Chemical Reactions And Quick Dispersion

From the perspective of danger to human health, the most important difference between UF_6 and other radioactive materials is that solid, liquid, or gaseous UF_6 will quickly form a highly toxic cloud on contact with air or water. This is the main reason UF_6 is kept in special steel containers. When UF_6 comes into contact with moisture in the air, a gaseous cloud is rapidly formed of highly corrosive, non-radioactive hydrofluoric acid (HF)[7] and fine particles of radioactive uranyl fluoride (UO_2F_2). The reactions can be written as follows:

a) when UF_6 is in the gaseous phase:

$$UF_6 \text{ (gas)} + {}_2H_2O \text{ (gas)} \longrightarrow$$
$$UO_2F_2 \text{ (solid)} + {}_4HF \text{ (gas)} + 156.8 \text{ kJ/mole.}$$

b) when UF_6 is in the solid phase:

$$UF_6 \text{ (solid)} + {}_2H_2O \text{ (liquid)} \longrightarrow$$
$$UO_2^{++} + {}_2F^- + {}_4HF \text{ (gas)} + 211.6 \text{ kJ/mole.}$$ [8]

A concise description by an NRC scientist of the reaction between UF_6 and air is,

> "The reaction occurs very rapidly, generally taking no more than a few seconds with a maximum of about 10 seconds if several tons of uranium hexafluoride are released as a gas or liquid into relatively dry air. The chemical reaction also releases heat, making the plume buoyant and causing it to rise.
>
> "One kg of UF_6 contains 0.68 kg of uranium ions and 0.32 kg of fluorine ions. The reaction with water in the air produces 0.23 kg of HF."[9]

The rate of reaction between UF_6 and water vapor in the air is slower when UF_6 is in the solid phase, as is normally the case during transport. British nuclear scientists writing about safety at the Capenhurst enrichment plant in the U.K. point out that even when UF_6 is in the solid phase,

> "One kg of water will react with approximately 10 kg of UF_6 to form approximately two kg of HF and a release of this size would present a serious hazard to site personnel in the vicinity. Hence it was concluded that, with sufficient moisture present a handling accident leading to a spill of UF_6 could produce a serious local hazard..."[10]

When a type 48Y cylinder is heated to 121°C and in a horizontal position with its valve open and at the lowest point, it takes only four minutes for 80% of the contents to leak out. At a temperature of 121°C it is estimated that 2.7 kg of UF_6 will vaporize every second.[11] How far the vaporized UF_6 travels depends on the temperature of the UF_6, as well as on wind conditions.

When describing the chemical properties of UF_6, E.J. Barber wrote,

> "UF_6 tends to be strongly chemisorbed[12] on most materials, giving a high surface coverage and consequently good molecular contact and greatly increasing the opportunity for reactions."[13]

UF_6 does not react with oxygen, nitrogen, or dry air, and will not excessively corrode dry aluminium, copper, monel, nickel, and aluminum bronze. Hydrocarbon oils are a special case. The IAEA has written,

> "Due to the oxidizing properties of UF_6, the reaction of liquid UF_6 with some organic materials is unpredictable and may be explosive. Small quantities of hydrocarbon oil may react vigorously resulting in a serious explosion. As a result extreme caution should be used to ensure cylinders are clean and free of organics."[14]

[7] Hydrofluoric acid and hydrogen fluoride are the same substance.

[8] IAEA, November 1990, p. 31. The "kJ/mole" is a measure of the heat released in the reaction per quantity of UF_6. A "mole" is a number of elementary units (atom, molecule, ion, electron, etc.) equal to the number of atoms in 0.012 kg of carbon-14.

[9] McGuire, April 1990, p. 2.

[10] Norsworthy and Howarth, 1978, p. 204; in: OECD, 1978.

[11] Bouzigues, et. al., 1978, p. 347; in: OECD, 1978.

[12] "Strongly chemisorbed" means that UF_6 spreads out and "sticks" to most materials.

[13] Barber, 1988, p. 4; in: Strunk and Thornton (eds), undated.

[14] IAEA, November 1990, p. 31. See also Barber, 1988, p. 4; and Williams, 1988, p. 18; both in: Strunk and Thornton (eds), undated.