Semester 1 2022/2023
Sistem Pengawasan Nuklir (RN6086)
FMIPA ITB

Sistem Pengawasan Nuklir (RN6086)

Isotopic Composition Actinide dan Kode Komputer ORIGEN

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Sistem Pengawasan Nuklir

1. tekait tema pengawasan, juga tema keselamatan atau safety dan juga keamanan atau security fasilitas nuklir

2. Sinergitas konsep 3S safety, secuarity dan safeguard proses dan implementasinya,

3. konsep dasar depence in depth dari safety dan safeguard,

4. analisa desain basis dari konsep safety dan safeguard by design

5. material nuklir terkait daur ulang bahan bakar, kuantitas materil nuklir terkait data

6. pelaporan khusunya material nuklir terkait uranium dan plutonium

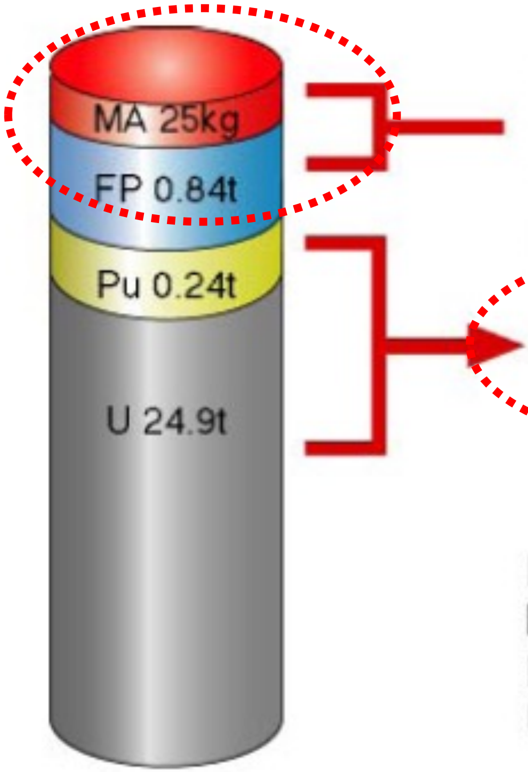
7. konsep non proliferasi nuklir, pengetahuan mengenai protected plutonium proliferation

8. Konsep material attractiveness,

Composition of Spent Fuel

1 GWe NPP class

3-5% of spent fuel



High Level Radioactive Waste (HLW)

Long-lived nuclides genarated
Np-237 (2.14 million yr)
Tc-99 (0.21million yr)
I-129 (15.7 million yr) etc.

Recover and Recycle

MA : Minor Actinide (Np, Am, Cm, etc.)
FP : Fission Products
Pu : Pultonium
U : Uranium

Burnup : 33000 MWD/T
Cooling : 3 yrs

Safeguarding a reprocessing plant

- Large commercial plant: 800 MTHM/yr, ~8 tPu/yr
- 1 close-out for measured inventory/yr
- 1% uncertainty ≈ 80 kg Pu
- If only challenge if MUF>3 σMUF ⍰ 240 kg Pu
- Also, can't meet timeliness goal with 1 inventory/yr
- Partial solutions:
  - Comprehensive transparency and containment and surveillance throughout plant – monitor all flows, detect all unusual activity
  - Near-real-time accountancy – much more frequent partial measurements of material in process, with statistical models designed to detect both abrupt and protracted diversions

Sumber : How IAEA Safeguards Work, Matthew Bunn IGA-232, Controlling the World's Most Dangerous Weapons, 20 September 2013, belfercenter.org/mta

Traditional safeguards

- Traditional safeguards use “material accountancy” and “containment and surveillance” to provide *timely detection* of diversion of *significant quantities* of nuclear material, and to *deter* such diversion by the *risk of detection*
- Significant quantities:
  - Pu or U233: 8 kg
  - HEU: 25 kg contained U-235
  - *Bombs can be made with less -- a key issue*
- Timeliness goal:
  - 1 month for unirradiated Pu or HEU (incl. MOX)
  - *Longer than estimated conversion time – another key issue*

Sumber : How IAEA Safeguards Work, Matthew Bunn IGA-232, Controlling the World’s Most Dangerous Weapons, 20 September 2013, belfercenter.org/mta

International accountancy standards

Facility Type	Relative STD (%)
Uranium enrichment	0.2
Uranium fabrication	0.3
Plutonium reprocessing	1.0
Plutonium fabrication	0.5
Scrap store	4.0
Waste store	25.0

Source: IAEA Inspector Training Course

Sumber : How IAEA Safeguards Work, Matthew Bunn IGA-232, Controlling the World's Most Dangerous Weapons, 20 September 2013, belfercenter.org/mta

Safeguards technologies: A wide range

TABLE 7: VERIFICATION MEASUREMENT METHODS FOR ON-SITE IAEA ANALYTICAL LABORATORIES

PROCESS AREA	SAMPLING POINT	INSTRUMENT OR METHOD	CONCENTRATION MEASUREMENT	SAMPLE FRACTION	GOAL ACCURACY
HEAD END	INPUT TANK	HYBRID K-EDGE DENSITOMETER (HKEDG)	Pu U	100 % 50 %	≤ 1 % ≤ 0.5 %
SEPARATION	BUFFER/FEED TANKS	ISOTOPE DILUTION MASS SPECTROMETRY (IDMS)	Pu U	25 % 2 %	≤ 0.2 % 0.2 %
SEPARATION	SCRUB AND WASTE TANKS	Pu(VI) SPECTROPHOTOMETRY	Pu	< 20 %	≤ 25 %
Pu PURIFICATION	COLLECTION AND FEED TANKS	HKEDG IDMS	Pu Pu	50 % ≤ 10 %	1 % ≤ 0.2 %
	PuN TANKS	KEDG IDMS	Pu Pu	25 - 100 % 10 - 90 %	0.2 % 0.1 %
	WASTE TANKS	Pu(VI) SPECTROPHOTOMETRY	Pu	< 10 %	≤ 25 %
U PURIFICATION	UN TANKS	K-EDGE DENSITOMETER (KEDGG)	U	≤ 10 %	0.2 %
	UO_3 CANS UO_3 CANNING	NDA (MEASUREMENTS MADE IN PLANT) KEDG	U U	≤ 10 % 1 %	< 5 % 0.2 %
MOX CONVERSION	U, Pu N TANKS	KEDG	U Pu	< 10 % 50 %	0.2 % 0.2 %
		IDMS	Pu	20 %	≤ 0.2 %
	MOX CANISTERS MOX CANNING	NDA (MEASUREMENTS MADE IN PLANT) KEDG	Pu Pu	100 % 25 %	1 % ≤ 0.2 %

Source: Shea et al., "Safeguarding Reprocessing Plants," JNMM, 1993

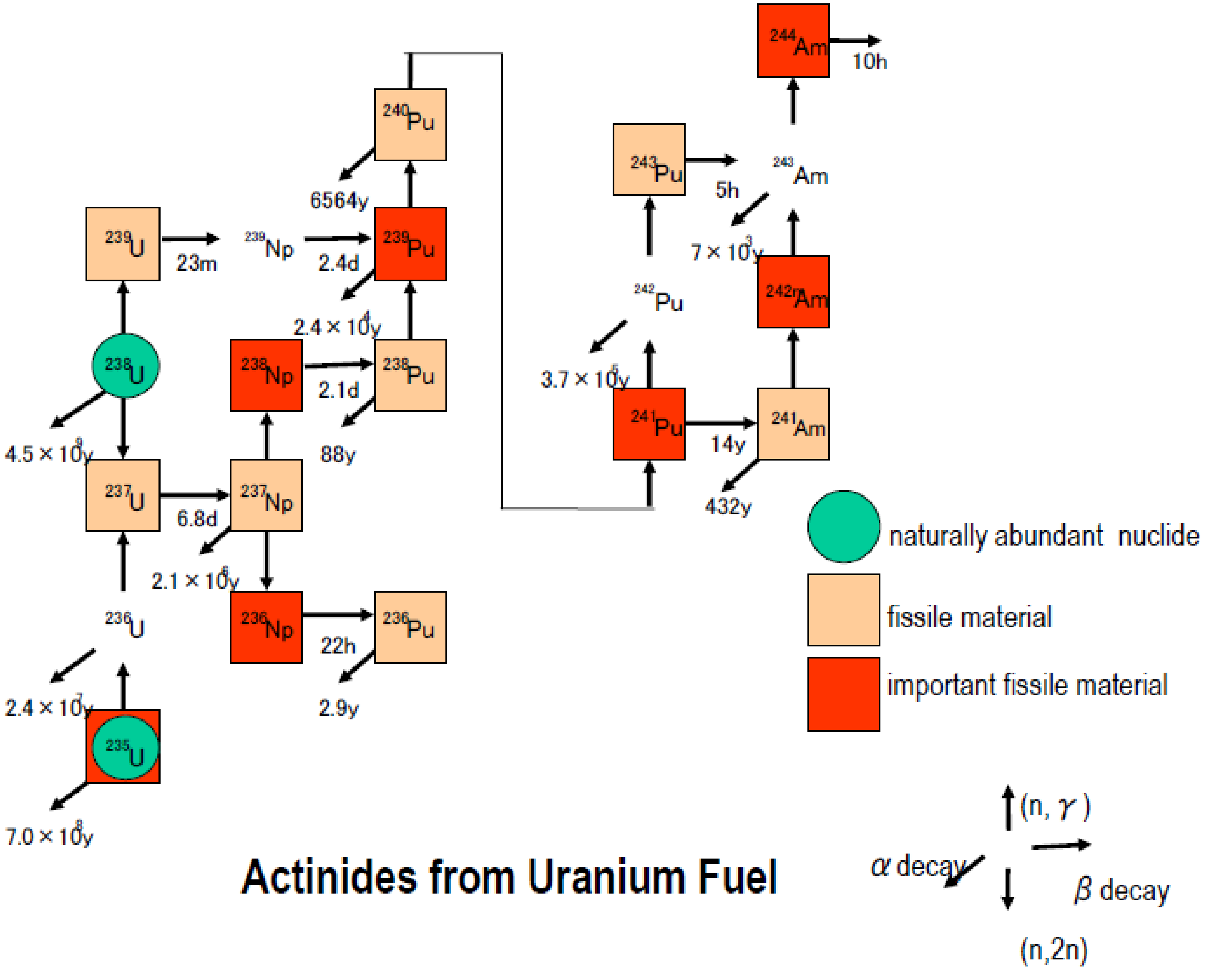
Sumber : **Capacity Building For Safeguards : Some Perspectives,** MANAGING THE DEVELOPMENT OF NATIONAL INFRASTRUCTURE FOR NUCLEAR POWER Vienna 9 - 12 February 2010

Konsep Seifgard (Safeguard)

Different steps, different safeguards

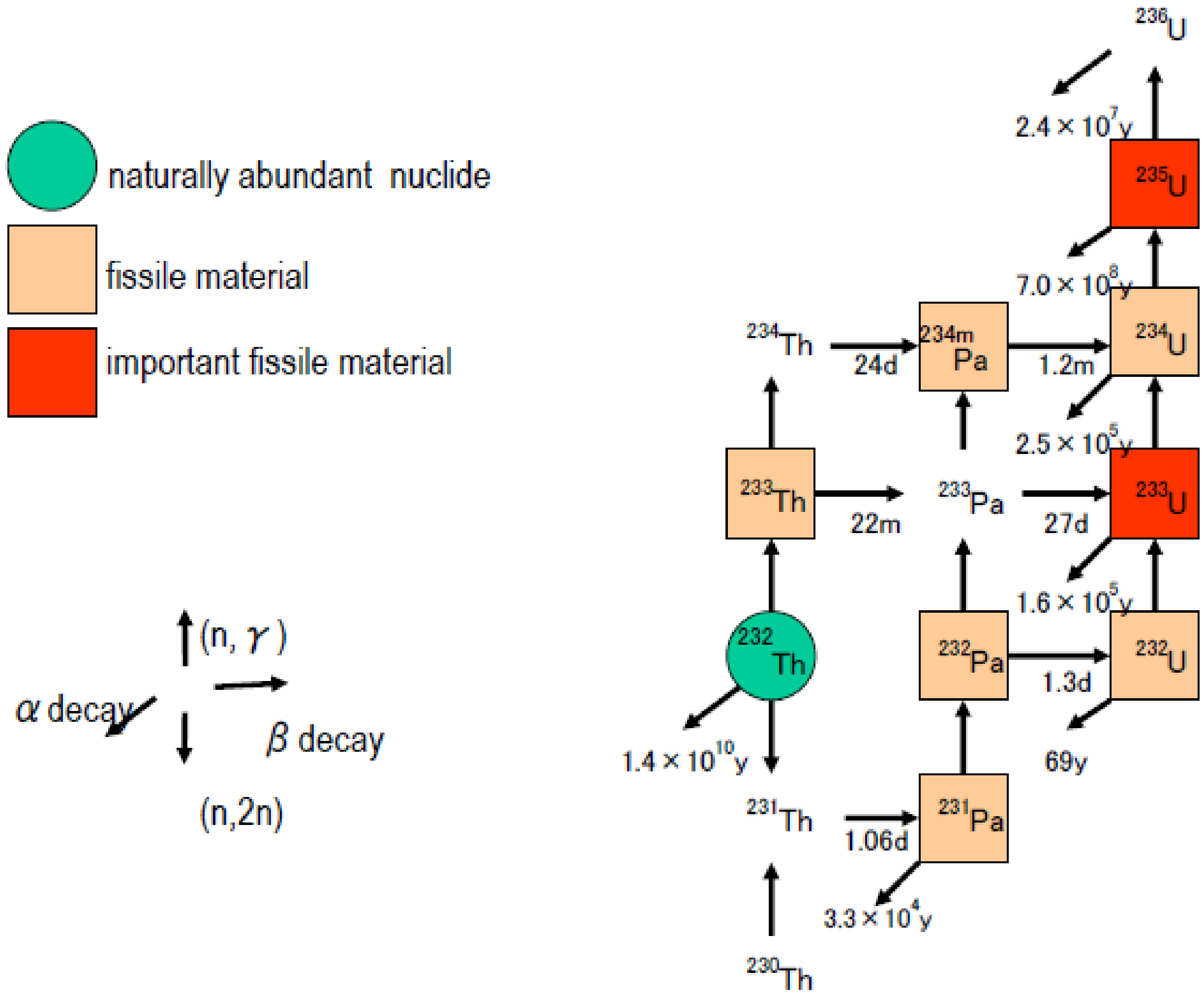
Fuel cycle step	Current safeguards	Future safeguards?
U mining and milling	Essentially none	Declarations +
U conversion	Covered; limited accountancy	Full accountancy
Enrichment	In-depth safeguards	Flow monitoring
LEU fuel fabrication	Covered; limited effort	Covered; limited effort
Power reactor operation	Covered; limited effort	Neutrino detection
Research reactors	Covered; limited effort	Increased effort
Spent fuel storage -- pool	Covered; limited effort	Remote monitoring
Spent fuel storage -- cask	Covered; v. limited effort	Remote monitoring
Reprocessing	In-depth safeguards--challenge	Still a challenge
Pu storage	In-depth safeguards	Remote monitoring
MOX fuel fabrication	In-depth safeguards--chalenge	Still a challenge
Spent fuel disposal	Not operational	Unmanned monitors
HLW disposal	Termination of safeguards	Termination of safeguards

Sumber : **Capacity Building For Safeguards : Some Perspectives,** MANAGING THE DEVELOPMENT OF NATIONAL INFRASTRUCTURE FOR NUCLEAR POWER Vienna 9 - 12 February 2010



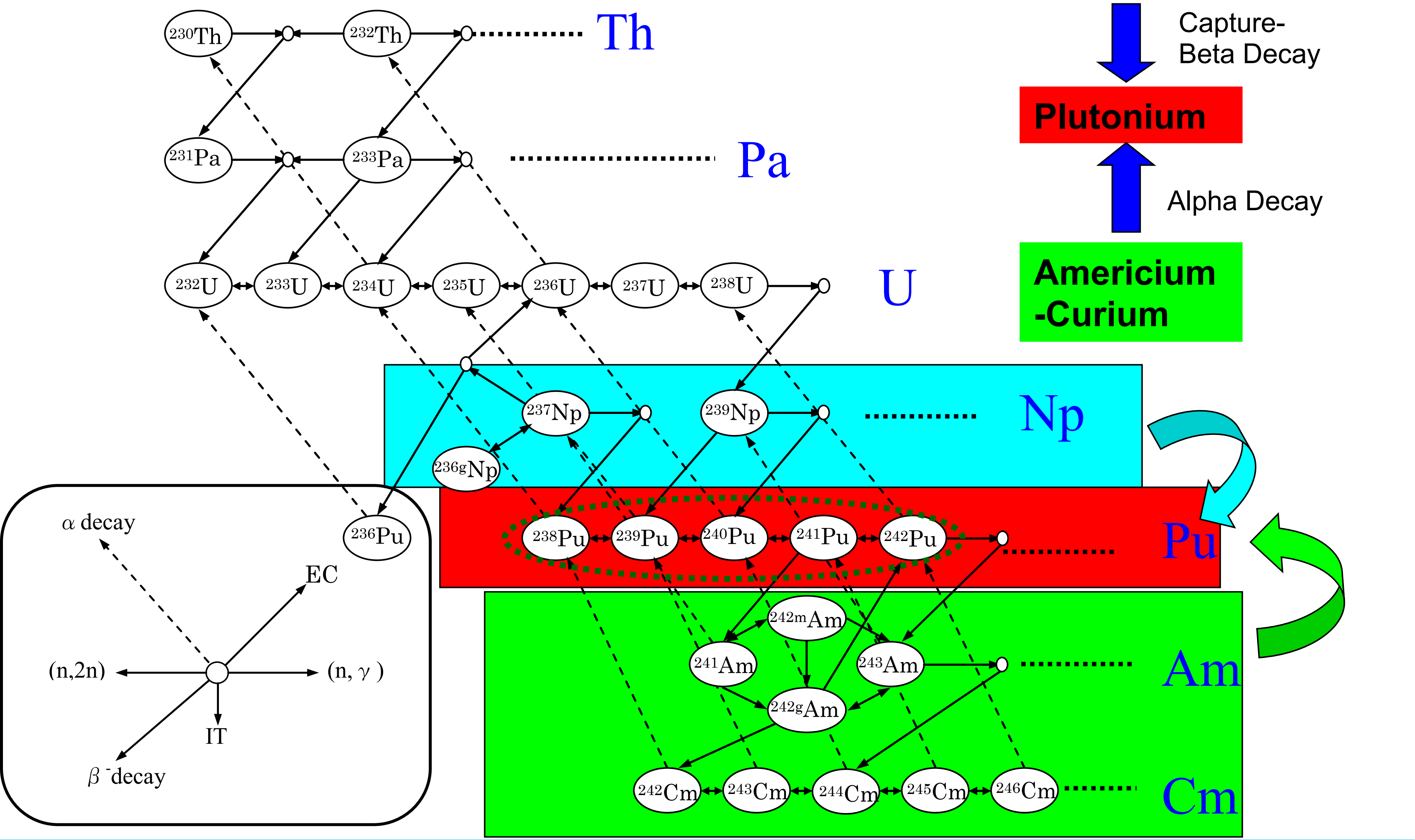
Actinides from Uranium Fuel

Mekanisme Transmutasi Aktinida



Actinides from Thorium Fuel

Nuclear Chain Mechanism



Isotopic Composition Evaluation

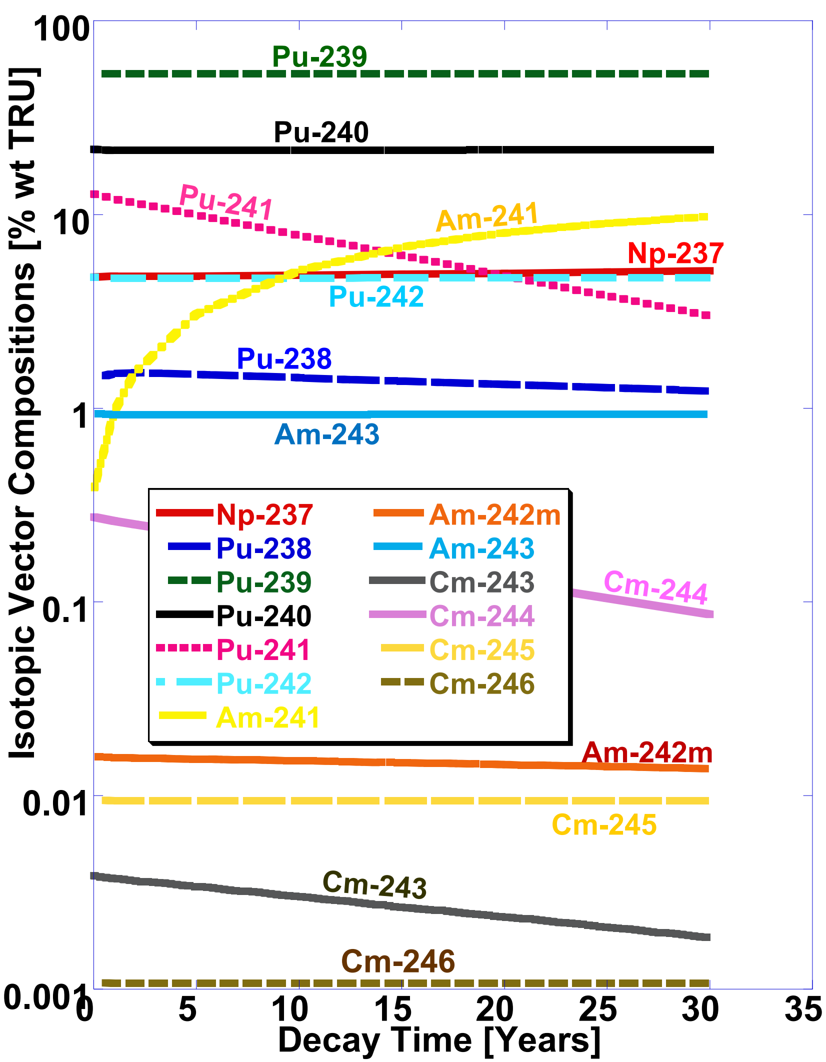
Irradiation Time (~Discharged Fuel Burnup)

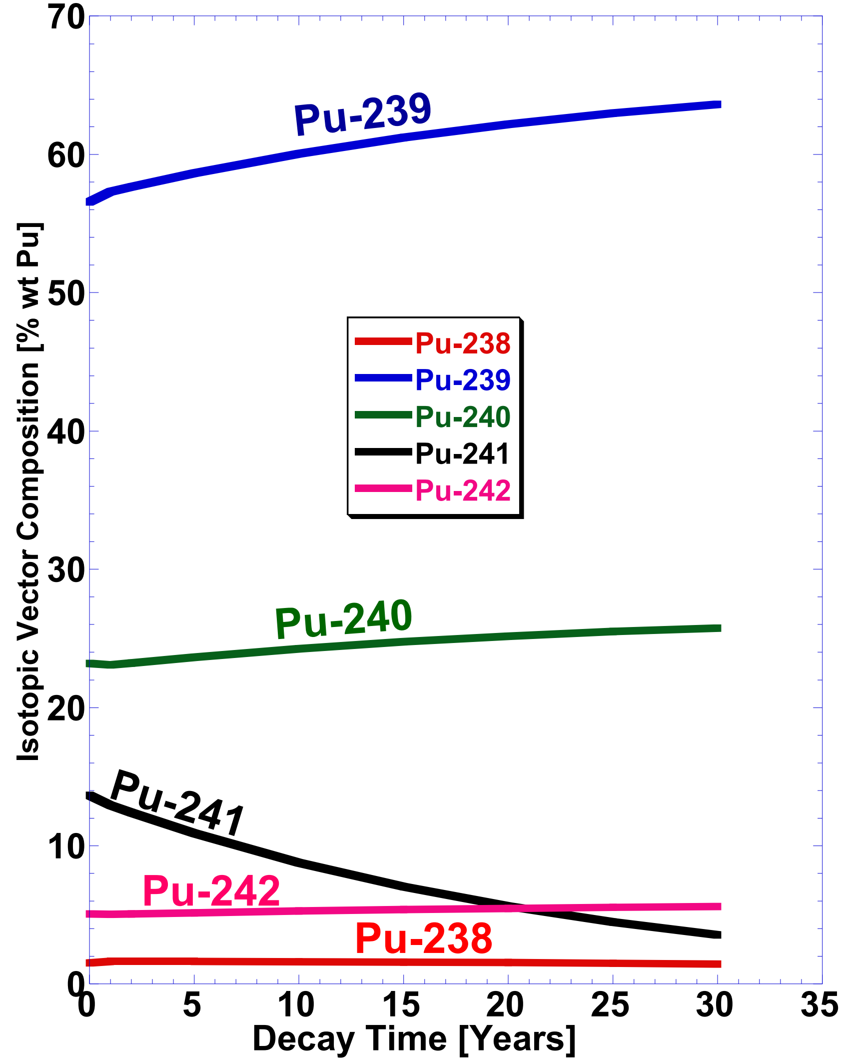
33 GWd/t	50 GWd/t	60 GWd/t
3.2 % U-235	4.15 % U-235	4.7 % U-235

Decay Time or Cooling Time (After fuel are discharged)

1.0 – 30.0 Years

Spent Fuel Compositions of LWR

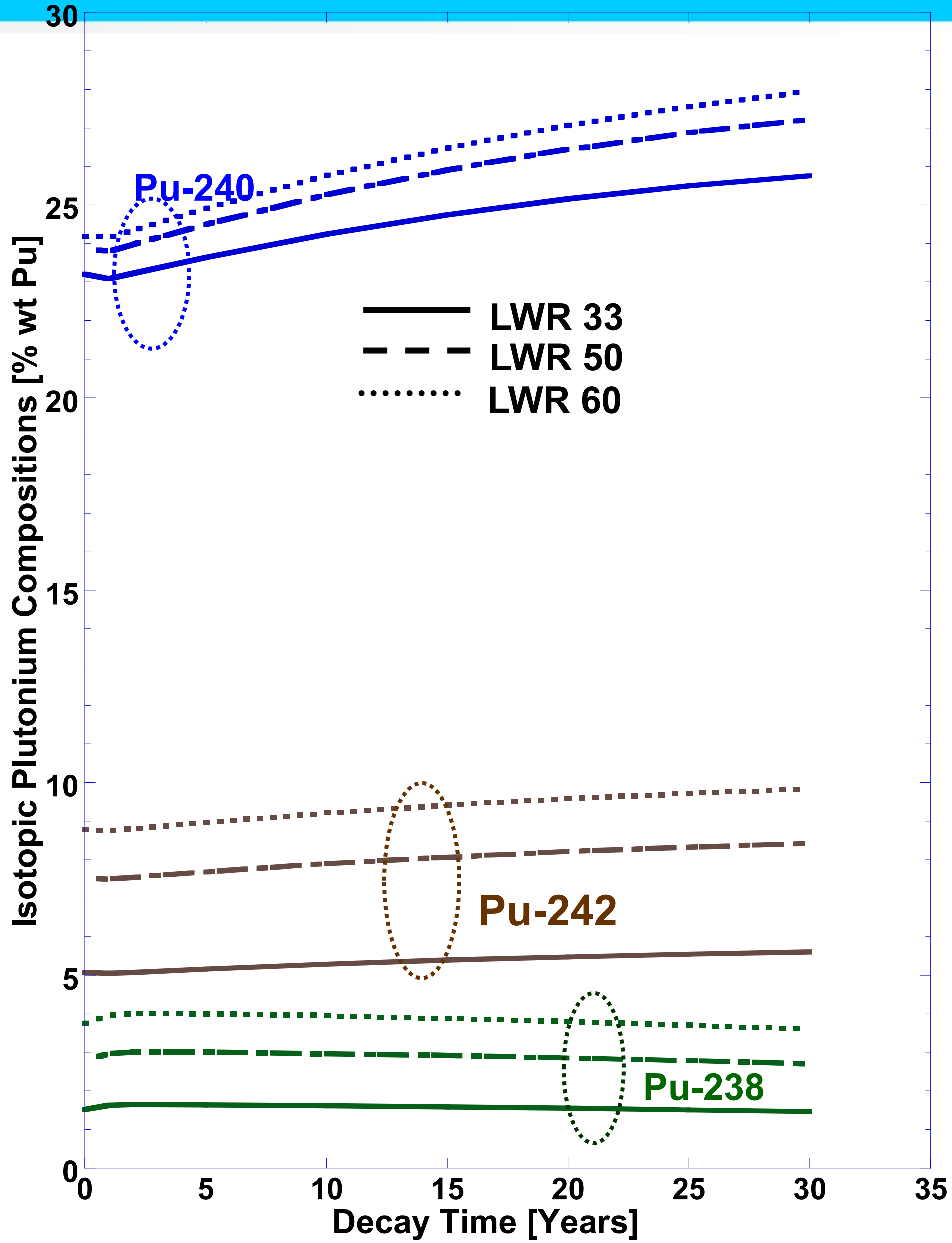




Spent Fuel Compositions of LWR

Different Burnup Constant

As A function of cooling time



Simulasi Peluruhan dengan ORIGEN Code

OAK RIDGE NATIONAL LABORATORY
managed by
UT-BATTELLE, LLC
for the
U.S. DEPARTMENT OF ENERGY
RSICC COMPUTER CODE COLLECTION

ORIGEN 2.2
Isotope Generation and Depletion Code
Matrix Exponential Method

Contributed by:
Oak Ridge National Laboratory
Oak Ridge, Tennessee

RISCC (RADIATION SAFETY INFORMATION COMPUTATIONAL CENTER)

Simulasi Peluruhan dengan ORIGEN Code

1. Induk Tunggal 1. Deret Uranium : a.U-235, b.U-238,
   2. Deret Thorium :a. Th-232
   3. Deret Neptunium : a. Np-237
   4. Deret Americium : a. Am-241, b. Am-244
   5. Deret Curium : a. Cm-243, Cm-244

- Contoh : Input→ 922380 :

92 : Nomor Atom Uranium

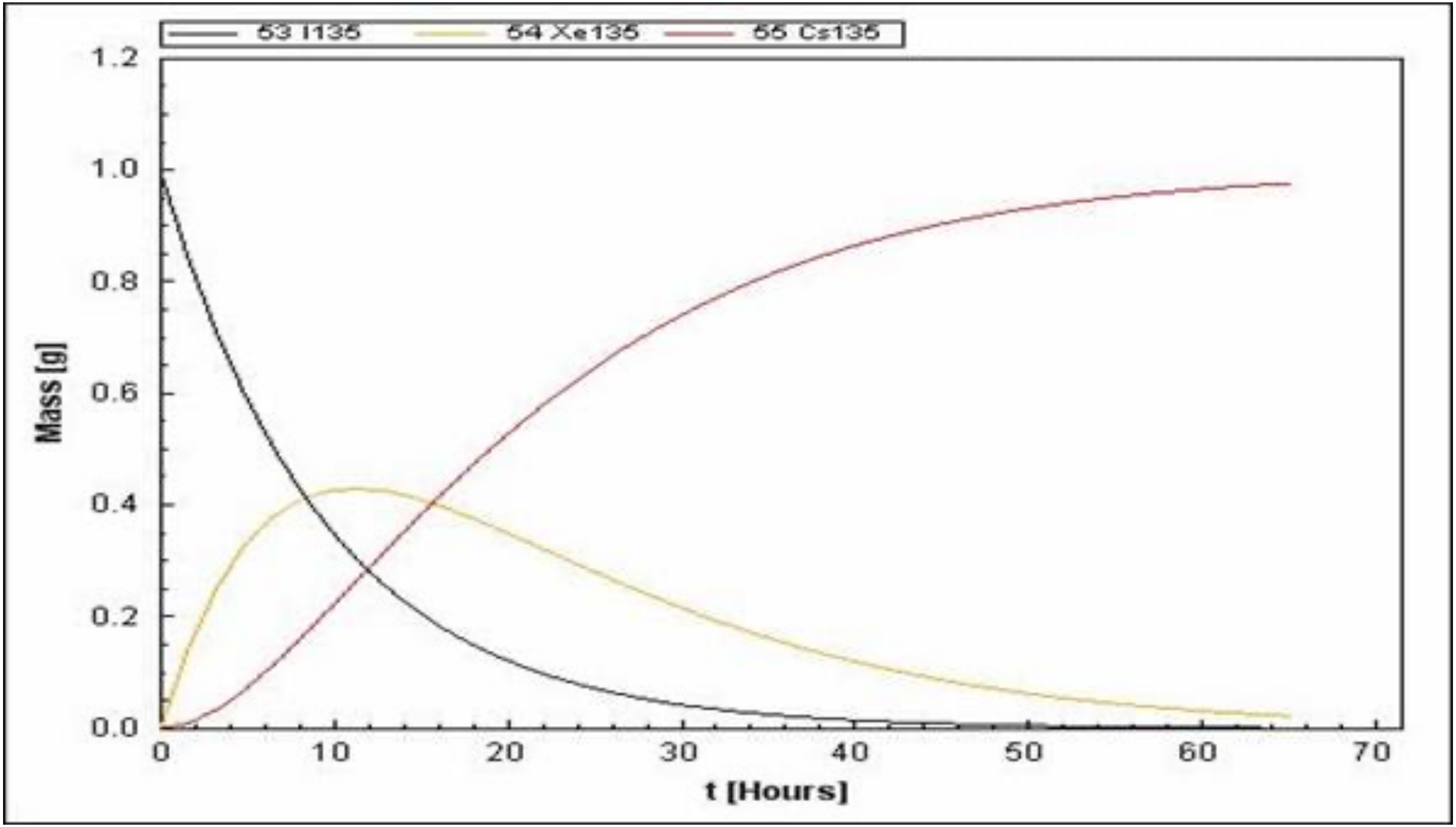
238 : Nomor Massa

0 : Status ground (Bukan meta stabil)

Untuk U-235 -→ 922350

Tugas 1 (kumpulkan minggu depan Selasa via edunex):

Peluruhan dengan Nuklida Banyak



Simulasi Peluruhan dengan ORIGEN Code

Tugas 1 (kumpulkan minggu depan Selasa via edunex):

1. Plot gambar y-axis : Massa (gram) dan x-axis : Waktu peluruhan
2. Plot semua nuklida induk dan turunan dari masing-masing induk tunggal
3. Buat perbandingan peluruhan induk tunggal dalam satu grafik untuk Thorium, Uranium dan Plutonium, Americium dan Curium
4. Buat analisa dari data dan juga tampilkan masing-masing waktu paruh nulida induk dan turunannya

Input file : DecaySampleTestU238.INP

BAT file : DecaySampleTestU238.BAT

Output File : DecaySampleTestU238.u6

Simulasi Peluruhan dengan ORIGEN Code

1. Blok Input untuk Peluruhan

```
------------------------
 RDA    ***** DECAY MODULE *****
  DEC   10  2  4  4  2
  DEC   100  4  3  4  0
  DEC   1.0  3  4  5  0
  DEC   10.0  4  5  5  0
  DEC   100.0  5  6  5  0
  DEC   1000.0  6  7  5  0
  DEC   10000.0  7  8  5  0
  DEC   100000.0  8  9  5  0
  DEC   1000000.0  9  10  5  0
  DEC   10000000.0  10  11  5  0
  DEC   100000000.0  11  12  5  0
```

Table 4.2. Time unit designation

1 = seconds
2 = minutes
3 = hours
4 = days
5 = years
6 = stable
7 = 10^3 years (kY)
8 = 10^6 years (MY)
9 = 10^9 years (GY)

Simulasi Peluruhan dengan ORIGEN Code

2. Blok Input untuk Nuklida dan konsentrasinya

```
-----------------------
END
2 922380  1000000.0  922350  0.   0  0.0 FUEL 100% U238
0
```

- Contoh : Input→ 922380 :

92 : Nomor Atom Uranium

238 : Nomor Massa

0 : Status ground (Bukan meta stabil)

Untuk U-235 -→ 922350

Simulasi Peluruhan dengan ORIGEN Code

2. Blok Output Jumlah Aktinida (gram)

Ambil dari file output : DecaySampleTestU238.u6

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5 SUMMARY TABLE: CONCENTRATIONS, GRAMS

1 MTIHM 3.2% UO2;BURNUP=33,000 MWD/MTIHM, 3 CYCLE

	FUEL CHG	FUEL DIS	100.0D	1.0YR	10.0YR	100.0YR	1000.0YR	1.0E+04YR	1.0E+05YR	1.0E+06YR	1.0E+07YR	1.0E+08YR
HE 4	0.000E+00	0.000E+00	7.138E-07	2.607E-06	2.607E-05	2.608E-04	2.611E-03	2.648E-02	3.439E-01	1.439E+01	2.015E+02	2.063E+03
PB206	0.000E+00	0.000E+00	0.000E+00	3.202E-23	3.391E-17	2.457E-12	5.498E-08	3.083E-04	4.228E-01	8.619E+01	1.290E+03	1.327E+04
PB210	0.000E+00	0.000E+00	1.024E-22	5.007E-20	5.842E-16	3.731E-12	7.281E-09	3.494E-06	3.852E-04	4.182E-03	4.395E-03	4.334E-03
RA226	0.000E+00	0.000E+00	5.713E-18	5.400E-16	6.192E-13	6.190E-10	5.624E-07	2.699E-04	2.975E-02	3.230E-01	3.395E-01	3.348E-01
TH230	0.000E+00	0.000E+00	8.487E-12	1.904E-10	2.105E-08	2.122E-06	2.116E-04	2.043E-02	1.457E+00	1.582E+01	1.663E+01	1.640E+01
U234	0.000E+00	0.000E+00	2.806E-05	1.380E-04	1.511E-03	1.524E-02	1.523E-01	1.504E+00	1.328E+01	5.064E+01	5.372E+01	5.298E+01
U238	1.000E+06	1.000E+06	1.000E+06	1.000E+06	1.000E+06	1.000E+06	1.000E+06	1.000E+06	1.000E+06	9.998E+05	9.985E+05	9.846E+05
SF250	0.000E+00	0.000E+00	2.275E-11	8.311E-11	8.311E-10	8.311E-09	8.311E-08	8.311E-07	8.311E-06	8.310E-05	8.304E-04	8.247E-03
SUMTOT	1.000E+06	1.000E+06	1.000E+06	1.000E+06	1.000E+06	1.000E+06	1.000E+06	1.000E+06	1.000E+06	1.000E+06	1.000E+06	1.000E+06
TOTAL	1.000E+06	1.000E+06	1.000E+06	1.000E+06	1.000E+06	1.000E+06	1.000E+06	1.000E+06	1.000E+06	1.000E+06	1.000E+06	1.000E+06

Sumber ORIGEN : https://drive.google.com/drive/folders/1KNbdPjm7sl9UMDWGJJJ7YwO1WO7sZJeL?usp=sharing

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^{232}Thank YoU^{238}

TeriMA Kasih

Merci

Sidik Permana
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