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By Nicholas Tsoulfanidis

Iranians (and others) with uranium — what exactly might they be doing?

For more than a year the international community has debated what to do about Iran's intention to enrich and reprocess uranium. Iran's leaders insist that they want only to generate electricity. Some politicians outside of Iran worry that this is a ruse and Iran's real aim is to build nuclear bombs.

International concern over nuclear weapons only increased after North Korea announced last fall that it had conducted a successful nuclear test underground. There's also the continuing fear that weapons-grade nuclear fuel from the former Soviet Union will find its way into the hands of terrorists, who will turn it into bombs.

In trying to understand these developments, it's useful to know how nuclear fission works, what is meant by enrichment and reprocessing, and what, if anything, is different about the nuclear fuel one needs to run a power plant versus building a bomb.

First, fission. Nuclear fission, or the splitting of a nucleus, was discovered in 1939. The nuclear reactor was born three years later. After World War II, the United States developed nuclear-powered submarines and aircraft carriers, and in 1957 the first commercial, civilian nuclear power plant produced electricity.

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When we talk about "splitting" a nucleus, we mean a neutron — one of the three basic subatomic particles, along with protons and electrons — collides with the nucleus of a chemical element. Sometimes the nucleus absorbs the neutron. One possible outcome after the absorption is the splitting of the nucleus into two major fragments and the emission of other particles, including about two to three neutrons. Those emitted neutrons can cause further fissions, which result in the emission of more neutrons, which cause more fissions, and so on. This is called a chain reaction. Fission can take place only with nuclei of heavy elements like uranium, which is the heaviest element found in nature.

Left unchecked, that chain reaction may produce an explosion. This is what happens in an atomic bomb. But when controlled, the chain reaction merely produces heat. In

U.S. Department of Energy

Spent nuclear fuel rods are removed from a reactor when they no longer have enough fissile material to keep the reactor running.

a nuclear power plant, this heat boils water, and the resulting steam turns a generator that produces electricity.

The neutrons coming out of fission are moving so fast that they're unlikely to cause enough fissions to keep a chain reaction going. But if the neutrons are forced to slow down, the probability of causing continued fissions increases dramatically.

Like a running back encountering would-be tacklers, neutrons naturally slow down when they collide with nuclei. How much they slow down depends on the size of the nuclei they hit. Light nuclei take away more energy per collision than heavy nuclei. So lighter nuclei, by slowing down the neutrons better, improve the odds of keeping the chain reaction going.

The element with the lightest nucleus is hydrogen. But because hydrogen is a gas and would be difficult to handle in a reactor, engineers use the next best medium to contain the collisions. That's water.

Water slows down the neutrons, increasing the probability of continued fission, but the process still won't continue unless the nuclei in the line of fire are from a particular form or isotope of uranium, U-235.

Like most elements, uranium consists of more than one type of nucleus. These variations are called isotopes. The two main uranium isotopes found in nature are U-235 and U-238. The number indicates the total count of particles in the nucleus.

The trouble is, U-235 is extremely rare, less than 1 percent of natural uranium. A power plant would need uranium that's at least 3 to 4 percent U-235. A nuclear weapon would require vastly enriched uranium, on the order of 90 percent U-235.

During World War II, U.S. scientists had two possible methods to enrich the uranium they were using to a level sufficient to build a bomb: diffusion and centrifuge. The goal of the United States at the time was to have a nuclear weapon ready as soon as possible; no financial or other considerations came into the decision-making process. So diffusion — which uses a membrane full of holes to separate out tiny quantities — was chosen, even though it required enormous amounts of electricity.

At the time the only available source of considerable amounts of electricity was the Tennessee Valley Authority's hydropower generating stations, so gaseous-diffusion plants were built in Tennessee in what is now the Oak Ridge National Laboratory.

It should be mentioned that a gaseous-diffusion operation involves lots of machinery and space. It occupies thousands of acres; it is not a "garage" or "basement" operation. And it takes time — months — especially if the goal is to produce weapons-grade fuel.

Today, countries that need new enrichment services, including the United States, opt for the centrifuge method of enrichment, which separates materials out by spinning them in a cylinder. The heavier materials fly out from the center. The main advantage of the centrifuge over diffusion is that it consumes about one-tenth the energy.

But the centrifuge method is also a huge operation, both in terms of machinery size and space needed. It is not easy to hide (like, say, a laboratory to make chemical or biological weapons of mass destruction). And, again, you cannot obtain the enriched product overnight. It takes time — months, depending, of course, on the amount of effort devoted to such a project.

How can anyone tell whether a country is enriching uranium to make it useful for electricity generation (3-5 percent U-235) versus preparing it for use in weapons (more than 90 percent)? If the country allows inspectors to sample the product, it is relatively easy to determine the enrichment level. But from a distance, it is not possible to tell.

As mentioned above, U-235 is the only uranium isotope found in nature that can be used as fuel in a water-cooled reactor. But this is not the only fuel available to us. In today's reactors, only 3-5 percent of the fuel is U-235; the rest is U-238. As the heavier isotope absorbs neutrons, it eventually turns into plutonium. Plutonium is a perfectly good nuclear fuel. In fact, in today's reactors, about 15-20 percent of the reactor power is produced by the plutonium made in the reactor core by the U-238 taking on extra neutrons.

When most of the U-235 is used up, the fuel is discharged from the reactor. This is called "spent nuclear fuel." The process by which useful isotopes are extracted from spent nuclear fuel and repackaged for future use is called reprocessing. Reprocessing also has been used by the major nuclear powers to extract plutonium for weapons.

Apparently North Korea did the same thing: It reprocessed its spent power-plant fuel to obtain weapons-grade fuel instead of enriching uranium. N

Ten Things You Didn't Know About…

Shakespeare

By Eric Rasmussen

1. Shakespeare invented nearly 2,000 words, including critic, exposure, fixture, housekeeping, hurry, laughable, lonely, Olympian, puke and road.

2. Shakespeare's wife was eight years older than the playwright — and three months pregnant when they got married.

3. Charles Jennens, an 18th century editor of Shakespeare's plays, wrote the libretto to Handel's *Messiah*.

4. Howard Staunton, another Shakespearean editor, invented the design of modern chess pieces.

5. Archeologists have found early clay pipe fragments near Shakespeare's house in Stratford-upon-Avon that show traces of marijuana and other hallucinogenic substances.

6. At a performance of *Macbeth* in 1672, the actor playing the title role apparently used a real dagger and murdered the actor playing Duncan.

7. The actors in Shakespeare's company didn't get a copy of the full script, just the lines spoken by their character written on a narrow strip of paper that could be rolled up, which became known as the actor's "role."

8. *King Lear*, with its portrayal of a mad king, was banned on the London stage from 1788 to 1820 because of the real insanity of the reigning monarch, King George III.

9. All of Uranus's 21 moons are named after Shakespearean characters.

10. In the 46th Psalm in the King James Bible, which was printed when Shakespeare was 46 years old, the 46th word is "shake" and the 46th word from the end is "spear." Proof positive, some argue, that Shakespeare wrote the Bible!

Eric Rasmussen, English professor, University of Nevada, Reno, is one of two editors chosen by the Royal Shakespeare Company to edit The RSC Complete Works of Shakespeare *as an official edition to accompany a Shakespeare stage extravaganza currently playing in Stratford-upon-Avon, England.*