Magnificent molecules

In this issue: uranium hexafluoride

Phillip Broadwith *examines the molecule that fuels the nuclear power industry*

Imagine trying to separate two isotopes of an element. The only difference between them is that one is just a tiny bit lighter than the other. Now imagine that the isotope you want makes up less than 1% of the total number of atoms.

That's the problem facing anyone trying to make fuel for a nuclear reactor – or a nuclear bomb: uranium-235 is the isotope required for the fission process that provides the energy for both nuclear bombs and power stations. Unfortunately, over 99% of natural uranium is the slightly heavier isotope uranium-238.

Isotopic enrichment

So how can we increase the proportion of uranium-235? The answer is: with great difficulty!

It all comes down to momentum. When you give a mixture of particles some energy – be they atoms, molecules or whatever – the heavier ones move slightly slower than the lighter ones. This is most pronounced for gases, so what we really need is a gaseous form of uranium.

But the boiling point of uranium is over 4000°C, which makes it rather impractical to work with. Enter uranium hexafluoride: this is a crystalline solid at room temperature, and sublimes directly to a gas at a much more achievable 57°C.

But uranium hexafluoride is not a particularly pleasant compound. Making it involves some pretty unfriendly chemicals: you have to use elemental fluorine, or nitric acid, ammonia and hydrofluoric acid. Not processes I'd be too keen to try in a hurry! And UF_6 itself is corrosive to most metals. It also needs to be kept really dry. The slightest whiff of water and it breaks down.

Spinning separation

But even with uranium hexafluoride, the task of separating the two isotopes is technologically challenging. The UF_6 is fed into massive gas centrifuges, which accelerate the gas molecules to over 100 000 revolutions per minute to separate them (the heavier ones move towards the outside wall of the centrifuge, whereas lighter ones stay nearer the middle).

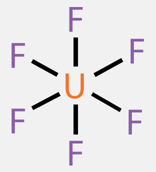
Because the difference in mass between the two molecules is so small, this process has to be repeated many times, so uranium enrichment facilities usually have hundreds or even thousands of centrifuges set up to feed from one to the next.

However, there are possible alternatives that could make uranium enrichment simpler and cheaper. One option is using a laser at just the right frequency to selectively excite and ionise only the UF_6 molecules containing uranium-235. The charged molecules are then much easier to separate from the neutral ones containing uranium-238, using an electromagnetic field.

But whether you use a laser or a centrifuge, and whether you're trying to help solve the world's energy crisis or destroy it in a nuclear war, you're going to need some very brave and experienced (or very reckless) chemists to deal with the compound that makes it all possible in the first place.

Did you know?

Once the ^{235}U isotope has been separated, the leftover material is called 'depleted uranium'. This has a very high density and is used in armour-piercing ammunition (among other things) though many countries are calling for this use to be stopped.



uranium hexafluoride

Uranium-based fuel rods are loaded into a nuclear power station's reactor core. The reactor is immersed beneath the water and lifting machinery is used to raise and lower the fuel rods into the core

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