden, or fully automatic installation with special ventilation. Both solutions complicate the production and increase price of the fuel. The presence of thoron in the fuel placed into a reactor is without any meaning, and was not under consideration in reactor physics background of the thorium, or uranium/thorium fuel.

References

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