Nuclear Fuel Cycle KD2430

2011-06-10, 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

Good Luck!

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1. Complete the nuclear reactions below

a. ____ → ^{99}Tc + γ

b. ^{237}Np → ____ + α

c. ____ → ^{150}Sm + n

d. n → ^{1}H + ____

e. ^{57}Co → ^{57}Fe + ____

f. ____ → ^{178}Lu + β^- (6p)

2. **a.** The ratio of neutrons to protons in "light" stable nuclides is: (1p)
a) 0.0 : 1.0 **b)** 0.5 : 1.0 **c)** 1.0 : 1.0 **d)** 1.5 : 1.0 **e)** 2.0 : 1.0 **f)** 2.5 : 1.0 **g)** 3.0 : 1.0

b. Upon entering an electric field, an α–particle is (1p)
a) deflected toward positive **b)** not deflected **c)** deflected toward negative

3. What is Čerenkov radiation? (2p)

4. Define and explain the concept LET. (2p)

5. Dose is sometimes expressed in the unit Gray and sometimes in Sievert.
What is the difference? (2p)

6. A portable detector is used to measure the activity of a sample. The surface are of the detector is 7 cm^2 and the efficiency is 1.2%. At a distance of 2.5 m. from the sample the signal is 15 cps. What is the activity of the sample? (3p)

7. What is a breeder reactor? (2p)

8. Which are the main barriers that are supposed to prevent radionuclides to escape to the biosphere in the KBS-3 concept? (2p)

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

10. 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)

11. 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)

12. 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)

13. A rock contains 257 mg of ^{206}Pb for every gram of ^{238}U. The half-life decay for uranium to turn into lead is 4.5×10^{9} yr. How old is the rock? (all ^{206}Pb originates from ^{238}U) (4p)

14. Coal tar is a complex combination of polycyclic hydrocarbons, phenols and heterocyclic oxygen, sulphur and nitrogen compounds. One of the most important coal tar components is naphthalene.

The concentration of naphthalene is to be determined in a coal tar. In a radiologic laboratory naphthalene is labeled with ^{14}C to contain 8.70 kBq/g. 4.30 gram of the labeled naphthalene is added to 630 g coal tar. The tar is carefully mixed for a day. 48.0 gram coal tar is taken from the mix. Through extraction, distillation and sublimation, 2.10 gram pure naphthalene (99.9%) is obtained. The pure naphthalene is measured in a liquid scintillator (with an efficiency of 75.2%). The β^--activity is measured to be 191.1 cps.

What is the naphthalene content (wt%) in the coal tar? (8p)

15. A sample containing element X is irradiated in a neutron flux of 5×10^{10} n s^{-1} cm^{-2} for 30 minutes and nuclides X-101 and X-103 are formed. Directly after the irradiation the sample is measured for β^--activity. After irradiation the sample is measured at time intervals, see table below for the results.
A piece of a nuclide chart around element X can be seen in the figure below. It is known that the half-life of X-101 is 200 hours. Since the half-life of X-101 is known it was possible to determine that the amount of X-101 directly after the irradiation was 9.4209×10^{-14} g. What are the half-lives of nuclides X-103 and Y-103? (8p)

Time [h]	Activity [Bq]
0	28 168.23
2.5	21 765.35
5	17 132.78
10	11 281.43
20	6 200.90
50	2 656.57
100	1 218.56
150	774.99

Z-102 68.3 σ 0.04	**Z-103** 24.2 σ 5.1	**Z-104** 0.97 σ 0.14	**Z-105** 19 d
Y-101 27.1 σ 1.6	**Y-102** 3.2 σ 0.58	**Y-103** ?	**Y-104** 2.1 s
X-100 31.5 σ 1.2	**X-101** 200 h	**X-103** 18.6 σ 0.49	**X-103** ?

Periodic Table of the Elements

H 1 1.0079																	**He 2** 4.0026
Li 3 6.941	**Be 4** 9.01218											**B 5** 10.81	**C 6** 12.011	**N 7** 14.0067	**O 8** 15.9994	**F 9** 18.9984	**Ne 10** 20.179
Na 11 22.9898	**Mg 12** 24.305											**Al 13** 26.9815	**Si 14** 28.0855	**P 15** 30.9736	**S 16** 32.06	**Cl 17** 35.453	**Ar 18** 39.948
K 19 39.0983	**Ca 20** 40.08	**Sc 21** 44.9559	**Ti 22** 47.88	**V 23** 50.9415	**Cr 24** 51.996	**Mn 25** 54.9380	**Fe 26** 55.847	**Co 27** 58.9332	**Ni 28** 58.70	**Cu 29** 63.546	**Zn 30** 65.38	**Ga 31** 69.72	**Ge 32** 72.59	**As 33** 74.9216	**Se 34** 78.96	**Br 35** 79.904	**Kr 36** 83.80
Rb 37 85.4678	**Sr 38** 87.62	**Y 39** 88.9059	**Zr 40** 91.22	**Nb 41** 92.9064	**Mo 42** 95.94	**Tc 43** 98.906	**Ru44** 101.07	**Rh 45** 102.96	**Pd 46** 106.4	**Ag 47** 107.868	**Cd 48** 112.41	**In 49** 114.82	**Sn 50** 118.69	**Sb 51** 121.75	**Te 52** 127.60	**I 53** 126.9	**Xe 54** 131.30
Cs 55 132.9	**Ba 56** 137.33	**La 57** 138.91	**Hf 72** 178.49	**Ta 73** 180.948	**W 74** 183.85	**Re 75** 186.207	**Os 76** 190.2	**Ir 77** 192.22	**Pt 78** 195.09	**Au 79** 196.966	**Hg 80** 200.59	**Tl 81** 204.37	**Pb 82** 207.2	**Bi 83** 208.980	**Po 84** (209)	**At 85** (210)	**Rn 86** (222)
Fr 87 (223)	**Ra 88** 226.025	**Ac 89** 227.028	**Unq 104** (261)	**Unp 105** (262)	**Unh 106** (263)												

Ce 58 140.12	**Pr 59** 140.9077	**Nd 60** 144.24	**Pm 61** 145	**Sm 62** 150.4	**Eu 63** 151.96	**Gd 64** 157.25	**Tb 65** 158.9254	**Dy 66** 162.50	**Ho 67** 164.9304	**Er 68** 167.26	**Tm 69** 168.9342	**Yb 70** 173.04	**Lu 71** 174.967
Th 90 232.0381	**Pa 91** 231.0359	**U 92** 238.029	**Np 93** 237.0482	**Pu 94** (244)	**Am 95** (243)	**Cm 96** (247)	**Bk 97** (247)	**Cf 98** (251)	**Es 99** (254)	**Fm 100** (257)	**Md 101** (258)	**No 102** 259	**Lr 103** 260