Nuclear Materials

Fall 2011

1 (20 minutes) Type 316 stainless steel is one of the most widely used materials in our daily lives. In nuclear engineering, however, type 316L is used instead.

a. (5 minutes) What does symbol "L" stand for? Or, answer the alternative question: what is the major composition difference between 316 and 316L steels.

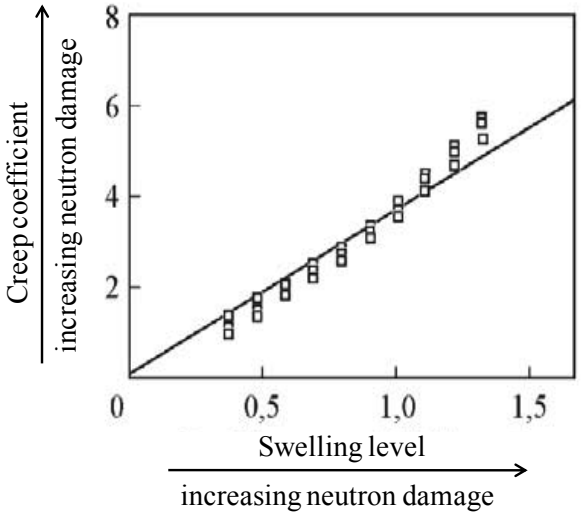
b. (5 minutes) What is the major material issue if 316 steel is used instead of 316L?

c. (5 minutes) Type 316L is an austenitic stainless steel. Schematically draw its crystal structure.

2 (20 minutes) Briefly explain the working principle (how it works) and the purpose (what you expect) of the following characterization methods and tools.

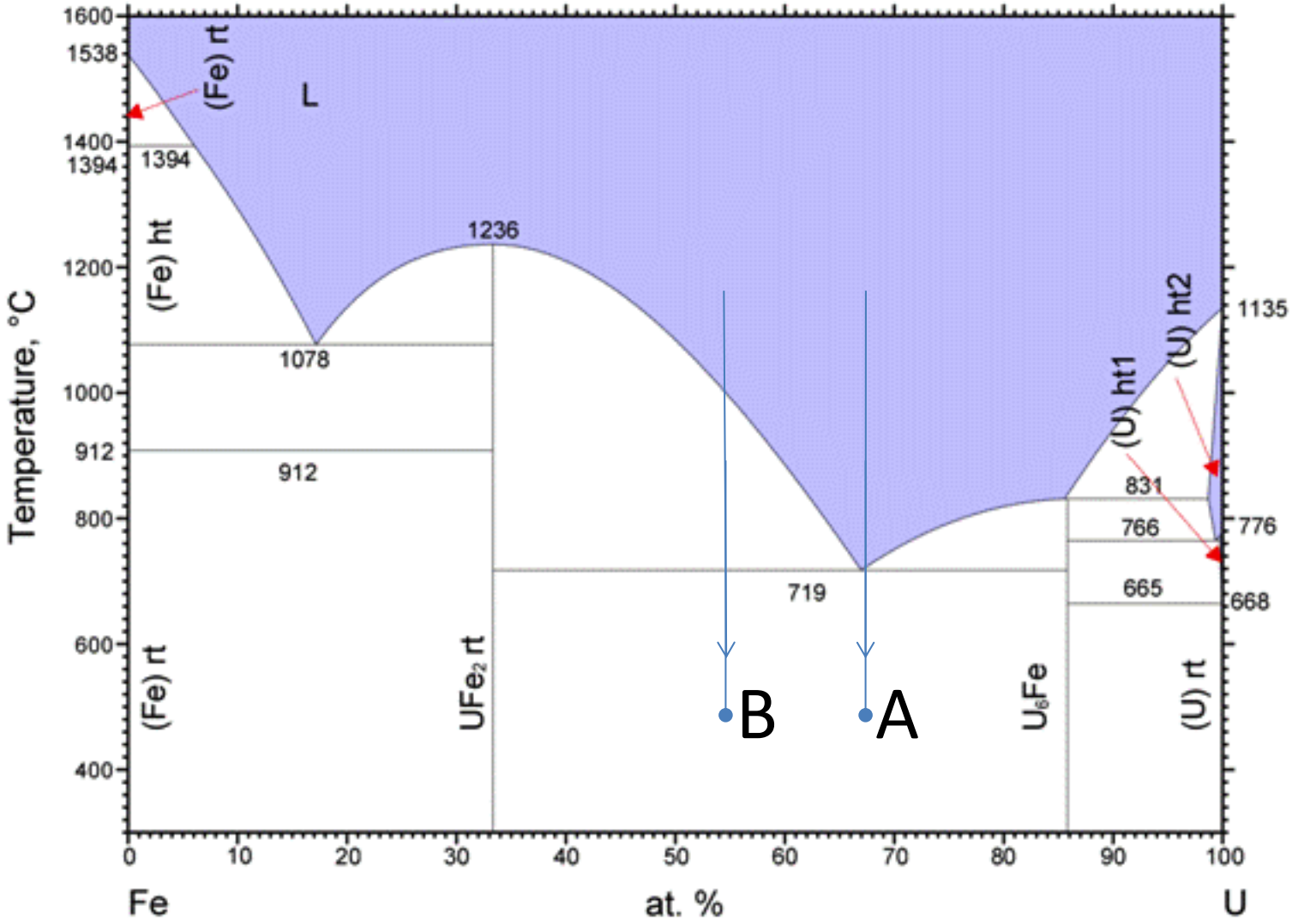
a. (5 minutes) X-ray diffraction analysis (XRD)
b. (5 minutes) Scanning electron microscope (SEM)
c. (5 minutes) Transmission electron microscope (TEM)
d. (5 minutes) Differential scanning calorimetry (DSC)

3 (10 minutes) The figure below is a plot of creep rate versus swelling rate for a typical cladding material with neutron damage. It shows creep rate increases with increasing swelling. Explain one possible mechanism.



4 (25 minutes) Based on the following U-Fe phase diagram, answer the questions

a. (5 minutes) What is the microstructure formed by slowly cooling the liquid alloy to the point A? What is the mechanism causing such structural formation?
b. (5 minutes) If the cooling rate is further increased, what is the microstructural change at point A and why?
c. (5 minutes) What is the microstructure formed by slowly cooling liquid to point B?
d. (10 minutes) Calculate at point B, the weight fraction of each component constituting the microstructure?



5 (15 minutes) Below are some measured data from γ phase U-Zr alloys from a 1961 report on the "Diffusion in uranium, its alloys, and compounds". (γ phase U-Zr exists between ~750°C and ~1150°C).

	D_o (cm^2/s)	Q (kcal/mol)
10 atom % Zr	$8x10^{-3}$	42
20 atom % Zr	$3x10^{-4}$	34
30 atom % Zr	$7x10^{-4}$	30

1 kcal = 4186.8 J

Calculate values for the temperature dependent diffusion coefficient (D(T)) for each alloy and sketch an arrhenius style plot of this data. Report two major observations that may be made from the data (what does it mean)?

6 (10 minutes) Consider a hypothetical metal with a yield stress of 400 MPa. Your current design project requires a long cylindrical rod that can support a vertical hanging load of 25,000 pounds (1 lb = 4.082 N). What is the minimum diameter (in cm) of the rod if your safety factor is ~2.5?

7 (10 minutes) For typical UO_2 fuel, explain why some fission products exist as oxide precipitates, metallic precipitates, oxides in solution, and gas bubbles.

8 (10 minutes) Describe the process of fission gas release from oxide, metal and TRISO fuels. What is similar and what is different?