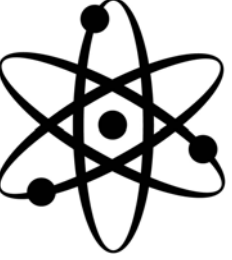




# The nuts and bolts of Nuclear Power



# From the atom and up

**Periodic Table of Elements**

1																	2			
1	IA																	0		
1	H																	He		
2	3	4																	10	
2	Li	Be																	Ne	
3	11	12	III B	IV B	V B	VI B	VII B	— VII —				IB	IB	5	6	7	8	9	17	18
3	Na	Mg																	Cl	Ar
4	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36		
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr		
5	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54		
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe		
6	55	56	57	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86		
6	Cs	Ba	*La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn		
7	87	88	89	104	105	106	107	108	109	110										
7	Fr	Ra	+Ac	Rf	Ha	106	107	108	109	110										

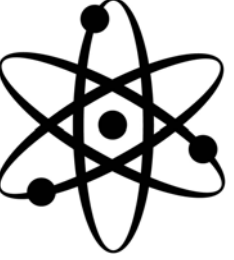
\* Lanthanide Series

58	59	60	61	62	63	64	65	66	67	68	69	70	71
Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu

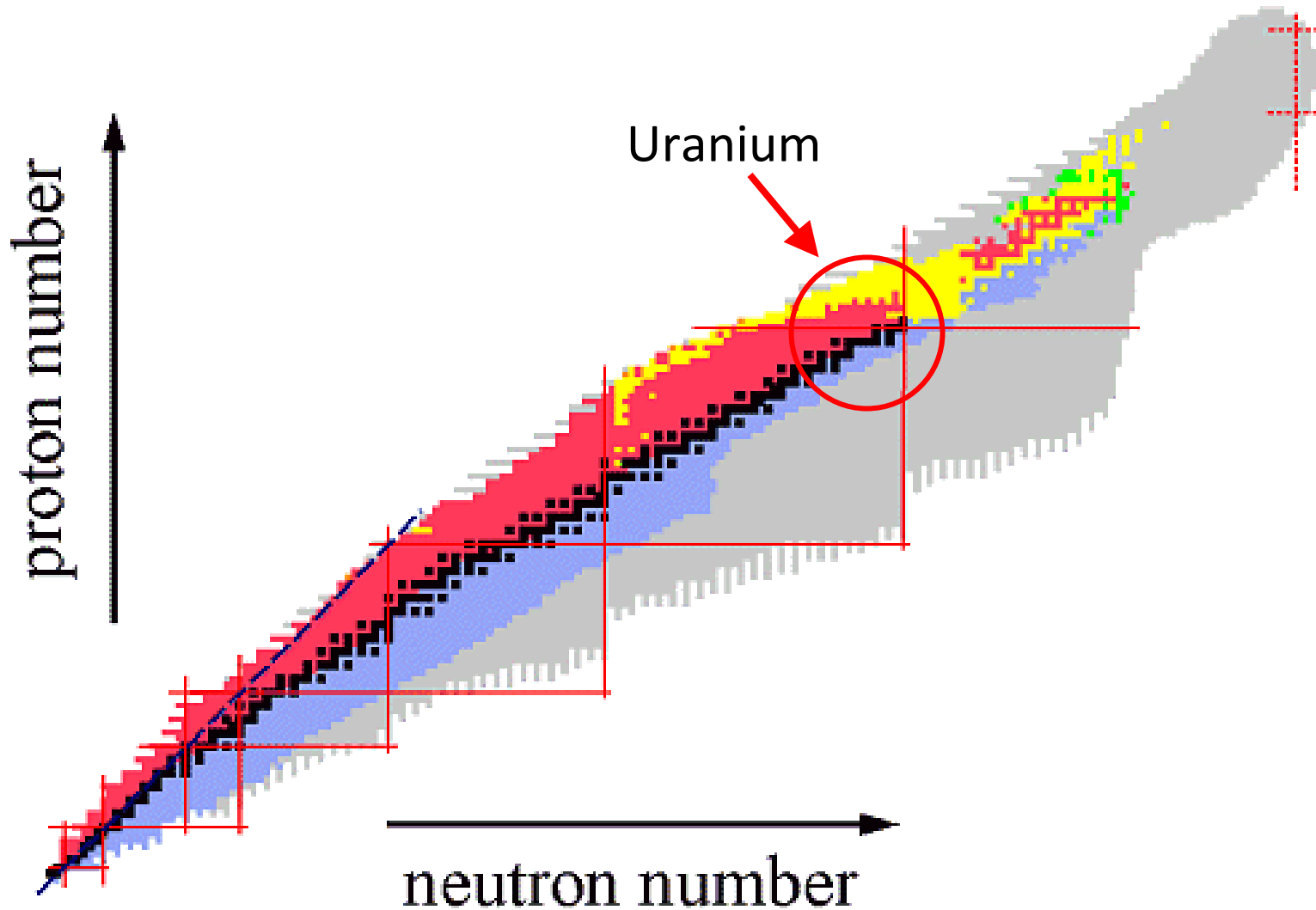
+ Actinide Series

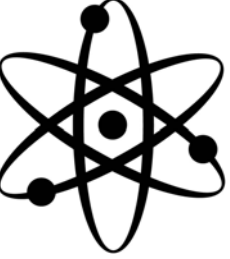
90	91	92	93	94	95	96	97	98	99	100	101	102	103
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

<b>H - gas</b>	<b>Li - solid</b>	<b>Br - liquid</b>	<b>Tc - synthetic</b>
Non-Metals	Transition Metals	Rare Earth Metals	Halogens
Alkali Metals	Alkali Earth Metals	Other Metals	Inert Elements

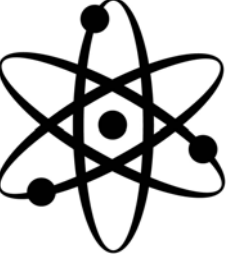


# Chart of the Nuclides



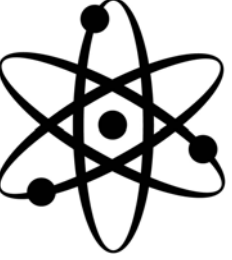


$^{232}\text{Pu}$	$^{233}\text{Pu}$	$^{234}\text{Pu}$	$^{235}\text{Pu}$	$^{236}\text{Pu}$	$^{237}\text{Pu}$	$^{238}\text{Pu}$	$^{239}\text{Pu}$	$^{240}\text{Pu}$	$^{241}\text{Pu}$	$^{242}\text{Pu}$	$^{243}\text{Pu}$	$^{244}\text{Pu}$
$^{231}\text{Np}$	$^{232}\text{Np}$	$^{233}\text{Np}$	$^{234}\text{Np}$	$^{235}\text{Np}$	$^{236}\text{Np}$	$^{237}\text{Np}$	$^{238}\text{Np}$	$^{239}\text{Np}$	$^{240}\text{Np}$	$^{241}\text{Np}$	$^{242}\text{Np}$	$^{243}\text{Np}$
$^{230}\text{U}$	$^{231}\text{U}$	$^{232}\text{U}$	$^{233}\text{U}$	$^{234}\text{U}$	$^{235}\text{U}$	$^{236}\text{U}$	$^{237}\text{U}$	$^{238}\text{U}$	$^{239}\text{U}$	$^{240}\text{U}$		$^{242}\text{U}$
$^{229}\text{Pa}$	$^{230}\text{Pa}$	$^{231}\text{Pa}$	$^{232}\text{Pa}$	$^{233}\text{Pa}$	$^{234}\text{Pa}$	$^{235}\text{Pa}$	$^{236}\text{Pa}$	$^{237}\text{Pa}$	$^{238}\text{Pa}$	$^{239}\text{Pa}$		
$^{228}\text{Th}$	$^{229}\text{Th}$	$^{230}\text{Th}$	$^{231}\text{Th}$	$^{232}\text{Th}$	$^{233}\text{Th}$	$^{234}\text{Th}$	$^{235}\text{Th}$	$^{236}\text{Th}$	$^{237}\text{Th}$			
$^{227}\text{Ac}$	$^{228}\text{Ac}$	$^{229}\text{Ac}$	$^{230}\text{Ac}$	$^{231}\text{Ac}$	$^{232}\text{Ac}$	$^{233}\text{Ac}$	$^{234}\text{Ac}$					
$^{226}\text{Ra}$	$^{227}\text{Ra}$	$^{228}\text{Ra}$	$^{229}\text{Ra}$	$^{230}\text{Ra}$	$^{231}\text{Ra}$	$^{232}\text{Ra}$	$^{233}\text{Ra}$	$^{234}\text{Ra}$				
$^{225}\text{Fr}$	$^{226}\text{Fr}$	$^{227}\text{Fr}$	$^{228}\text{Fr}$	$^{229}\text{Fr}$	$^{230}\text{Fr}$	$^{231}\text{Fr}$	$^{232}\text{Fr}$					
$^{224}\text{Rn}$	$^{225}\text{Rn}$	$^{226}\text{Rn}$	$^{227}\text{Rn}$	$^{228}\text{Rn}$								
$^{223}\text{At}$												



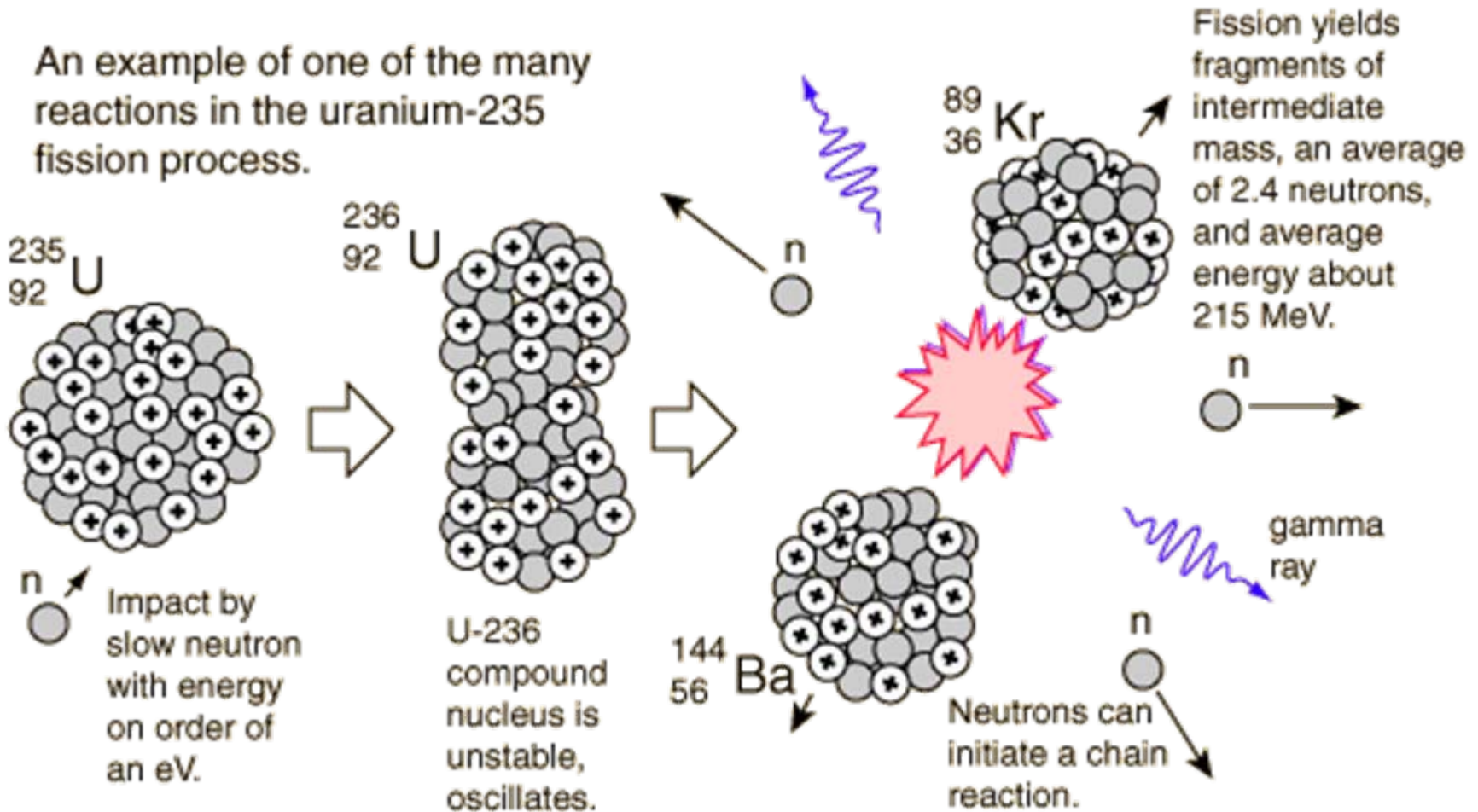
# Uranium-235

- **Atomic Mass:**  $235.0439231 \pm 0.0000021$  amu
- **Excess Mass:**  $40914.062 \pm 1.970$  keV
- **Binding Energy:**  $1783870.285 \pm 1.996$  keV
- **Beta Decay Energy:** B-  $-123.716 \pm 0.869$  keV
  
- **Atomic Percent Abundance:** 0.720%
- **Half life:**  $7.038 \times 10^8$  years

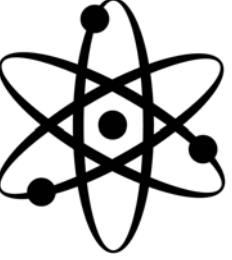


# Slow neutron capture and fission

An example of one of the many reactions in the uranium-235 fission process.



<http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html>



# Energy comparison

## Fission

215 MeV per fission =  $2.07 \times 10^{13}$  kJ/mol

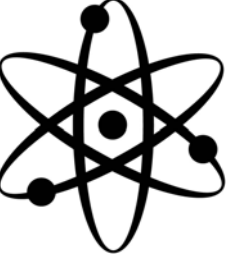
## Methane Combustion

810 kJ/mol

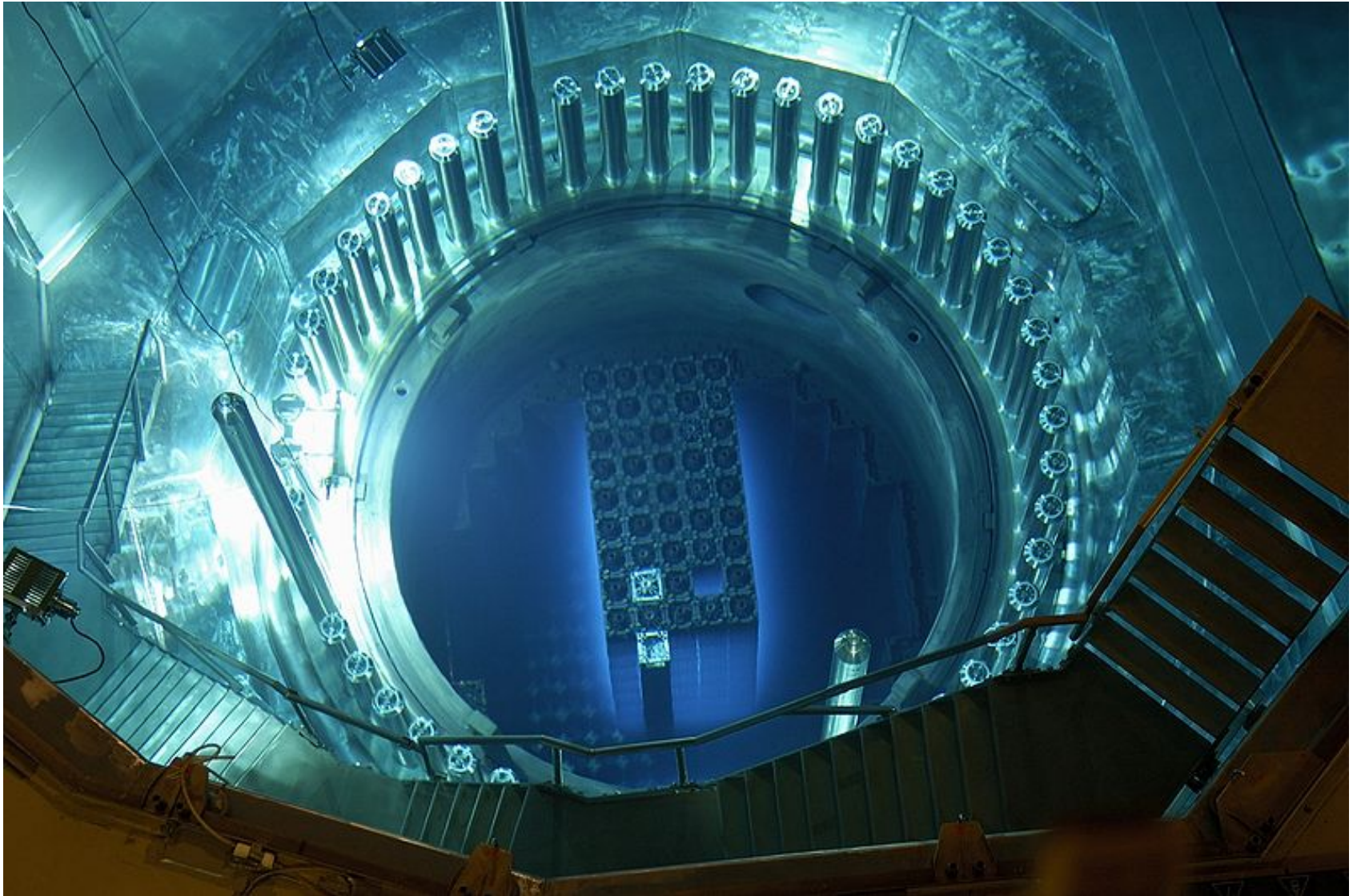
## Ratio

$2.56 \times 10^{10}$

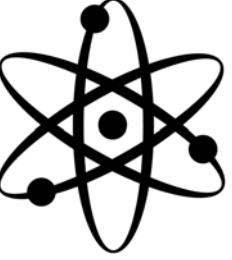




# The Reactor

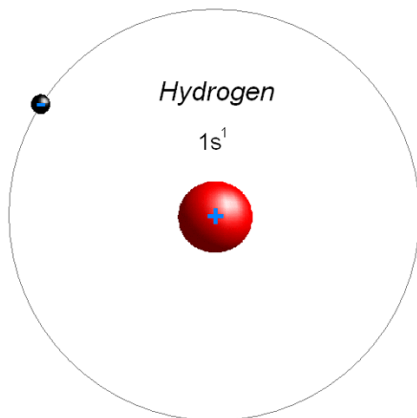




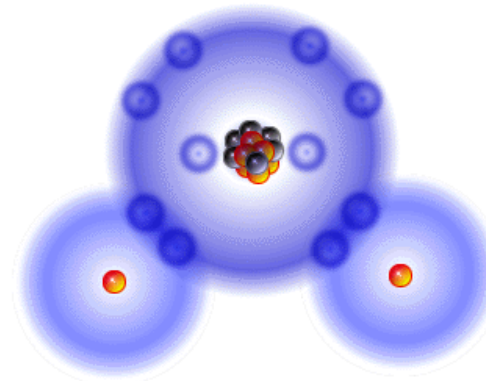


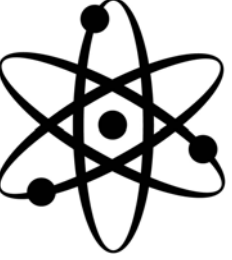
# Why water?

- Fission reactors work best if the fission neutrons are moving slowly, but they are born moving very fast
- Water is very efficient at slowing down the neutrons, as well as taking heat away from the fuel rods

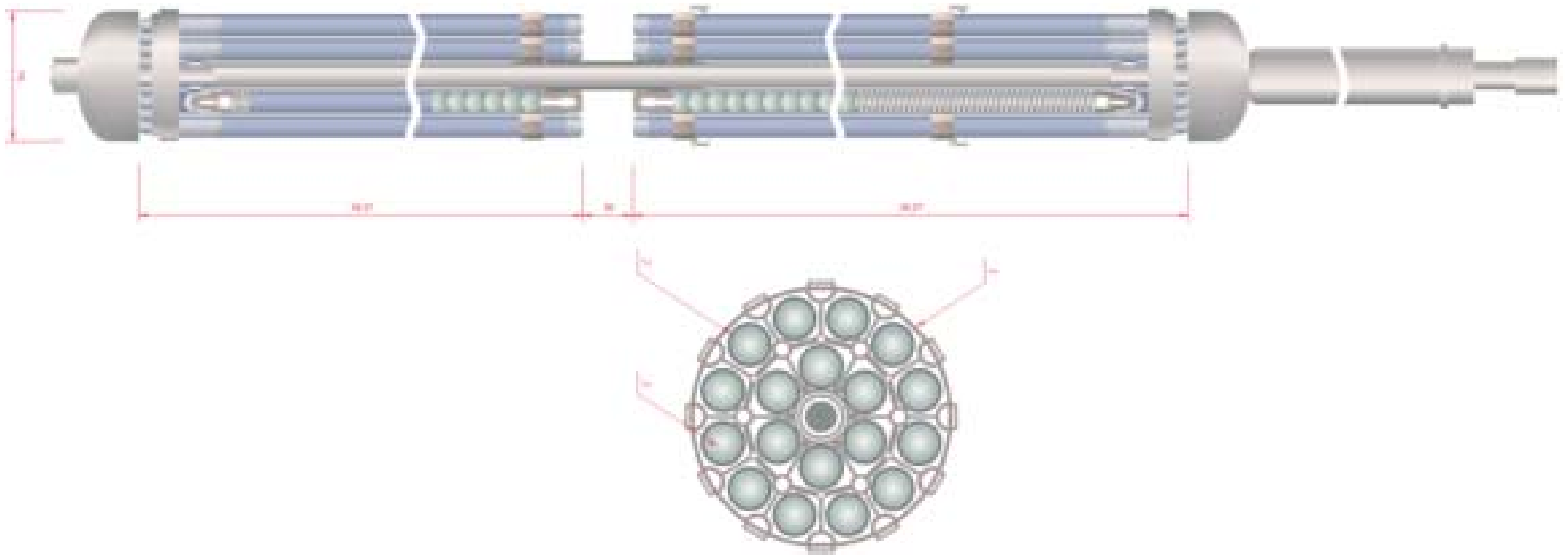


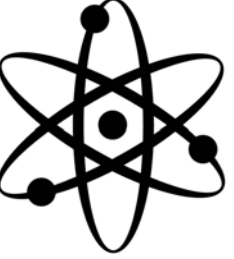
Water Molecule



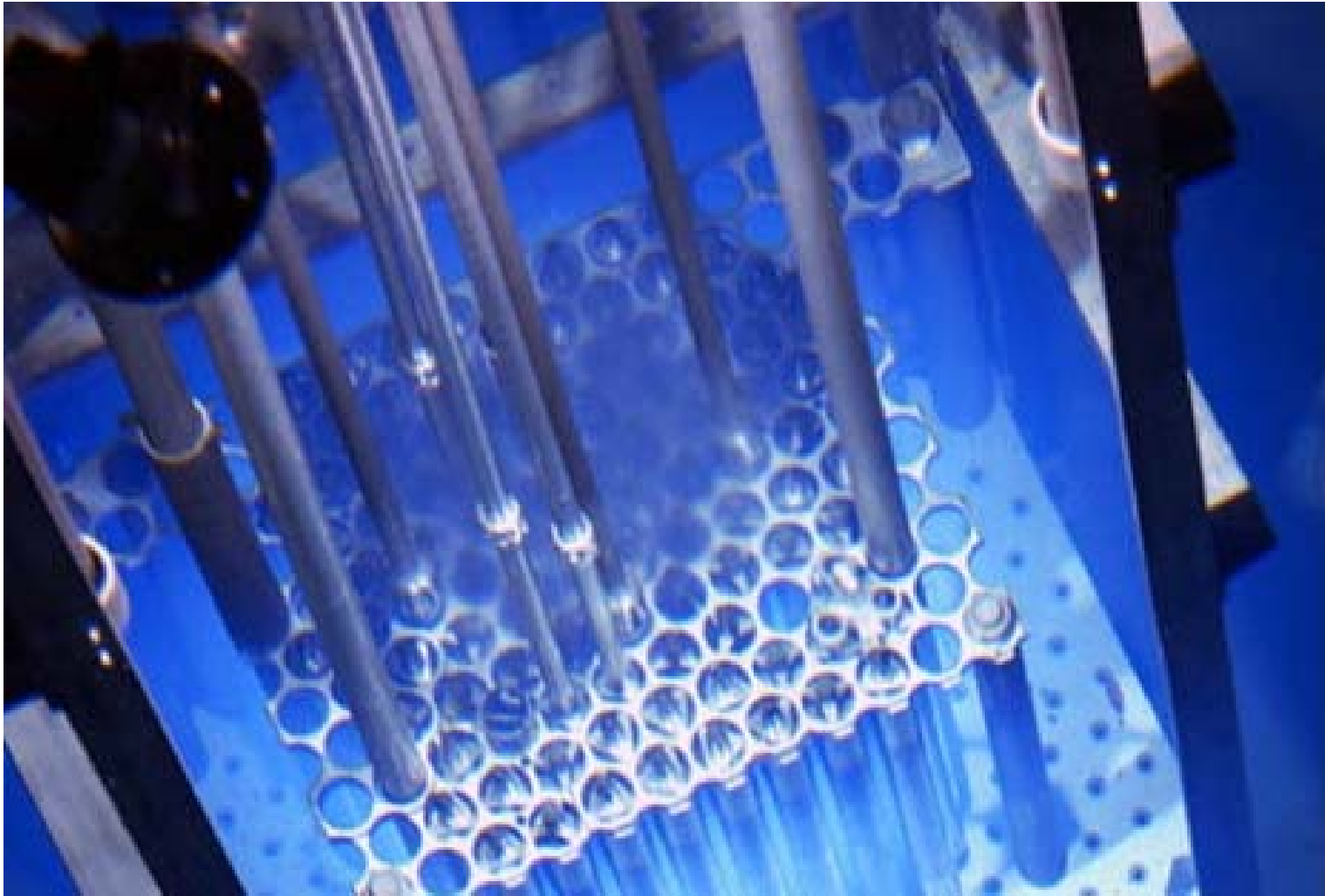


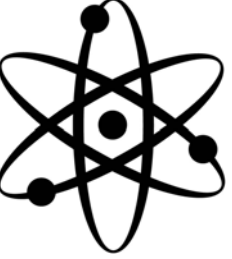
# The Fuel



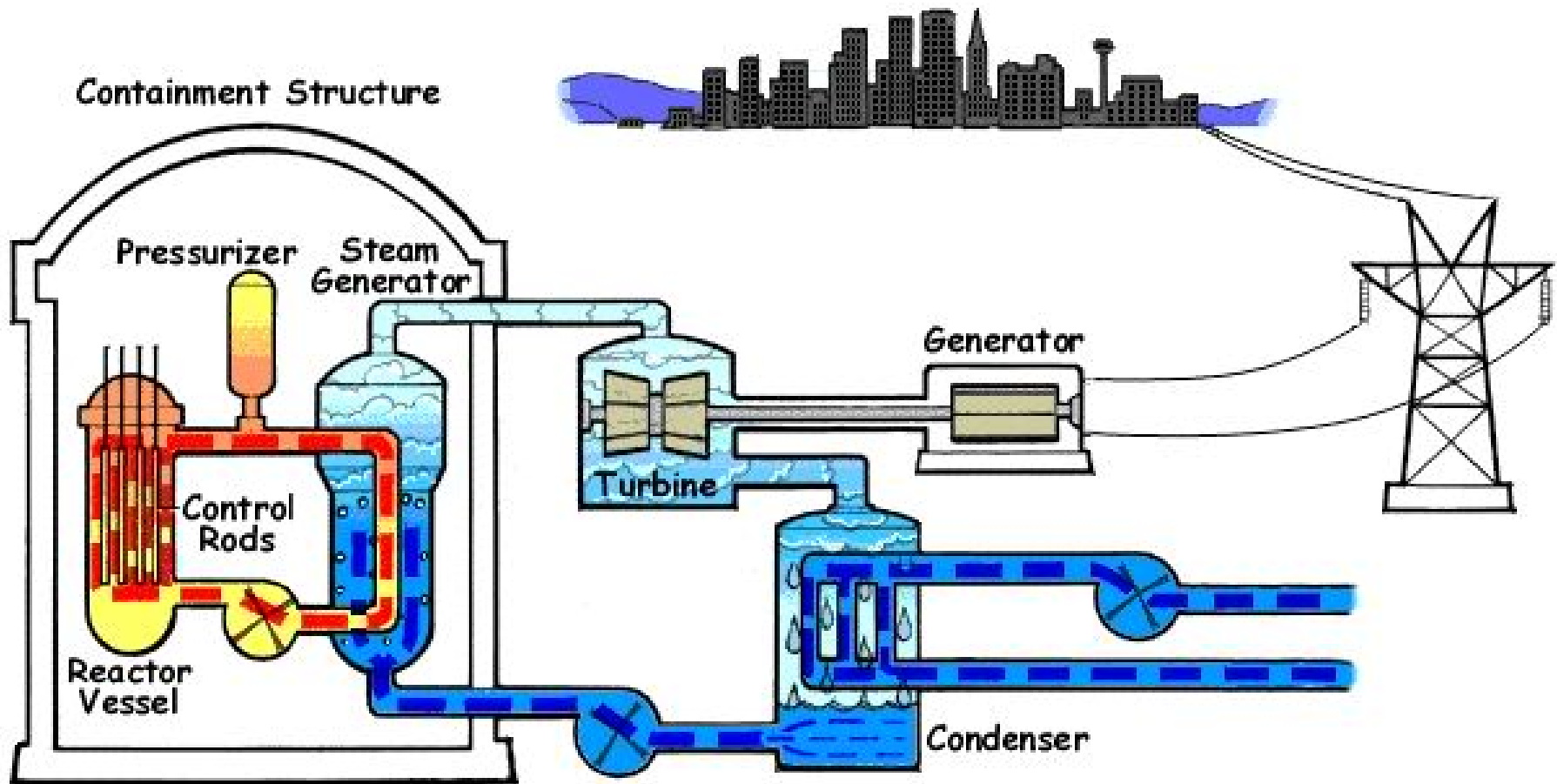


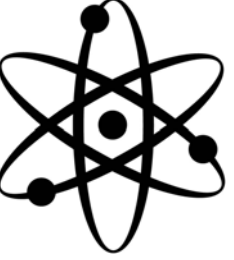
# The Core





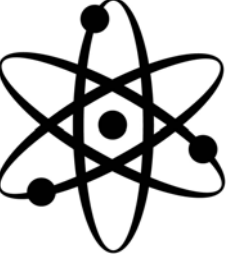
# Basic Design





# What happens afterwards?

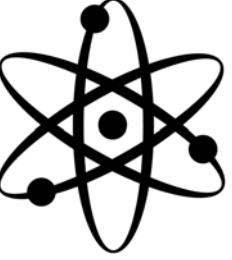
- Each and every fission of U-235, generates two new atoms, most likely radioactive atoms, such as Kr-89, Ba-144, Cs-137, I-131
- Some of these new, radioactive atoms are gaseous, and some are very water soluble



# The 100,000 year dilemma

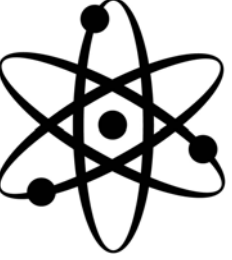






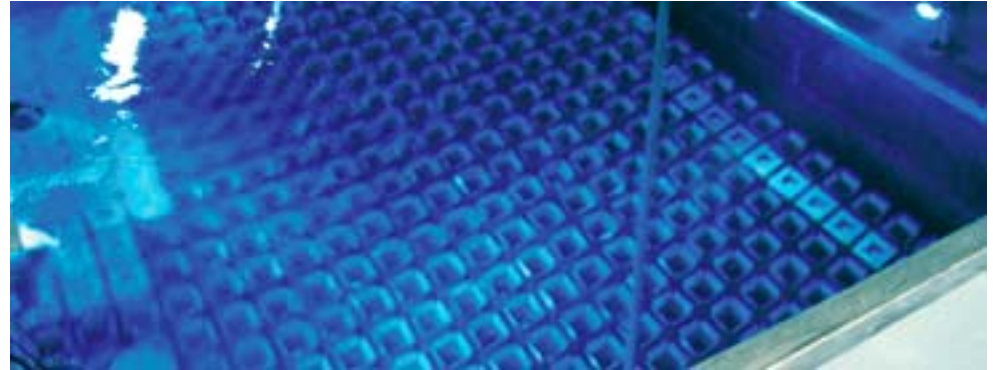
# High Level Waste

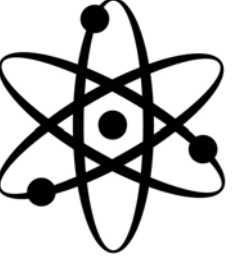
- 1. Burial** – current method for both high and low level radioactive waste in the US
- 2. Transmutation/recycling** – offers the potential to reduce the volume of high level radioactive material produced in the future



# Burial Methods

- Short Term –
  1. Pool storage
  2. Concrete/steel
  
- Long Term –
  - Geologic burial
  - Methods:
    1. Glassification
    2. Steel/concrete containers

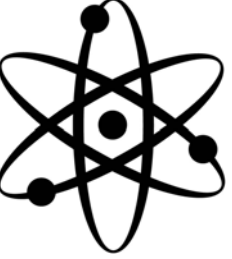




# Burial Methods

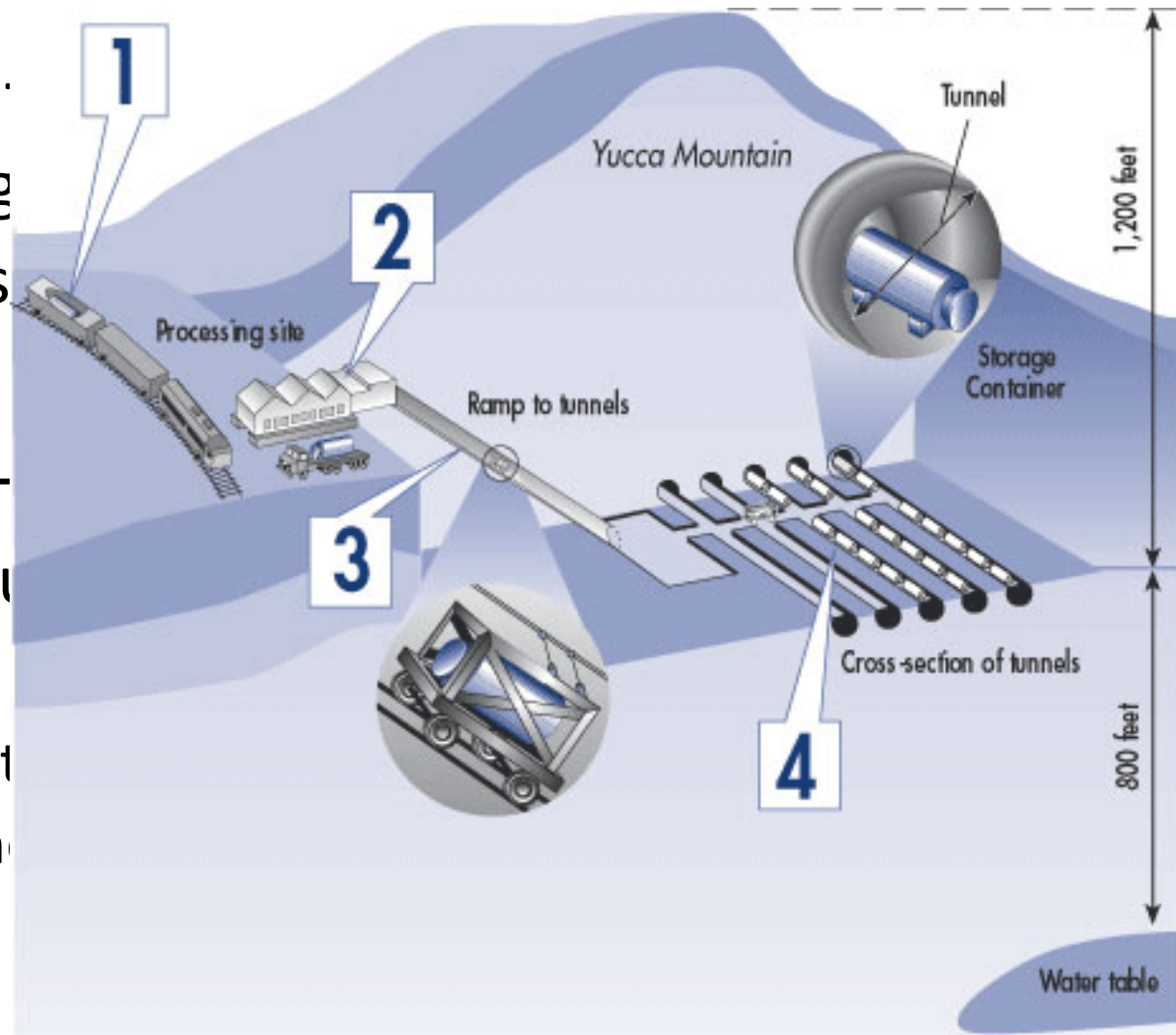
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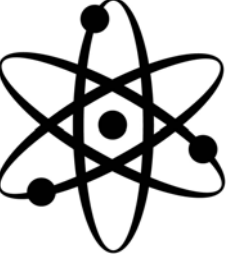




# Burial Methods

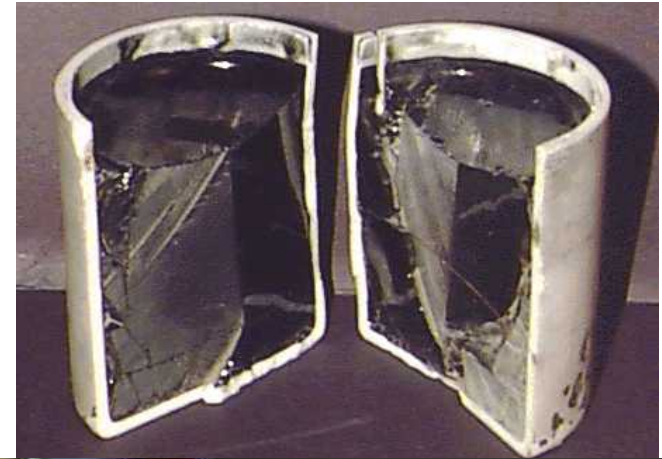
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  1. Pool storage
  2. Concrete/s
- Long Term –
  - Geologic bu
  - Methods:
    1. Glassificat
    2. Steel/con

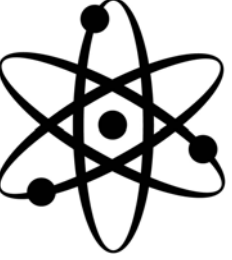




# Burial Methods

- Short Term –
  1. Pool storage
  2. Concrete/steel
- Long Term –
  - Geologic burial
  - Methods:
    1. Glassification
    2. Steel/concrete conta





# Low Level Waste

- Nuclear Reactor facilities have finite life span (~40 years)
- Constant exposure to radiation:
  - Brittle metals
  - “Activates” non-radioactive materials

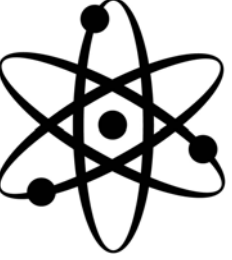




# Low Level Waste

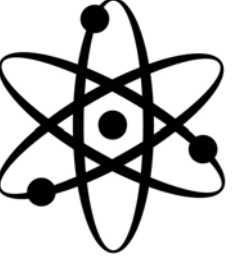
- Containment vessel and plumbing





# Breeder Reactors

- Breeder reactors are simply reactors that are dual purpose in design:
  - Generate power via fission
  - Generate new nuclear fuel by taking advantage of U-238's ability to absorb neutrons and turn into Pu-239
- Banned by President Jimmy Carter in 1977 due to concerns about weapons grade plutonium being stolen



# Transportation of waste

- <http://www.youtube.com/watch?v=1mHtOW-OBO4>