Nuclear Fuel Cycle KD2430

2011-03-18, 8^{00}-13^{00}

Please write readable. Write your name on every paper. Only one task per paper!
You can answer either in Swedish or English
You are allowed to use a calculator

Please read through questions 8-10

Good Luck!

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1. **a.** Describe how α–radiation interacts with matter.
b. Describe how β–radiation interacts with matter.
c. Describe how γ–radiation interacts with matter. (6p)

2. In radiation protection absorbed dose is measured in Gray (kJ/kg). When calculating *the effective dose* (earlier *the effective equivalent dose*) two different factors are introduced. What do these two factors compensate for? (2p)

3. Describe the principles of how a liquid scintillator works. (2p)

4. Which property of a material determines the penetration depth of ionizing radiation? (2p)

5. What behavior does a reactor with a positive void coefficient display? (3p)

6. What is the function of a moderator in a nuclear reactor? (2p)

7. Why is technetium a nuclide of great interest in a deep repository for spent nuclear fuel? (2p)

8. Describe the concepts of fissile and fertile actinides. Also give two examples of fissile actinides and one example of a fertile actinide (4p)

9. The research team for investigations of the environmental impact of accidents from the nuclear industry is heading for Mayak to study the area around the reprocessing site. Your task is to study the lakes on the sites and in particular to analyze Pu.
What types of samples will you take? Motivate in what samples you expect the highest Pu concentrations. How would you know which form of Pu to look for to find a suitable analysis technique? (6p)

10. Compare the geological and chemical principles in the concepts for depositing spent nuclear fuel in the Swedish KBS-3 model and in Yucca Mountain (which today is disclosed). (5p)

11. Describe shortly all the steps in the Nuclear Fuel Cycle with and without reprocessing from mining to handling of the waste. Which of the steps require most energy? (4p)

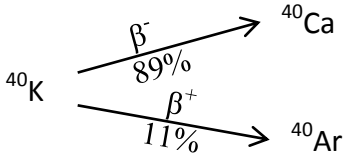
More questions at the back of the page =>

12. What was the isotopic abundance of ^{235}U 3 billion (3×10^9) years ago? (4p)

U	U 232	U 233	U 234	U 235	U 236	U 237	U 238	U 239	U 240
238,029	71,7 a α 5,320; 5,264	$1,57\cdot10^5$ a α 4,824; 4,783	0,0055 $2,44\cdot10^5$ a α 4,724; 4,722	0,720 $7,04\cdot10^8$ a α 4,401; 4,385	$2,342\cdot10^7$a α 4,494; 4,445	6,75 d β^- 0,2… γ 60; 208	99,28 $4,47\cdot10^9$ a α 4,196; 4,149	23,5 m β^- 1,2; 1,3… γ 75…	14,1 h β^- 0,4… γ 44…

13. Potassium is the eighth or ninth most common element by mass (0.2%) in the human body (sulfur is approximately as common). ^{40}K has a branched decay, see figure below.
How much argon (volume) is produced in a human being during a life-time (80 years)?
Assume a life-long average weight of 70 kg.
Ar can be considered an ideal gas and the gas constant is 8.3144 J mol^{-1} K^{-1}. (6p)

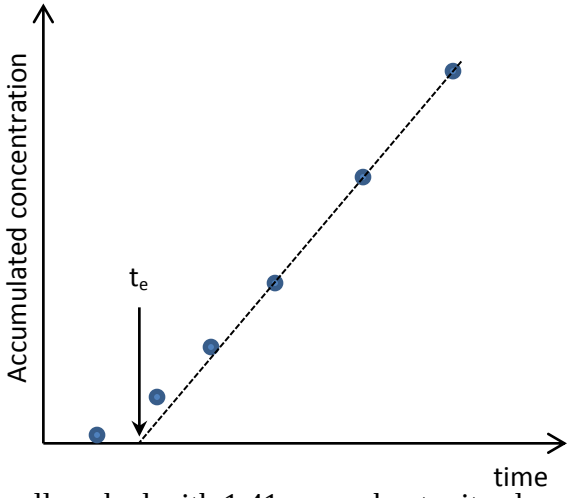
K	K39	K40	K41
39.1	93.2581 σ 2.1	$1.28\cdot10^9$a σ 0.42	6.7302 σ 1.46



14. In a diffusion experiment in porous media it is possible to obtain the apparent diffusivity, D_a, from the time lag, t_e, which is the point where the symptote of the break through curve intercepts the time axis (see figure) via the formula

$$D_a = \frac{L^2}{6t_e}$$

Where t_e is the time lag and L is the length of the diffusion cell.



In a diffusion experiment a 1.0 cm long diffusion cell packed with 1.41 grams bentonite clay (which gave a dry density of 1.8 g/cm^3) is used. I^- is the ion to be studied and the inlet solution contains 10 mM NaI spiked with ^{131}I (which is a β^--emitter, $t_{½}$ = 8.02 d). Samples are taken at different times from the outlet solution. The samples are measured for activity in a liquid scintillator (η = 83%).

The following values were obtained (all samples were measured for 15 minutes):

Time [h]	110	384	563	755	947	1112
Specific activity [cps/ml]	13.74	48.97	52.62	44.26	30.56	20.60
Sample volume [ml]	3.5	1.9	2.2	1.3	1.2	0.9

Determine the apparent diffusivity. Your answer must contain at least one plot.
Give your answer in SI-units. (8p)