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LASER CHEMISTRY AND THE NUCLEAR FUEL CYCLE

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LASER CHEMISTRY AND THE NUCLEAR FUEL CYCLE

I. Nuclear Fuel Cycle Chemistry Problems

The outstanding problems in energy-related chemistry as viewed from the nuclear fuel industry are those dealing with highly selective and complete separation of elements or nuclides of importance in reactors. As supplies of fossile fuels are exhausted, the world is turning to nuclear fuel. The expansion of this component of energy supply depends upon increased capacity in each of the following areas:

1. Supply of ore
2. Isotope Enrichment
3. Fuel Fabrication
4. Fuel recycle and waste management

Item number four is currently the most problematical,and the area in which there is the most room for improvement of present practice. Item one is also a severe problem because according to presently projected supplies and economics there is only enough uranium to last a few dozen years.[1] The breeder reactor option could stretch this to over a hundred years if appropriate improvements are also made in the area of fuel recycle. Item two is one for which technology presently exists, but the current techniques are very capital and energy intensive. This high expense arises from the inefficiency of gaseous diffusion which expends over 10^8 times the entropy of mixing in order to separate isotopes. Gas centrifuge systems seem to be better by about a factor of three, but still leave much room for improvement. It appears that some form of isotopically selective laser-induced chemistry could improve this cost picture by more than a order of magnitude.[2]

A dramatically improved method of isotope separation of heavy elements could expedite establishment of a breeder reactor economy, and even provide for the removal of ^{232}U from bred thorium fuel allowing the use of that relatively plentiful fuel.

The chemistry of nuclear reactor fuel recycle and waste has not received the attention it deserves. The problem is very complex -- not simply because of the large number of chemical elements present in the used fuel rod -- but because the entire assembly is radioactive and can rapdily degrade fragile reagents needed in the process. The spent fuel rods are mechanically distorted and deteriorating when about 3 to 10% of the fissionable material is spent. At this point they contain all of the elements from Ga to Cm in the periodic chart.

The present method of extracting the plutonium and unused uranium is a liquid-liquid extraction process based on the relative solubilities of Pu^{4+} and U^{6+} in an organic solution of tributylphosphate in kerosene. The Pu and U are extracted into the organic phase while the fission products are left behind in the aqueous phase. The process has two major problems: the radioactivity of the used rod degrades the reagents, and the separations are not sufficiently complete to allow for easy management of the various effluents. The normal tendency to add a reagent to improve the process often increases the amount of radioactive material to be stored without giving a commensurate benefit. Any photochemical enhancement or improvement of the process by inducing desirable reactions with material already in the stream is of great advantage. Lasers could play an important role in both the research and the process of photochemical improvements to the fuel recycle process.

II. Lasers

The laser power needed for industrial scale processes is very modest. For isotope separation, infrared power of near 100 watts and uv or visible power of about 10^4 to 10^5 watts will be adequate for a 10^7 SWU per year plant (equal to the improved version of the present diffusion plants). While requirements are less defined for fuel recycle plants, average powers of less than .1 MW are indicated for most industrial scale processes we have considered.

The outstanding requirement for lasers used in laser-induced chemical processes is modest power at very specific frequencies. There is a great need for precisely tunable, .05 cm^{-1} band width lasers throughout the infrared region. It is expected that the development of lasers will pace the progress in the above problems for the foreseeable future.

REFERENCES

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