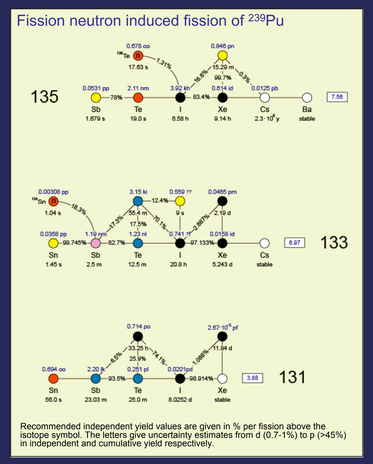
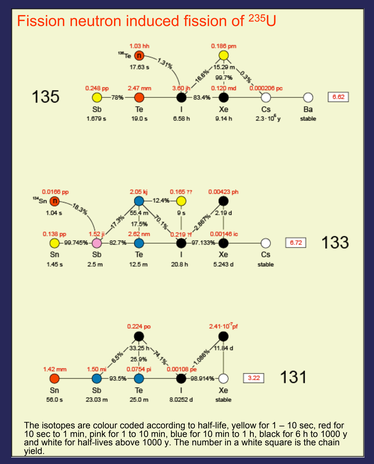
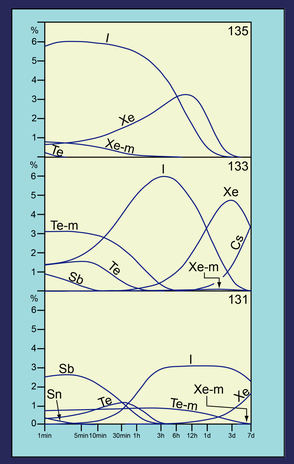
# Radioxenon signatures from underground nuclear explosions

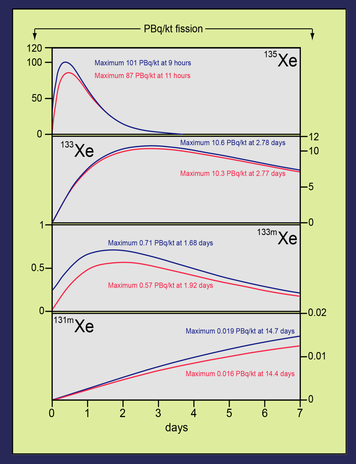
Lars-Erik De Geer, Swedish Defence Research Agency (FOI), Stockholm, Sweden

In the past radioactive noble gases quite commonly leaked from underground nuclear tests. Such gases do not attach to the cavity walls or other structures underground and are therefore quite complex and expensive to fully contain inside the cavity. The CTBT system focuses on two xenon nuclides ($^{133}$Xe, $^{135}$Xe) and two isomers ($^{131m}$Xe, $^{133m}$Xe) (all in this poster referred to as isotopes), which have different half-lives and are all products within a set of three different decay chains. Measured concentration relations in a sample taken off-site some time after the test, can be used to conclude on the scenario, e.g. the time of the leak, or more generally when a cut-off of the xenon precursors in the decay between iodine and xenon occurred (in the poster this is referred to as the iodine disconnection time). Note that the disconnection time does not necessarily coincide with the leak/emission time as e.g. the former can be due to xenon filtration through an internal plug and the latter can simply be due to a later opening of a portal. There is also a potential to gain some insight into whether the device was actually charged with $^{239}$Pu or $^{235}$U.

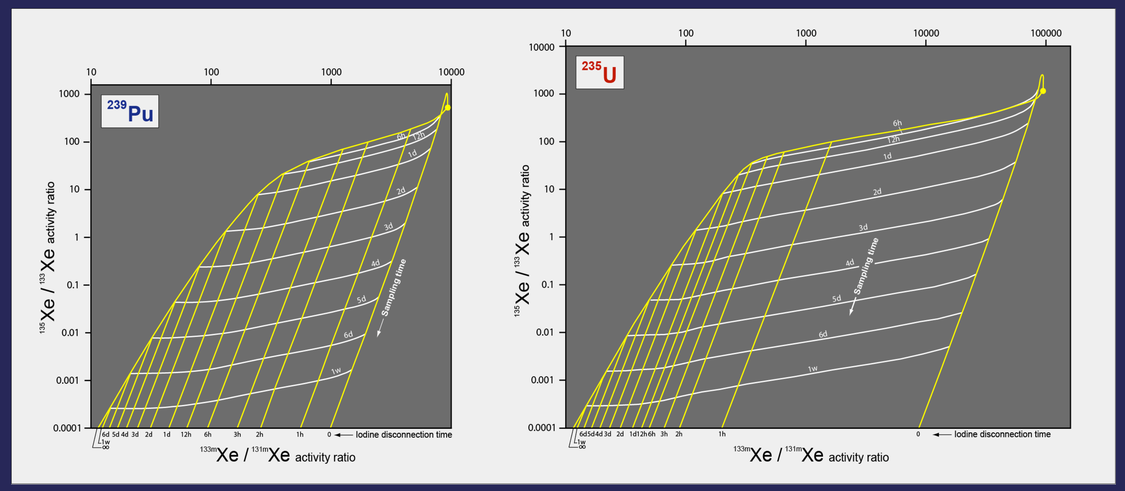


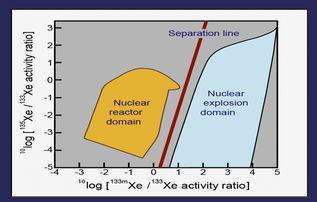



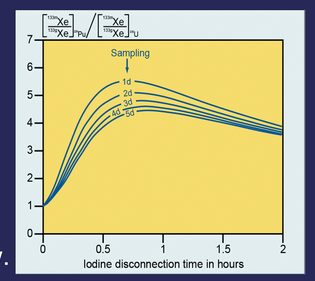
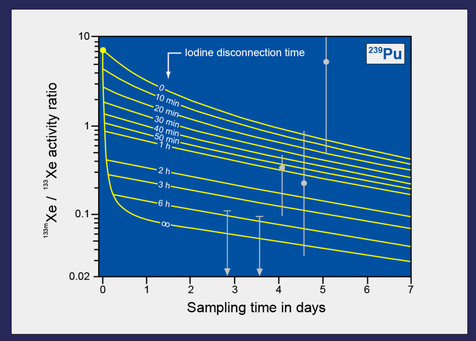
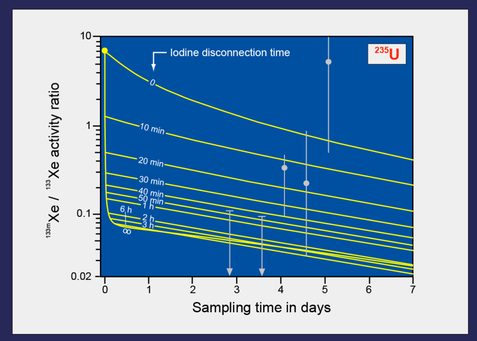
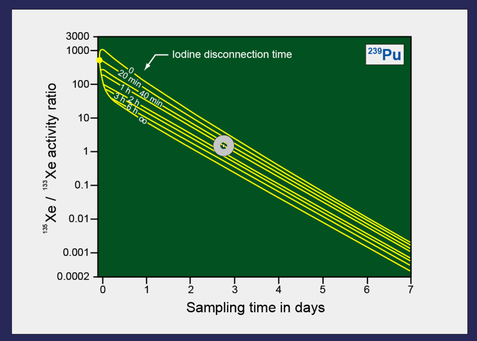
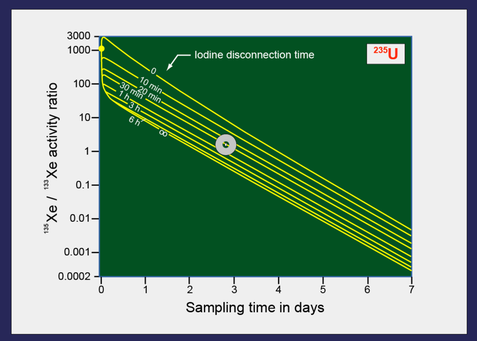




For the analysis the best available basic data is needed on the decays and what isotopes are produced initially in the fission process, be it fission of $^{239}$Pu or $^{235}$U. The latest available such data is summarized above in the two leftmost panels. The next panel gives the resulting yield development with time and the rightmost panel gives the xenon activity development in a cavity of full integrity.




If a full four nuclide signature is observed, marking it in a 135/133-activity-ratio to 133m/131m-activity-ratio plot (as introduced by Martin Kalinowski, see panel just to the left) one can in a very lucid way see whether it probably corresponds to a reactor emission or to a leak from an underground nuclear explosion. The leftmost panels fill the explosion domain with curve multitudes representing different iodine disconnection and sampling times for $^{239}$Pu and $^{235}$U explosives.

In many situations one can only expect to detect two or three of the isotopes (often not 131m as it has a very low production in explosions and also such a long half-life that it is often present globally or at least regionally as a reactor or medical isotope facility generated background). The panels below show the four combinations of two ratios (133m/133 and 135/133) and two fissile materials ($^{239}$Pu and $^{235}$U). The marked data points refer to detections of NK1, the first North Korean explosion on 9 October 2006 (133m/133 by Sweden and South Korea near the border (see poster by Ringbom et al.) and 135/133 by the US above the Japan See).

The 133m/133 ratio is, at disconnection times of about one hour, quite sensitive to the fissile material (see below). The 135/133 panels show NK1 disconnection times of 1 or 0.5 h and the 133m/-133 panels then show NK1 to be most consistent with $^{239}$Pu fuel (samples at > 4d, which were shown by meteorological analyses to be due to a very early leak). Had these samples been measured immediately (and not delayed by transport to Stockholm) the uncertainty bars would have been much smaller and a much firmer conclusion would have been possible to draw.