22.251 Systems Analysis of the Nuclear Fuel Cycle

Fall 2009

Lab #4 Solution

(a)

Data required for solution:

Cell power = 104.5 W/cc * Cell Volume = 104.5 * 6.3504 = 663.62 W

k-inf = 1.3827 ± 0.0012

weight loss to fission = 0.56184

neutron yield per fission = $\frac{k}{w_f} = \frac{1.3827}{0.56184} \approx 2.46$

To obtain real reaction raters, Flux Multiplication Factor (FMF) in needed

$$FMF[FSN/\sec] = \frac{P[J/\sec] \times \nu[FN/fiss]}{k[FN/FSN] \times E_f[J/fiss]} \approx \frac{663.62 \times 2.46}{1.3827 \times 200 \times 1.602 \times 10^{-13}} = 3.686 \times 10^{13}[FSN/\sec]$$

Real reaction rates are calculated from the tallied reaction rates as:

$$RR\left[\frac{reactions}{\sec}\right] = rr\left[\frac{barn}{FSN \times cm^2}\right] \times FMF\left[\frac{FSN}{\sec}\right] \times V_{Cell}\left[cm^3\right] \times N_{nuclide}\left[\frac{\#}{cm \times barn}\right]$$

Table 1. Summary of the reaction rate [#/sec] calculation results for UO_2 and NU fuel

		UO_2	UN
(n,γ) in U-238	Thermal	1.66E+12	1.46E+12
	Epithermal	8.35E+12	1.10E+13
	Total	1.00E+13	1.24E+13
(n,f) in U-235	Thermal	1.54E+13	1.33E+13
	Epithermal	4.21E+12	5.78E+12
	Total	1.96E+13	1.91E+13

Table 2. Spectral indices

	UO_2	UN
C^*	0.512	0.651
δ_{25}	0.274	0.435
ρ_{28}	5.019	7.529

(b)

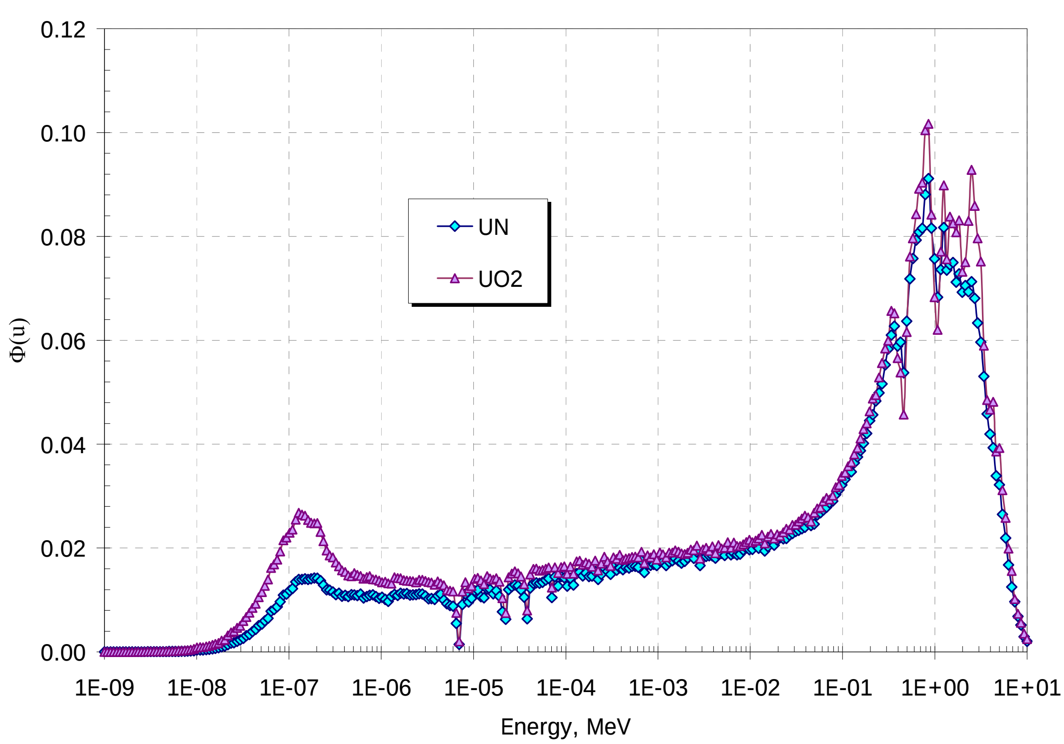
Table 3. Flux ratios for the UO_2 and UN fuel

	UO_2	UN
φ_2	0.743	0.420
φ_1	6.167	5.596
φ_2/φ_1	0.120	0.075

With increasing H/HM, spectrum softens due to better moderation.

Higher enrichment hardens the spectrum because of the higher absorption of thermal neutrons by U-235 as it is primarily thermal absorber.

(c)



High density of nitride fuel effectively reduces H/HM and thus hardens the neutron spectrum (see above figure). Criticality is also reduced ($k = 1.2366 \pm 0.0011$) due to the lower H/HM and somewhat high neutron absorption by N-14. The reduction in thermal flux component can also be observed from Tables 3 and 4.

(d)

Table 4. Flux ratios in the fuel and moderator

	UO_2		UN	
	Fuel	Water	Fuel	Water
φ_2	0.743	0.853	0.420	0.511
φ_1	6.167	6.071	5.596	5.527
φ_2/φ_1	0.120	0.140	0.075	0.092

Fast neutrons are produced in the fuel and eliminated mainly in water as they slow down. Thermal neutrons are born in water and absorbed mainly in the fuel. Therefore, fraction of thermal neutrons is larger in water than in the fuel.

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