Ans: 1

(a) $T = 625\,K$

$t = 400\,\text{days}$

$$t^*(d) = (6.62\times10^{-7})\, e^{\frac{11949}{625}}$$

$$= 133.22 \text{ days.}$$

$$\delta^*(\mu m) = 5.1\, e^{\frac{-550}{625}}$$

$$= 12.3\,\mu m$$

$$k_L\left(\frac{\mu m}{d}\right) = (7.48\times10^{6})\, e^{\frac{-12500}{625}}$$

$$= 0.0155\ \mu m/day$$

$$\therefore\ \delta(\mu m) = \delta^* + k_L\,(t - t^*)$$

$$= \{12.3 + 0.0155\,(625 - 133.22)\}\ \mu m$$

$$= 20\ \mu m$$

(Ans:

(5)

$$C_H = \frac{2f \times \delta \times \rho_{ZrO_2} \times f_{ZrO_2} \times \frac{M_H}{M_O}}{\left(t - \frac{\delta}{PBR}\right) \times \rho_{Zr}} \times 10^6$$

$$= \frac{2 \times 0.18 \times 2.07 \times 5.68 \times \left(\frac{16\times2}{(16\times2)+91}\right) \times \frac{1}{16}}{\left(625 - \frac{2.07}{1.56}\right) \times 6.5} \times 10^6 \quad (f = 18\% = 0.18)$$

wt. ppm

$$= \frac{0.069}{4053.855} \times 10^6 \text{ wt. ppm}$$

$= 17.021$ wt. ppm.

Ans :-

Ans: 2

$$B = \frac{\dot{F}t}{N_U}$$

$$= \frac{(3.5\times10^{13}) \times (85\times24\times3600)}{2.45\times10^{22}} \text{ FIMA}$$

$$N_U = \frac{N_a \rho_U}{M_U}$$

$$= \frac{6.022\times10^{23} \times 10.97}{269.9} \text{ atoms of U/cm}^3$$

$= 2.45\times10^{22}$ atoms of U/cm3

$= 0.010$ FIMA

$$\varepsilon_{th} = \alpha_{th} \Delta T$$

$$= 11 \times 10^{-6} \times (1200-300)$$

$$= \cancel{0.001}\ 0.01$$

$$\varepsilon_D = \Delta \rho_0 \left(e^{\frac{\beta \ln 0.01}{C_D \beta_D}} - 1 \right)$$

$$= 0.01 \times \left(e^{\frac{0.010 \ln 0.01}{1 \times 0.0053}} - 1 \right)$$

$$\beta_D = \frac{5MWD}{kgU} \times \frac{1}{950}$$

$$= 0.0053\ FIMA$$

$$= 0.01 \times (e^{-8.69} - 1)$$

$$= \cancel{-0.001}\quad -0.01$$

$$\varepsilon_{sfp} = 5.577 \times 10^{-2} \rho \beta$$

$$= (5.577 \times 10^{-2}) \times (10.97) \times (0.010)$$

$$= 0.006$$

$$\varepsilon_{gfp} = (1.96 \times 10^{-28}) \rho \beta \, (2800-T)^{11.73} \times e^{-0.0162(2800-T)} \times e^{-17.8 \rho \beta}$$

$$= (1.96 \times 10^{-28}) \times (10.97) \times (0.010) \times 1600^{11.73} \times e^{-0.0162 \times 1600} \times e^{-17.8 \times 10.97 \times 0.010}$$

$= 0.001$

$\therefore \varepsilon_{tot} = \varepsilon_{th} + \varepsilon_{D} + \varepsilon_{sfp} + \varepsilon_{gfp}$

$= \cancel{0.001}\ 0.01 - 0.01 + 0.006 + 0.001$

$= \cancel{-0.002}\ 0.007$

Ans:- 0.7%

~~Ans~~: <u>Ans: 3</u>

$$\dot{\varepsilon}_{ss} = A_0 \left(\frac{\sigma_m}{G}\right)^n e^{\frac{-Q}{RT}}$$

$$= (3.14 \times 10^{24}) \times \left\{ \frac{200}{4.2519 \times 10^{10} - (2.2185 \times 10^{7} \times 600) \times 10^{-6}} \right\}^5 \times e^{\frac{-2.7 \times 10^5}{8.3145 \times 600}}\ s^{-1}$$

$$= (3.14 \times 10^{24}) \times \left(\frac{200}{29208} \right)^5 \times e^{\frac{-2.7 \times 10^5}{8.3145 \times 600}}\ s^{-1}$$

$$= 1.48 \times 10^{-10}\ s^{-1}$$

$$\dot{\varepsilon}_{ir} = C_0 \varphi^{C_1} \sigma_m^{C_2}$$

$$= \left\{ (3.557 \times 10^{-24}) \times (3 \times 10^{11} \times 150)^{0.85} \times (200)^1 \right\} s^{-1}$$

$$= 2.867 \times 10^{-10} \, s^{-1}.$$

$$\therefore \dot{\varepsilon}_{tot} = \dot{\varepsilon}_{ss} + \dot{\varepsilon}_{ir}$$

$$= \left\{ (1.48 \times 10^{-10}) + (2.867 \times 10^{-10}) \right\} s^{-1}$$

$$= \cancel{4.248 \times 10^{-20}} \; 4.347 \times 10^{-10} \, s^{-1}$$

$$\therefore 1.5 \text{ years} = (4.347 \times 10^{-10}) \times (3600 \times 24 \times 365 \times 1.5)$$

$$= 0.021$$

$$= 2.1\% \text{ strain}$$

(Ans:

Ans: 4

→ Solid solution

→ Oxidi precipitates

→ Metallic precipitates

→ Nobel gases.

Ans: 5

In the microstructure based fuel performance modelling we can model the fuel behaviour according to the microstructural properties. ~~This~~ we can model operating conditions like neutron flux and coolant and use variables such as form, displacement etc.

Such modelling is beneficial because —

It provide a structure property relationship to replace the existing burnup. ~~such~~ depend models.

Ans: 6

— Low neutron cross section.

— Corrosion resistance in 300°C water

— Affordable cost.

Ans: 7

Oxide pellets used are always hypostoichiometric with O/M. Thus O_2 is redistributed radially, brings composition close to stoichiometry. Fuel is redistributed due to such O/M.

Ans: 8

Difference :

→ Burnup twice in LWR

→ Power density and heat fluxes are much higher in MOX fuel than LWR. The neutron flux is very intense in MOX approx ($\sim 7 \times 10^{15}\ n/cm^2/s^{-1}$) in the core center. Burn up is around 50 GWd/ton in MOX.

Ans: 9

Four conditions →

(1) Corrosive environment

(2) Susceptible material

(3) Sufficient stress

(4) Sufficient time.

IV (1)

met

Can be ~~measure~~ by —

1) chemically aggressive fission product accumulating in pellet cladding ~~gap~~ gap

2) Influenced by composition, microstructure texture.

3) For coolant pressure and creep, stress from fuel, should be controlled

4) Depends on local linear power, should be controlled.

Ans: 10

During high burnup high fragmentation can occur during LOCA. Scientists hypothesizes that during LOCA, trapped gas in bubbles heat up and cause cracking due to pressure. Work in progress to model such behaviour.

Ans: 11

. RIA is related to reactivity and accident happens if it is influenced beyond expectation due to other conditions. LOCA is related to cooling and happens when coolant flow is ~~too~~ hampered. RIA can happen if there is rapid increase in temp that will shift the reactivity. This will increase the pressure of bubbles and can cause break in the fuel.

Ans: 12

a) Improved cladding properties
b) Enhanced fission product retention

ATF option for improved cladding properties: cladding coating/liners, eg. Ti_3SiC_2 etc.

Ans: 13

⇒ PCMI → happens when pellet to cladding gap is influenced due to different phenomena (stress) and cause fragmentation or defects.

⇒ fuel rod internal pressure – It threatens cladding integrity if rod's internal pressure increase significantly. Significant reopening of gap should be avoided to avoid fuel failure related to this.