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Contact: Claire Bowles
claire.bowles@rbi.co.uk
44-207-331-2751
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Gamma-ray weapons

AN EXOTIC kind of nuclear explosive being developed by the US Department of Defense could blur the critical distinction between conventional and nuclear weapons. The work has also raised fears that weapons based on this technology could trigger the next arms race.

The explosive works by stimulating the release of energy from the nuclei of certain elements but does not involve nuclear fission or fusion. The energy, emitted as gamma radiation, is thousands of times greater than that from conventional chemical explosives. The technology has already been included in the Department of Defense's Militarily Critical Technologies List, which says: "Such extraordinary energy density has the potential to revolutionise all aspects of warfare."

Scientists have known for many years that the nuclei of some elements, such as hafnium, can exist in a high-energy state, or nuclear isomer, that slowly decays to a low-energy state by emitting gamma rays. For example, hafnium178m2, the excited, isomeric form of hafnium-178, has a half-life of 31 years.

The possibility that this process could be explosive was discovered when Carl Collins and colleagues at the University of Texas at Dallas demonstrated that they could artificially trigger the decay of the hafnium isomer by bombarding it with low-energy Xrays (New Scientist, 3 July 1999, p42). The experiment released 60 times as much energy as was put in, and in theory a much greater energy release could be achieved.

Before hafnium can be used as an explosive, energy has to be "pumped" into its nuclei. Just as the electrons in atoms can be excited when the atom absorbs a photon, hafnium nuclei can become excited by absorbing high-energy photons. The nuclei later return to their lowest energy states by emitting a gamma-ray photon. Nuclear isomers were originally seen as a means of storing energy, but the possibility that the decay could be accelerated fired the interest of the Department of Defense, which is also investigating several other candidate materials such as thorium and niobium.

For the moment, the production method involves bombarding tantalum with protons, causing it to decay into hafnium-178m2. This requires a nuclear reactor or a particle accelerator, and only tiny amounts can be made. Currently, the Air Force Research Laboratory at Kirtland, New Mexico, which is studying the phenomenon, gets its hafnium-178m2 from SRS Technologies, a research and development company in Huntsville, Alabama, which refines the hafnium from nuclear material left over from other experiments. The company is under contract to produce experimental sources of hafnium178m2, but only in amounts less than one ten-thousandth of a gram.

But in future there may be cheaper ways to create the hafnium isomer - by bombarding ordinary hafnium with high-energy photons, for example. Hill Roberts, chief scientist at SRS, believes that technology to produce gram quantities will exist within five years. The price is likely to be high- similar to enriched uranium, which costs thousands of dollars per kilogram- but unlike uranium it can be used in any quantity, as it does not require a critical mass to maintain the nuclear reaction.

The hafnium explosive could be extremely powerful. One gram of fully charged hafnium isomer could store more energy than 50 kilograms of TNT. Miniature missiles could be made with warheads that are far more powerful than existing conventional weapons, giving massively enhanced firepower to the armed forces using them.

The effect of a nuclear-isomer explosion would be to release high-energy gamma rays capable of killing any living thing in the immediate area. It would cause little fallout compared to a fission explosion, but any undetonated isomer would be dispersed as small radioactive particles, making it a somewhat "dirty" bomb. This material could cause long-term health problems for anybody who breathed it in.

There would also be political fallout. In the 1950s, the US backed away from developing nuclear mini-weapons such as the "Davy Crockett" nuclear bazooka that delivered an explosive punch of 18 tonnes of TNT. These weapons blurred the divide between the explosive power of nuclear and conventional weapons, and the government feared that military commanders would be more likely to use nuclear weapons that had a similar effect on the battlefield to conventional weapons. By ensuring that the explosive power of a nuclear weapon was always far greater, it hoped that they could only be used in exceptional circumstance when a dramatic escalation of force was deemed necessary.

Then in 1994, the US confirmed this policy with the Spratt-Furse law, which prevents US military from developing mini-nukes of less than five kilotons. But the development of a new weapon that spans the gap between the explosive power of nuclear and conventional weapons would remove this restraint, giving commanders a way of increasing the amount of force they can use in a series of small steps.

Nuclear-isomer weapons could be a major advantage to armies possessing them, leading to the possibility of an arms race.

AndrŽ Gsponer, director of the Independent Scientific Research Institute in Geneva, believes that a nation without such weapons would not be able to fight one that possesses them. As a result, he says, "many countries which will not have access to these weapons will produce nuclear weapons as a deterrent", leading to a new cycle of proliferation.

The Department of Defense notes that there are serious technical issues to be overcome and that useful applications may be decades away. But its Militarily Critical Technologies List also says: "We should remember that less than six years intervened between the first scientific publication characterising the phenomenon of fission and the first use of a nuclear weapon in 1945."

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Author: David Hambling

UK CONTACT - Claire Bowles, New Scientist Press Office, London:
Tel: 44-207-331-2751 or email claire.bowles@rbi.co.uk
US CONTACT - Michelle Soucy, New Scientist Boston Office:
Tel: 617-558-4939 or email michelle.soucy@newscientist.com

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