FISPACT-II Extended exercises: answers

Thomas Stainer, Mark Gilbert, Greg Bailey, Andrew Davis
UKAEA

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1 Waste Classification with FISPACT-II : Answers

1. Question 1
   (a) 250 years. $\alpha = 0.0$ Bq/kg $\beta + \gamma = 10052494.699$ Bq/kg
   (b) 75 years. $\alpha = 0.0$ Bq/kg $\beta + \gamma = 31805804.449$ Bq/kg
   (c) For nuclides:
      - ^{60}Co 5 years
      - ^{99}Tc 1 year
      - ^{55}Fe 20 years
   (d) ^{99}Tc, ^{93}Zr, ^{10}Be, ^{93m}Nb, ^{91}Nb, ^{92}Nb, ^{94}Nb. 6 nuclides.
2. Question 2
   (a) Total activity higher than previously but only affects Spain's time frame.
      - UK: 250 years, $\beta + \gamma = 9965133.014$ Bq/kg
      - Spain : 50 years, $\beta + \gamma = 34891945.151$ Bq/kg
   (b) The nuclides difference shown in the table. What is possibly surprising is that the nuclides whose percentage amounts did not change show large changes in activity. This will be explored in the pathways exercises.

Nuclide	**Comp 1**	**Comp 2**	$\Delta_{activity}$
^{14}C	961408.86	1009330.88	47922.02
^{94}Nb	7369.79	7472.74	102.95
^{63}Ni	1462125.03	23219040.96	21756915.92

   (c) Carbon-14 as risen in prominence now second dominant. Several Sn isotopes are now present.

3. Question 3
   (a) 500 years for β activity to be 100 times UK $\beta + \gamma$ limit
   (b) For nuclides:
      - ^{60}Co 50 years
      - ^{99}Tc Never meets limit
      - ^{55}Fe 50 years
   (c) ^{14}C activity $= 368587749.48$ Bq/kg, approximate increase of 3.67×10^8.
   Its long half-life allows it to persist.
   (d) Unlikely, impossible.

2 Pathways Analysis answers

1. Question 1
   (a) $62 - 5 = 57$
   (b)
      - 3

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Target nuclide Fe 59    100.000% of inventory given by  3 paths
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 path  1   2.714% Ni 58 ---(R)--- Co 58 ---(b)--- Fe 58 ---(R)--- Fe 59 ---(S)-
                  100.00%(n,p)     99.89%(b+)     100.00%(n,g)
                                    0.11%(n,p)

 path  2   1.815% Ni 58 ---(R)--- Co 58m---(b)--- Co 58 ---(b)--- Fe 58 ---(R)-
                  100.00%(n,p)    100.00%(IT)      99.89%(b+)     100.00%(n,g
                                    0.00%(n,E)      0.11%(n,p)
                                    0.00%(n,n)

 path  3  95.736% Ni 62 ---(R)--- Fe 59 ---(S)---
                  100.00%(n,a)
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      - Pathway 1

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 Target nuclide Co 60     99.272% of inventory given by  2 paths
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 path  1  60.552% Ni 60 ---(R)--- Co 60m---(b)--- Co 60 ---(L)---
                  100.00%(n,p)    100.00%(IT)
                                    0.00%(n,E)
                                    0.00%(n,n)

 path  2  38.720% Ni 60 ---(R)--- Co 60 ---(L)---
                  100.00%(n,p)
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2. Question 2

(a)

Quantity	Dominant	Reaction	Parent
Activity	^{55}Cr	(n,γ)	^{54}Cr
Dose Rate	^{52}V	(n,p)	^{52}Cr
Ingestion	^{56}Mn	(n,p)	^{56}Fe
Inhalation	^{62}Co	(n,p)	^{62}Ni

(b) Total number of ^{55}Fe atoms = 1.22199×10^{14}

- 1.082×10^{14} atoms
- 1.361×10^{13} atoms
- 3.89×10^{11} atoms

3. Question 3

   (a) Added additional pathway, 3.081% created via $^{64}\mathrm{Ni}(n,\alpha)^{61}\mathrm{Fe}$ then β^- decay to ^{61}Co.

   (b) ^{52}Cr is used to create:

   - 99.547% of ^{52}V via $^{52}\mathrm{Cr}(n,p)^{52}\mathrm{V}$
   - 1.557% of ^{51}Cr via $^{52}\mathrm{Cr}(n,2n)^{51}\mathrm{Cr}$

3 Self-shielding with FISPACT-II : Answers

1. Question 1

   - After 10 years, there will be approximately 3.5 atomic % Re, and 1.4 atm.% Os in the material, with W almost all of the remainder.

2. Question 2

   - With self-shielding included, the amount of Re after 10 years should fall to around 2.4 atm.%, while Osmium will be under 1 atm.%.

3. Question 3

   - Estimating the secondary self-shielding factors for Re using the final composition from part 2 (`SSFCHOOSE` with W, Re, and Os) and re-running will not alter the final concentration of W, but the Re concentration should increase by around 0.1-0.2 atm.%, while Osmium should decrease.
     These concentrations are small, but the performance of tungsten (particularly its thermal conductivity) could be significantly altered even at these percentages, and so accurate predictions will have engineering relevance.

4 Graphical output and library variation: Answers

1. Question 1

   - The resulting plot will show the decaying heat from the material as a function of time.

2. Question 2

   - The nuclide contribution plot should reveal that several nuclides contribute to the decay-heat during cooling: Zr89m dominates in the first 30 minutes, and then there are contributions from Y94, Y89m, Zr89, etc., at longer cooling times.

3. Question 3

   - The TENDL-2017 result should be a very close match to the experimental result at all cooling times, while JEFF-3.3 underpredicts at short cooling times. This is due to the absence of the Zr90(n,2n)Zr89m reaction channel, which TENDL-2017 predicts is the main contributor to the decay-heat during the first 30 minutes of cooling