Spent nuclear fuel

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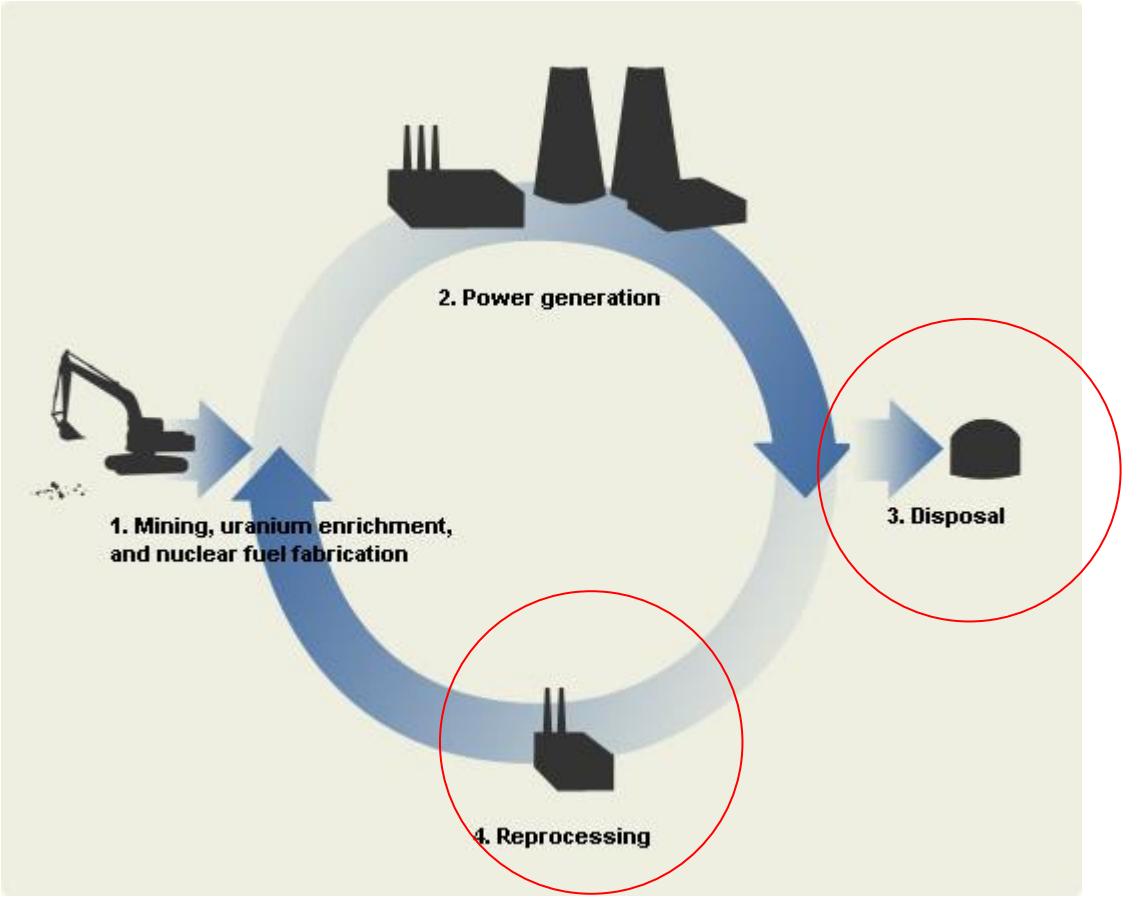
The nuclear fuel cycle



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Who is Mats Jonsson?

- MSc in Chemistry and Chemical Engineering (1991)
- PhD in Nuclear Chemistry (1995)
- Postdoc at NRC, Ottawa, Canada (1995/1996)
- Researcher at ABB Corporate Research (Swe) (1996/1997)
- Assistant Professor at KTH (1997-2003)
- Associate Professor at KTH (2003-2005)
- Professor (Nuclear Chemistry) at KTH (2005-)
- Head of department of Chemistry (2009-2011)
- Vice Dean School of Chemical Science and Engineering (2011-)

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Mats Jonsson: Research history

- 1991-1996: Free radical (radiation) chemistry
- 1996/1997: Reactor chemistry (CRUD)
- 1997-1999: Free radical chemistry (including polymer chemistry)
- 2000- : Geological repositories for spent nuclear fuel, Interfacial radiation chemistry, Polymer chemistry, Photocatalysis

- Focus on radiation chemistry

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Lectures: Outline

- Part 1: Characteristics of spent nuclear fuel
- Part 2: Geological repositories for spent nuclear fuel
- Part 3: Reprocessing of spent nuclear fuel

- Part 2 is the main part

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Part 1: Characteristics of spent nuclear fuel

- What is nuclear fuel?
- What happens to the nuclear fuel in the reactor?
- What is spent nuclear fuel?

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Nuclear fuel (UO_2)

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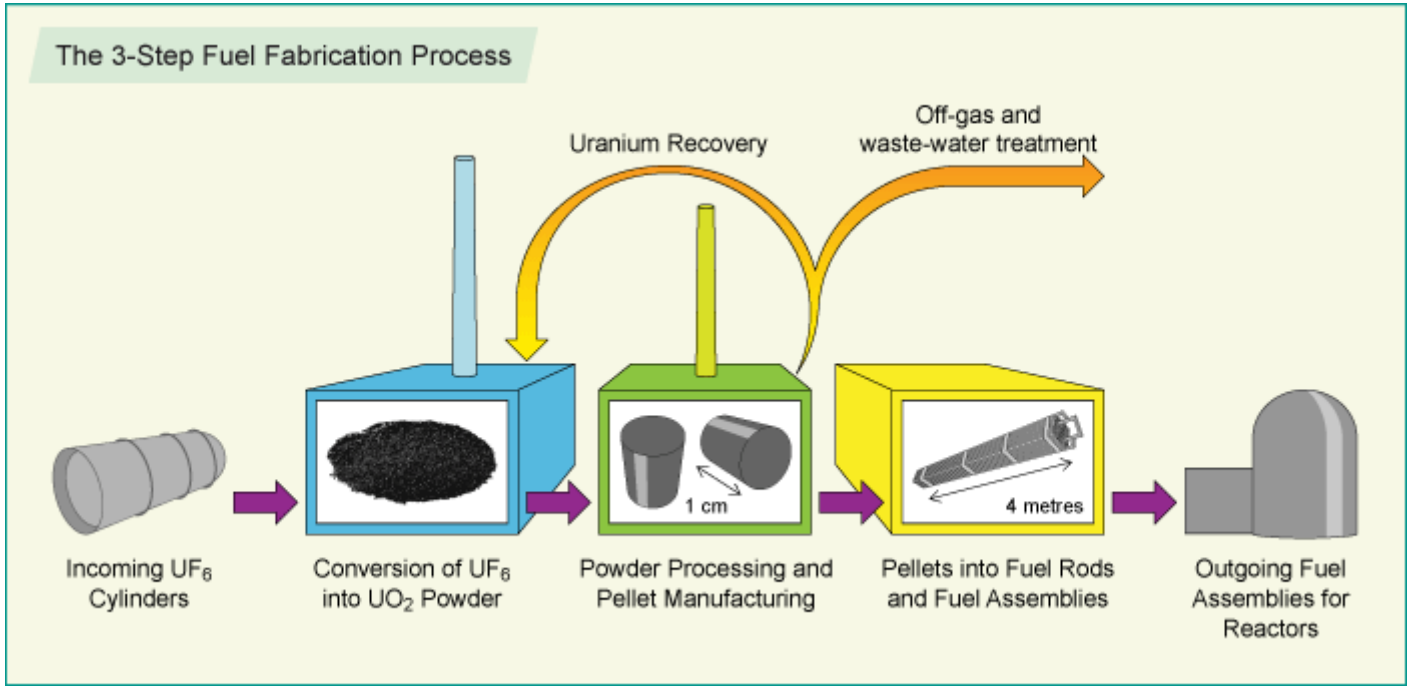
Fuel manufacturing



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Nuclear fuel

- Ceramic material with very high density
- Homogeneous material
- Chemically fairly stable in the absence of oxidants (e.g. O_2)
- UO_2 powder is pyrophoric in oxygen atmosphere!

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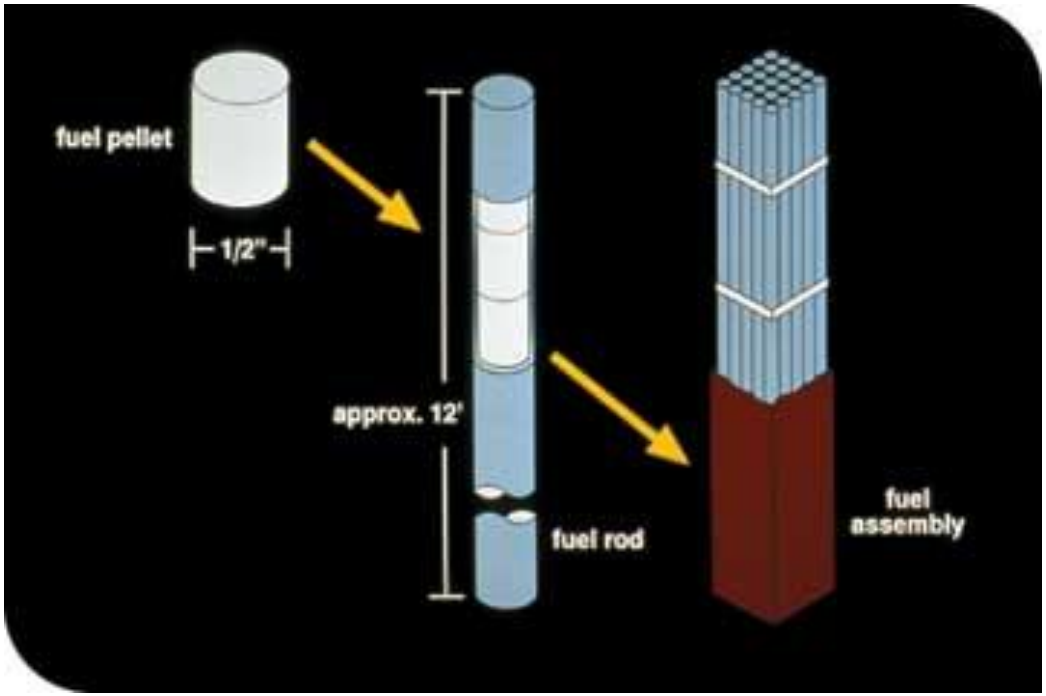
Fuel elements



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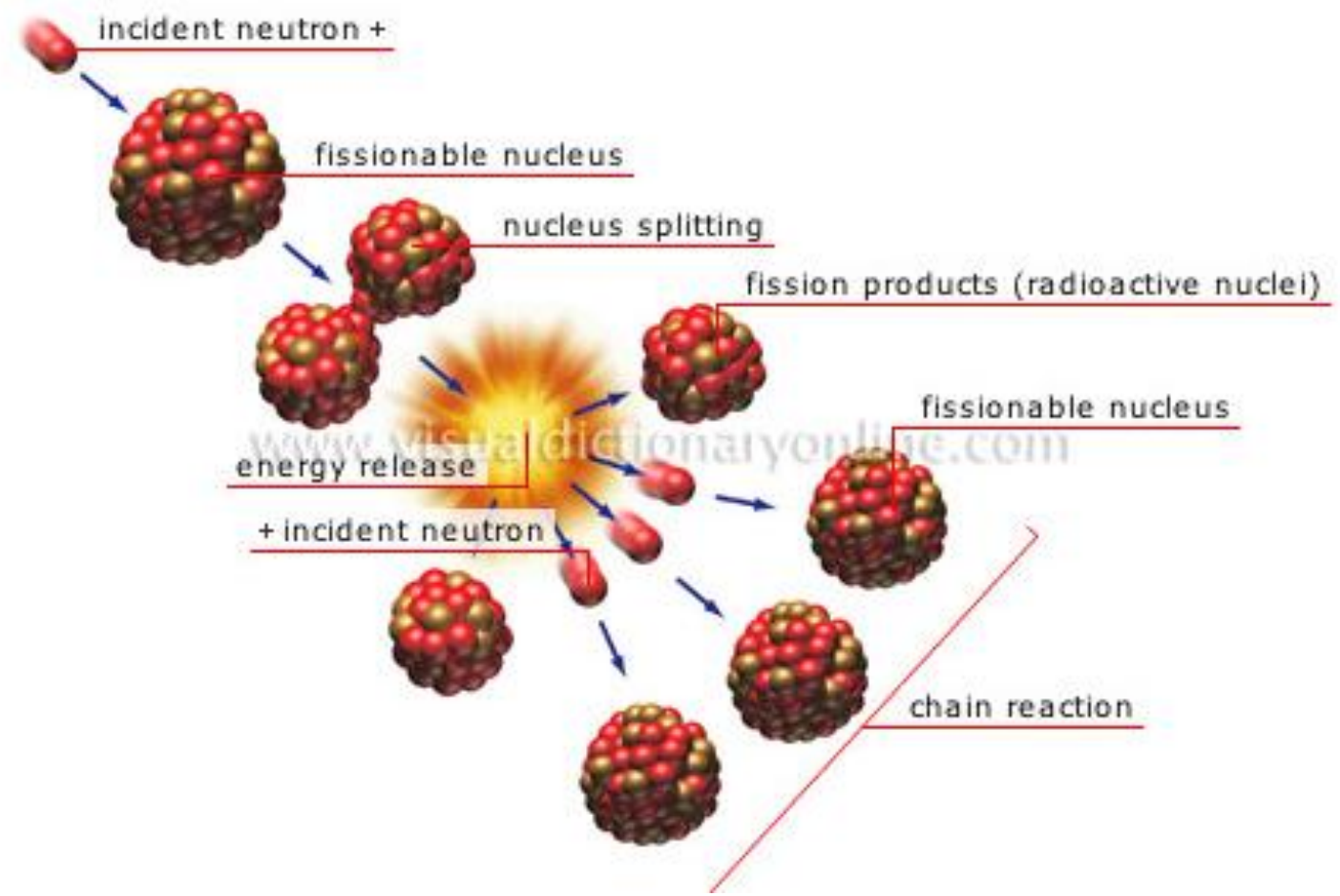
What happens in the reactor?



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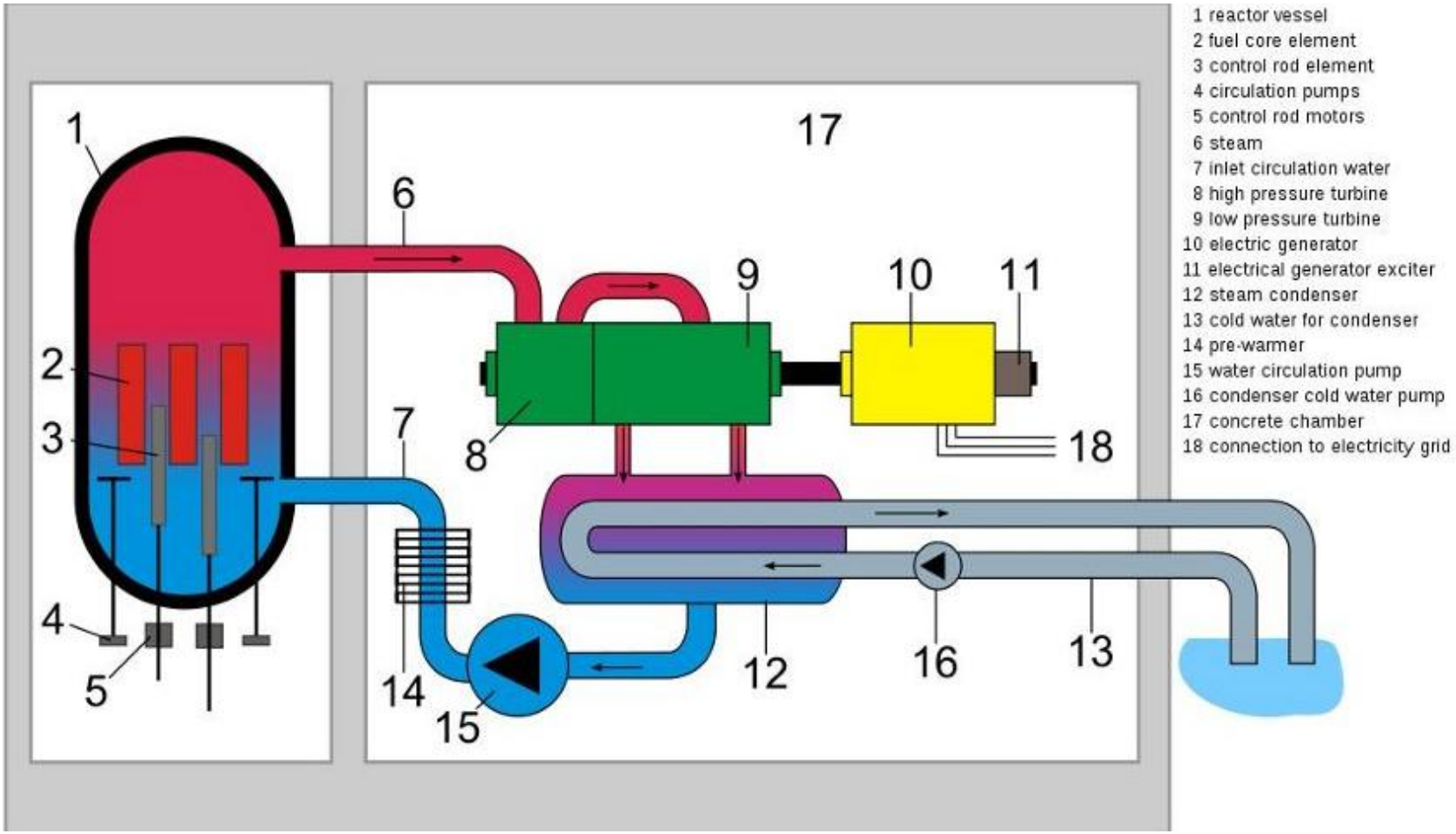
What happens in the reactor?



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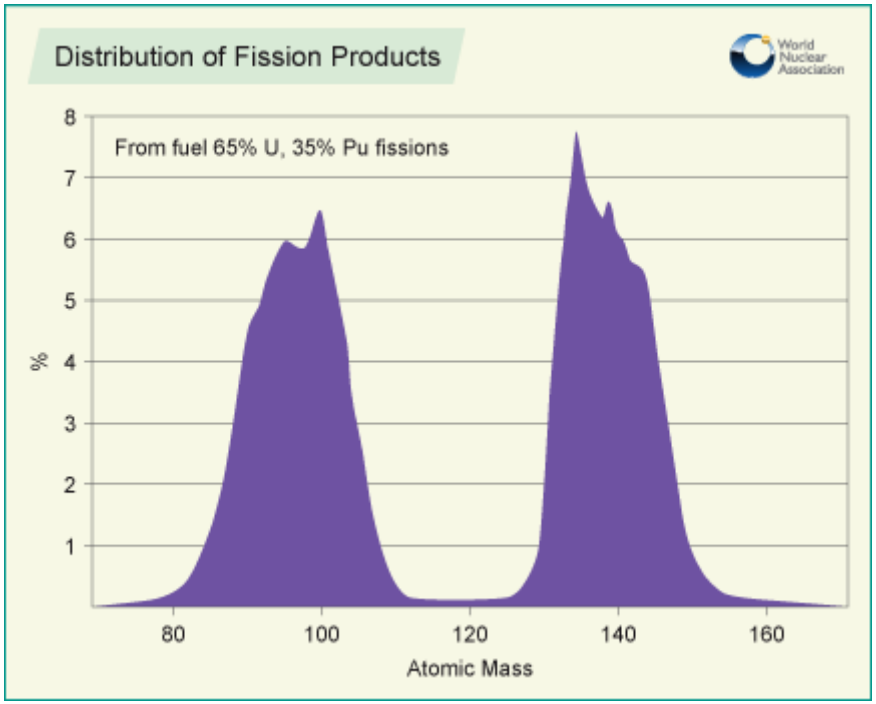
Fission product distribution



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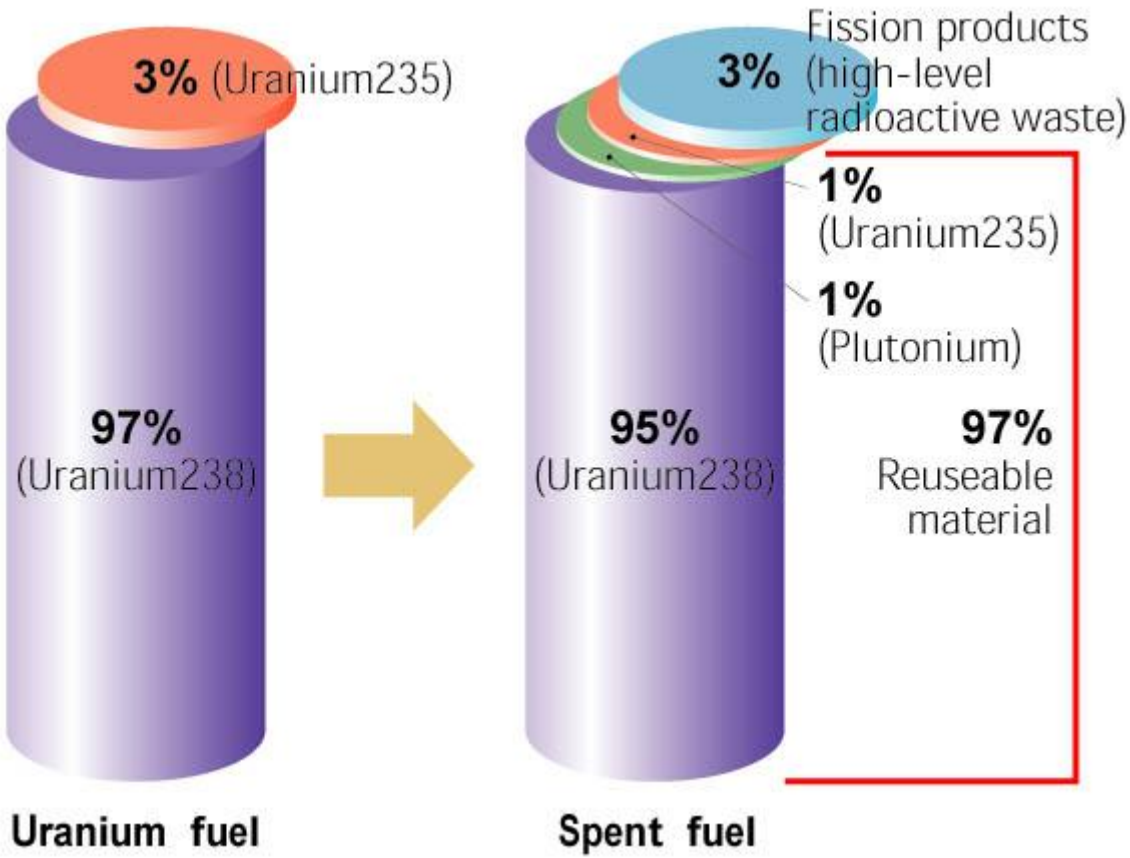
Composition of spent nuclear fuel



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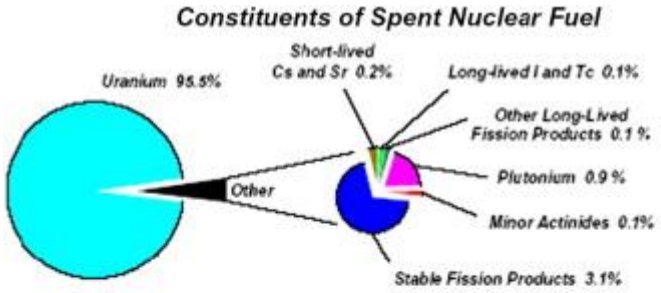
Composition of spent nuclear fuel



1 metric tonne of SNF contains:*

955.4 kg U
8.5 kg Pu (5.1 kg ^{239}Pu)

Minor actinides (MAs):

0.5 kg ^{237}Np
0.6 kg Am
0.02 kg Cm

Long-lived fission products (LLFPs):

0.2 kg ^{129}I
0.8 kg ^{99}Tc
0.7 kg ^{93}Zr
0.3 kg ^{135}Cs

Short-lived fission products (SLFPs):

1.0 kg ^{137}Cs
0.7 kg ^{90}Sr

Stable isotopes:

10.1 kg lanthanides
21.8 kg other stable

**33,000 MWD/MT, 10 yr cooling*

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What happens in the reactor?

- The pellets are exposed to intense radiation fields
- The temperature gradient in the pellet is extreme
- Vibrations in the fuel bundles

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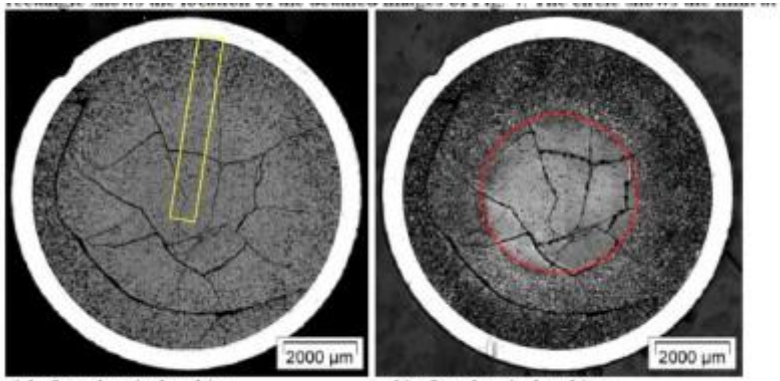
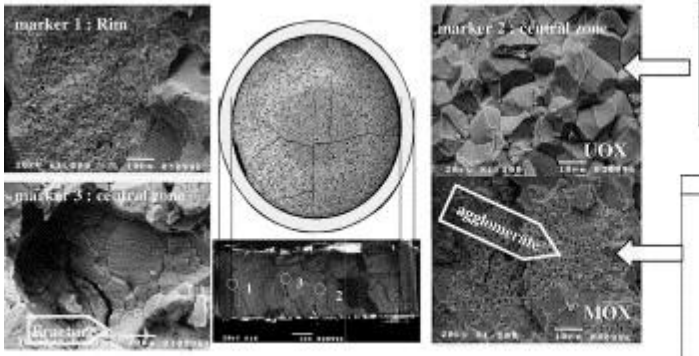
Nuclear fuel after use in the reactor



a) before chemical etching b) after chemical etching

More spent fuel



Element	UOX
Pu	1.0
Nd	0.5
Zr	0.4
Sr	<600ppm RIM : 1000ppm
Cs	0.4

Element		MOX
Pu	Matrix	1.5
	Agglomerate	12 à 15
Nd	Matrix	0.2
	Agglomerate	1.3
Zr	Matrix	0.2
	Agglomerate	1.3
Sr	Matrix	<600ppm
	Agglomerate	until 0.15 %
Cs	Matrix	0.25
	Agglomerate	0.7 à 1

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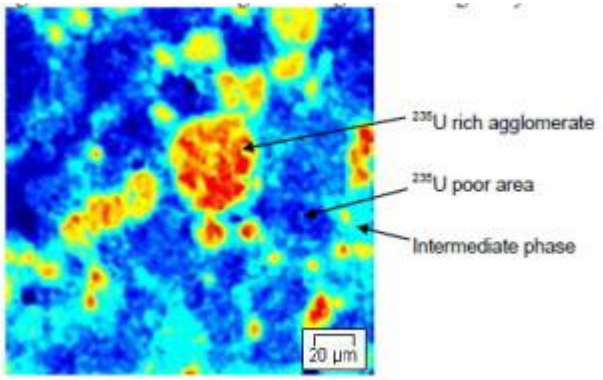
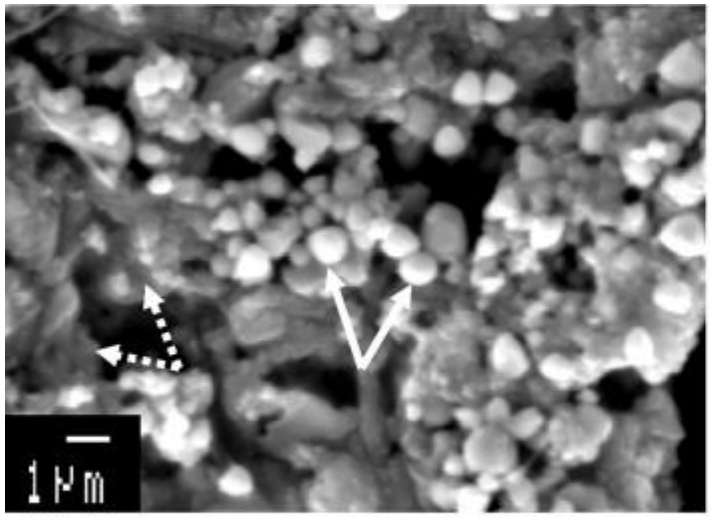
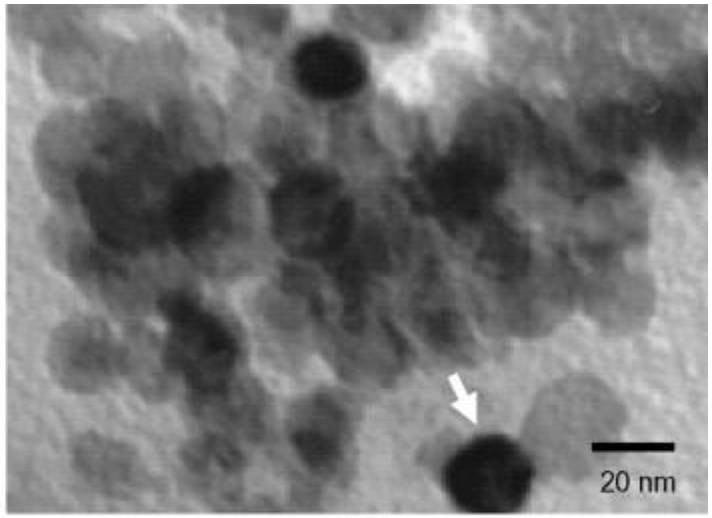
Uranium distribution



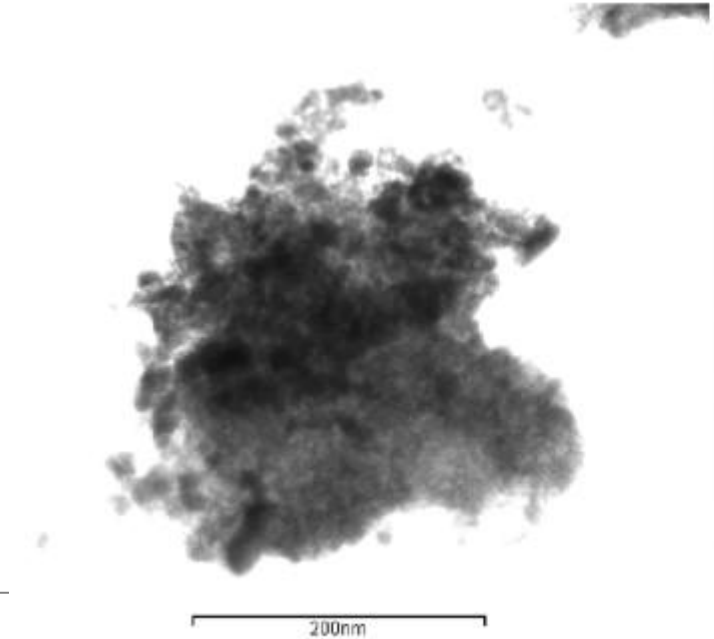
Noble metal inclusions (fission products)



(a)



(c)



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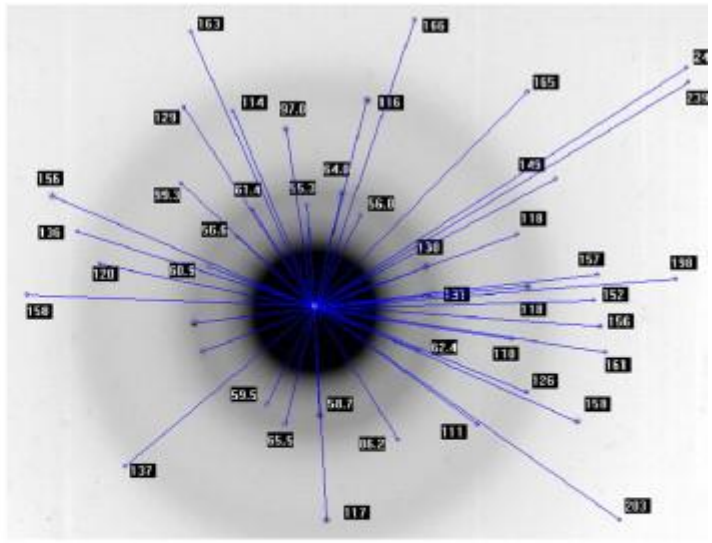

(d)

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Noble metal inclusions

- Sometimes called ε-particles or ε-phase
- Composed of metals that are insoluble in the oxide matrix

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Spent nuclear fuel is

- a highly heterogeneous material (chemical composition and microstructure)
- a hot material both in terms of temperature and radioactivity

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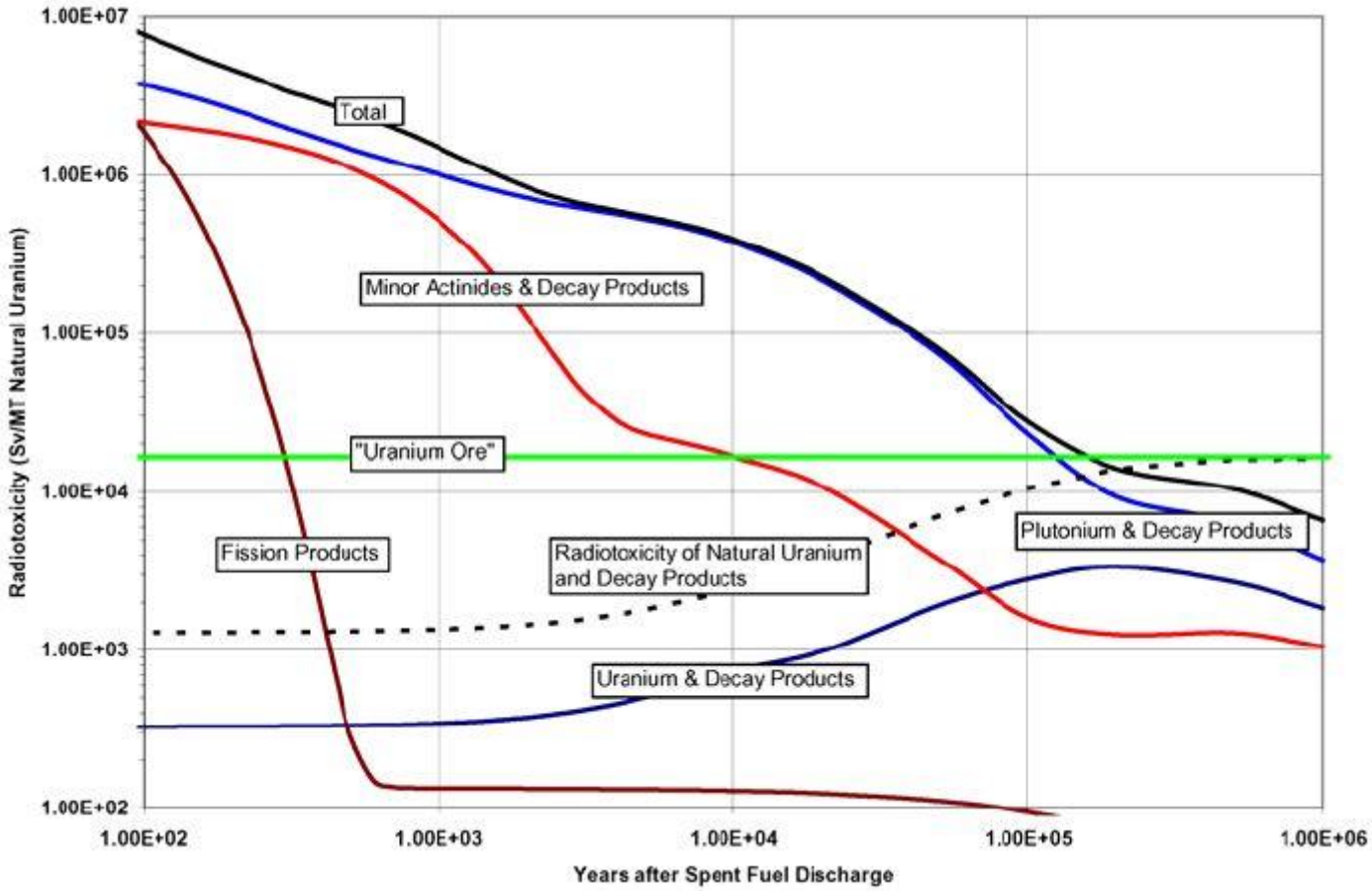
Radioactivity



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Spent nuclear fuel can be seen as

- a resource containing fissile material for nuclear fuel
- OR
- waste containing highly radiotoxic elements

Both are correct! (The second one is always correct)

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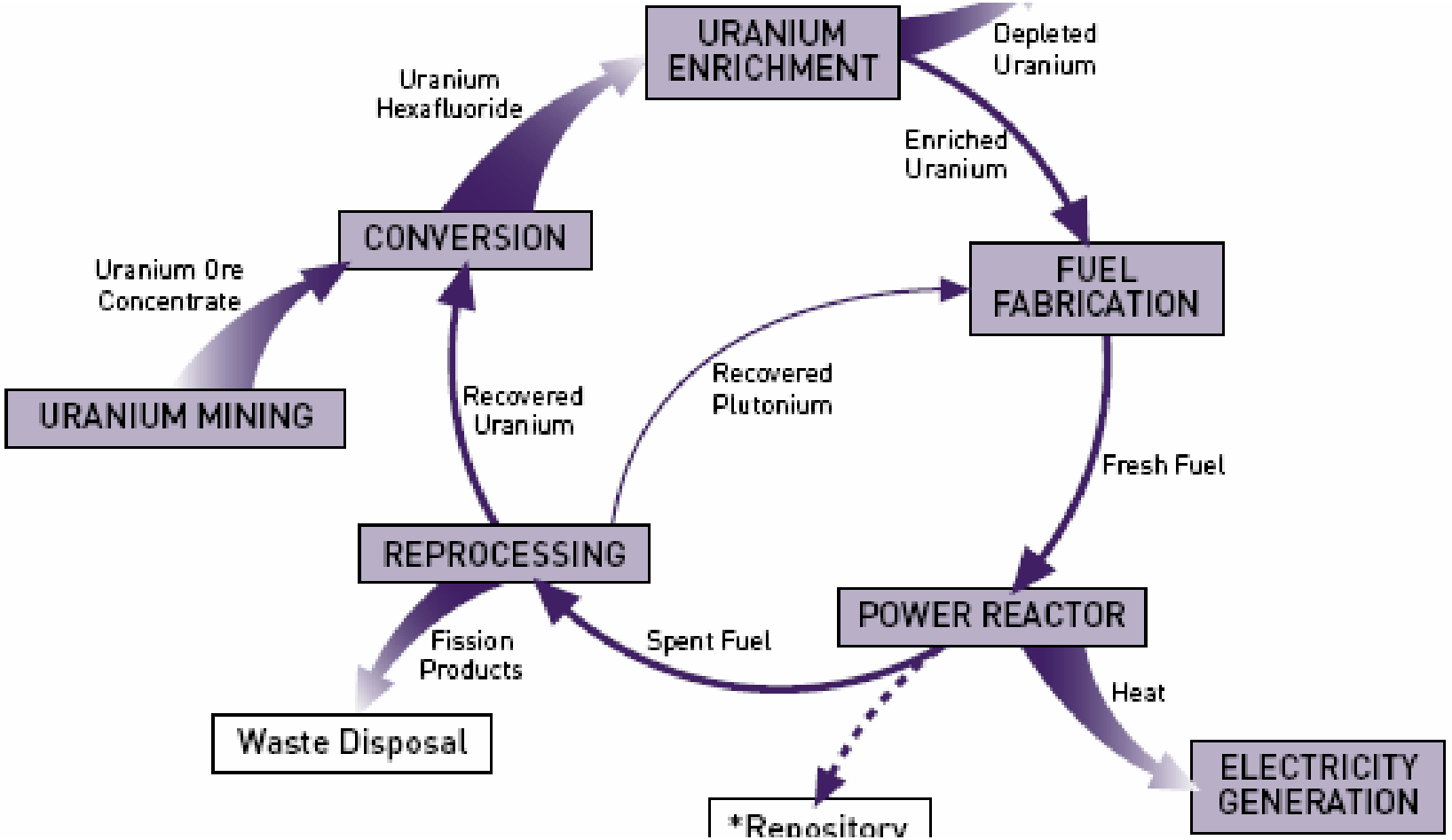
Options



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End of part 1