ENGINEERING TRIPOS PART IIB

Friday 26 April 2013 9.30 am to 11.00 am

Module 4I5

NUCLEAR MATERIALS

*Answer not more than **two** questions.*

All questions carry the same number of marks.

*The **approximate** percentage of marks allocated to each part of a question is indicated in the right margin.*

There are no attachments

STATIONERY REQUIREMENTS
Single-sided script paper

SPECIAL REQUIREMENTS
Engineering Data Book
CUED approved calculator allowed

You may not start to read the questions printed on the subsequent pages of this question paper until instructed that you may do so by the Invigilator

algV2

1 (a) Identify the materials characteristics that are desirable in a nuclear fuel and briefly explain why they are relevant. [30%]

(b) In use, the microstructure of uranium dioxide fuel degrades. What are the key aspects of this restructuring? [15%]

(c) How can the stoichiometry of uranium dioxide fuel be used to improve its performance? [5%]

(d) Identify features of the crystal structure of uranium dioxide that are particularly favourable for its application as a nuclear fuel. [10%]

(e) Compare the merits and demerits of uranium metal and uranium dioxide as a nuclear fuel. [30%]

(f) Which other uranium-based fuels are under consideration for potential use? Which features might make them attractive? [10%]

2 (a) What are the main characteristics required in the cladding for a nuclear fuel? [15%]

(b) Which are the main aspects of cladding performance that limit the attainable fuel burn-up? [10%]

(c) Which are the two categories of cladding material in common use? Describe the main degradation mechanisms in each case, identifying those aspects that are in common for the two types of material, and those aspects that are distinctive. [75%]

3 (a) Briefly explain the process by which actinides and fission products are separated in the reprocessing of nuclear fuel. Considering the disposal of nuclear waste, state the advantages of separating the two types of radionuclides produced during the operation of a fission reactor. [25%]

(b) SYNROC is a concept for the disposal of nuclear waste. Explain the concept and indicate how the material is processed and what the final products are. How are changes in waste stream accommodated within the SYNROC concept and what is the major factor that leads it to have superior aqueous durability to borosilicate glass? [30%]

(c) The pyrochlore structure is closely related to one of the mineral phases in SYNROC. This caused a $Ca_2Ti_2O_7$-based pyrochlore to be chosen as a tailored ceramic in the *Swords to Ploughshares* options programme to dispose of weapons-grade plutonium (^{239}Pu). Suggest an experiment to test the suitability of this material for the disposal of plutonium. If the plutonium were kept in the +3 oxidation state, describe how the composition could be adjusted to accommodate the plutonium in the pyrochlore structure. If the long-term durability needed to be tested for 10,000 years with a 10 wt% Pu loading, describe an experiment that could test this on a laboratory time scale and estimate how long would it take. [45%]

[$t_{1/2}$ (^{239}Pu) = 24,100 years; $t_{1/2}$(^{238}Pu) = 87.7 years]

END OF PAPER