Lecture 3 Example

make 10 kg U enriched to 20% $x_p = 0.20$
- from natural U
$x_b = 0.002$

how much feed is needed?

$$\frac{F}{P} = \frac{x_p - x_b}{x_F - x_b} = \frac{0.2 - 0.002}{0.007 - 0.002} = 39.6$$

$\rightarrow$ 396 kg natural U

how many SWU?

$$W = P\,V(x_p) + T\,V(x_b) - F\,V(x_F)$$

$$V = (2x-1)\ln\left(\frac{x}{1-x}\right)$$

$$V(x_p) = \left(2(0.2)-1\right)\ln\left(\frac{0.2}{1-0.2}\right) = 0.882$$

$$V(x_b) = \left(2(0.002)-1\right)\ln\left(\frac{0.002}{1-0.002}\right) = 6.188$$

$$V(x_F) = \left(2(0.007)-1\right)\ln\left(\frac{0.007}{1-0.007}\right) = 4.895$$

$$T = F - P$$

$$T = 396 - 10 = 386$$

$$W = 10(0.882) + 386(6.188) - 396(4.895) = 462 \text{ SWU-kg}$$

$$= 46.2 \text{ SWU/kg}$$

Heat generation rate?

$$Q = E_f N_f \sigma_f \phi$$

$\rho = 10.97$ g/cc

$\phi = 5 \times 10^{13}$ n/cm²·s

$\epsilon = 0.03$ = 3%

$m(UO_2) = 235 \times 0.03 + 238 \times 0.97 + 2 \times 16$

$= 269.9$ g/mol

$$\rho^{U\text{-}235} = 10.97 \text{ g/cc} \; \frac{1 \text{ mol}}{269.9 \text{ g}} \; \frac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol}} \; \frac{1 \text{ U}}{1 \text{ UO}_2} \times 0.03$$

$$\rho^{U\text{-}235} = 7.343 \times 10^{20} \text{ U}^{235}/\text{cc}$$

$$Q = \left(200 \times 10^6 \text{ eV}\right)\left(1.602 \times 10^{-19} \frac{\text{J}}{\text{eV}}\right)\left(7.343 \times 10^{20} \frac{\text{U}^{235}}{\text{cc}}\right)\left(587 \times 10^{-24} \frac{\text{cm}^2}{\text{U}^{235}}\right) \times \left(5 \times 10^{13} \frac{\text{n}}{\text{cm}^2 \cdot \text{s}}\right)$$

$$Q = 690 \frac{\text{J}}{\text{cm}^3 \cdot \text{s}} = \boxed{690 \text{ W/cc}}$$