Thermodynamics of Energy Conversion and Storage

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EXERCISES 7

1) Estimate the energy density in the isotopes e.g. ^{235}U.

(8.7-7.5) MeV·235·6·10^{23}/235g = 1.2·6·10^{23}·10^6·1.6·10^{-19}/0.001 kg/g/3600s/h = 32 GWh/kg

2) Calculate the number of fissions N after 1 second if K = 1.01. ?

τ : life time of a neutron generation (10^{-4} s)
K : growth factor

$$N = N_0 \cdot e^{\frac{(K-1)\cdot t}{\tau}}$$

$$K = \frac{N_{i+1}}{N_i}$$

N = 1·exp(0.01·1/0.0001) = 2·10^{43}

3) Calculate the amount of coal necessary for a power plant with a power of 1 $GW_{el.}$ and an efficiency of 25% and compare to the amount of nuclear fuel.

Coal: 15 kWh/kg
^{235}U: 32·10^6 kWh/kg
The energy density of ^{235}U is 2·10^6 times greater than the one of coal.
P = 10^6 kW/0.25·24h·365 days/year = 3.5·10^{10} kWh/year
m(C) = 3.5·10^{10} kWh/year / 15 kWh/kg = 2.33 Mio. t/year = 6400t/day
m(^{235}U, 4%) = 3.5·10^{10} kWh/year / 32·10^6 kWh/kg / 0.04 = 27 t / year

4) Calculate the amount of water evaporated from a nuclear power plant with a power of 1 $GW_{el.}$ and an efficiency of 25% ($\Delta H_{vap}(H_2O)$ = 2200 kJ/kg).

3 GW = 3·10^6 kW = 3·10^9 kJ/s
(3·10^9 kJ/s)/(2200 kJ/kg) = 1363 kg/s

5) Calculate the half life time for the sum of the isotopes in nuclear waste.

10 years: 10^{12} Bq/kg
10'000'000 years 10^7 Bq/kg
N = N_0·exp(-k·t) -> ln(10^7/10^{12})/10'000'000 = -k -> k = 1.15·10^{-6}
ln(2)/k = $t_{1/2}$ -> $t_{1/2}$ = 6·10^5 years