CH3771 Nuclear Chemistry Final Exam

(January 21, 2016)

- You will have 3 hours to complete this exam.
- Use of slides or book is not allowed
- Please add your name and student number on each sheet that you use and number the sheets
- Please do not use a pencil to write your answers
- You MUST show your work in order to receive any partial credit for incorrect answers.

GOOD LUCK!

Question 1

Find the energy needed to remove a neutron from ^{81}Kr. Given M(^{1}H) = 1.007825 amu, m(n)=1.008665 amu. The masses for Krypton isotopes can be found in the atomic mass table at the end of this document. (2 points)

Question 2

Explain the principle of active and passive targeting and give one example of each targeting mechanism. (2 points)

Question 3

A sample of leather from a tomb is burned to obtain 0.20 g of carbon. The measured activity of the sample is 0.017 Bq. How old is the sample? In the environment, about one carbon atom in 7.7×10^{11} is ^{14}C. The half-life of ^{14}C is 5730 a. (2 points)

Question 4

Would you prefer a high E_{max} or a low E_{max} positron emitter for PEPT tracking of glass particles in a glass-gas fluidized bed? (1 point)

Question 5

For a laboratory experiment 10 mL of 2mM tungsten (W) solution is needed containing the isotopes W-187 ($t_{1/2}$ = 23.9 h) and W-188 ($t_{1/2}$ = 69.4 d). Each isotope should have an activity concentration in the final solution of 370 kBq/mL.

a. W-188 is obtained from an outside supplier with a specific activity of 2.2×10^{11} Bq/g. How much gram of tungsten are added to the final solution by adding the required activity of W-188? (1 point)
b. To produce W-187, 10 mg of natural abundance W-186 (σ = 38 b, h = 28.43%) are irradiated with thermal neutrons. The neutron flux is $2 \cdot 10^{12}$ $n \cdot cm^{-2} \cdot s^{-1}$, and the irradiation time is 2 h. What is the specific activity of the produced W-187 at end of irradiation and how much gram of tungsten are added to the final solution by adding the required activity of W-187? (2 points)
c. How much non-radioactive tungsten needs to be added to the solution to reach a final tungsten concentration of 2 mM? Calculate first the amount of tungsten contained in a 2 mM solution. (1 point)
d. What happens to the specific activity of W-187 if it can only be used 24 h after irradiation? Can it be used for the planned experiment, and if not, what would be a solution to this problem? (2 points)

Question 6

The $^{99}Mo/^{99m}Tc$ radionuclide generator is widely applied worldwide. The standard generators utilized in Europe contain 2 Ci of ^{99m}Tc, in equilibrium with the parent isotope ^{99}Mo, when they are received at the hospitals. ^{99m}Tc is applied for different diagnoses using SPECT cameras. Every patient is dosed with a labelled compound that contains 10 mCi of ^{99m}Tc (measured at the time of generator elution). Assume that ^{99}Mo decays 100% to ^{99m}Tc.

$T_{1/2}(^{99}Mo)=66$ h
$T_{1/2}(^{99m}Tc)=6$ h

a. Explain briefly what a radionuclide generator is and what makes it convenient to use in hospitals. (1 point)
b. On arrival in the hospital a generator is eluted once to remove all ^{99m}Tc and its decay product ^{99}Tc that have accumulated. This first eluate cannot be used for patients. Calculate the time needed after the first elution to reach again the activity needed for the diagnosis of 10 patients. (2 points)
c. A generator is considered useless as soon as it is not able to provide more than 100 mCi. Calculate the total time a generator can be used in the hospital before a replacement is needed. (1 point)

Question 7

Write down the outer shell electronic configuration of Flerovium. What chemical behaviour is expected of this element due to relativistic effects? Explain in short what relativistic effects are and how they can influence the chemical behaviour of specifically this element. (2 points)

Useful constants:

Avogadro's number (N_A) = 6.022137×10^{23}/mol
mass of proton = 1.007276 amu
mass of neutron = 1.008664 amu
mass of electron = 5.485799×10^{-4} amu
speed of light (c) = 3.0×10^8 m/s
6.022137×10^{23} amu = 1g
1 J = 1 kg•m^2/s^2
1 eV = 1.602×10^{-19} J
1 Mev = 10^6 eV

Table B.1. Atomic mass tables *(cont.)*

N	Z	A	El	Atomic Mass (μu)
39	38		Sr	76 937760
38	39		Y	76 949620
50	28	78	Ni	77 963800
49	29		Cu	77 952810
48	30		Zn	77 938570
47	31		Ga	77 931660
46	32		Ge	77 922853
45	33		As	77 921829
44	34		Se	77 917309.5
43	35		Br	77 921146
42	36		Kr	77 920386
41	37		Rb	77 928141
40	38		Sr	77 932179
39	39		Y	77 943500
50	29	79	Cu	78 955280
49	30		Zn	78 942680
48	31		Ga	78 932920
47	32		Ge	78 925400
46	33		As	78 920948
45	34		Se	78 918499.8
44	35		Br	78 918337.6
43	36		Kr	78 920083
42	37		Rb	78 923997
41	38		Sr	78 929707
40	39		Y	78 937350
39	40		Zr	78 949160
51	29	80	Cu	79 961890
50	30		Zn	79 944410
49	31		Ga	79 936590
48	32		Ge	79 925445
47	33		As	79 922578
46	34		Se	79 916521.8
45	35		Br	79 918530.0
44	36		Kr	79 916378
43	37		Rb	79 922519
42	38		Sr	79 924525
41	39		Y	79 934340
40	40		Zr	79 940550
51	30	81	Zn	80 950480
50	31		Ga	80 937750
49	32		Ge	80 928820
48	33		As	80 922133
47	34		Se	80 917992.9
46	35		Br	80 916291
45	36		Kr	80 916592
44	37		Rb	80 918994
43	38		Sr	80 923213
42	39		Y	80 929130
41	40		Zr	80 936820
40	41		Nb	80 949050
52	30	82	Zn	81 954840
51	31		Ga	81 943160
50	32		Ge	81 929550
49	33		As	81 924500
48	34		Se	81 916700.0
47	35		Br	81 916805
46	36		Kr	81 913484.6
45	37		Rb	81 918208
44	38		Sr	81 918401
43	39		Y	81 926790
42	40		Zr	81 931090
41	41		Nb	81 943130
52	31	83	Ga	82 946870
51	32		Ge	82 934510
50	33		As	82 924980
49	34		Se	82 919119
48	35		Br	82 915180
47	36		Kr	82 914136
46	37		Rb	82 915112
45	38		Sr	82 917555
44	39		Y	82 922350
43	40		Zr	82 928650
42	41		Nb	82 936700
41	42		Mo	82 948740
53	31	84	Ga	83 952340
52	32		Ge	83 937310
51	33		As	83 929060
50	34		Se	83 918465
49	35		Br	83 916504
48	36		Kr	83 911507
47	37		Rb	83 914385
46	38		Sr	83 913425
45	39		Y	83 920390
44	40		Zr	83 923250
43	41		Nb	83 933570
42	42		Mo	83 940090
53	32	85	Ge	84 942690
52	33		As	84 931810
51	34		Se	84 922240
50	35		Br	84 915608
49	36		Kr	84 912527
48	37		Rb	84 911789.3
47	38		Sr	84 912933
46	39		Y	84 916427
45	40		Zr	84 921470
44	41		Nb	84 927910
43	42		Mo	84 936590
42	43		Tc	84 948940
54	32	86	Ge	85 946270
53	33		As	85 936230
52	34		Se	85 924271
51	35		Br	85 918797
50	36		Kr	85 910610.3
49	37		Rb	85 911167.1
48	38		Sr	85 909262.4
47	39		Y	85 914888
46	40		Zr	85 916470
45	41		Nb	85 925040
44	42		Mo	85 930700
43	43		Tc	85 942880
54	33	87	As	86 939580
53	34		Se	86 928520
52	35		Br	86 920711
51	36		Kr	86 913354.3
50	37		Rb	86 909183.5
49	38		Sr	86 908879.3
48	39		Y	86 910877.8
47	40		Zr	86 914817
46	41		Nb	86 920360
45	42		Mo	86 927330
44	43		Tc	86 936530
43	44		Ru	86 949180
55	33	88	As	87 944560
54	34		Se	87 931420
53	35		Br	87 924070
52	36		Kr	87 914447
51	37		Rb	87 911319
50	38		Sr	87 905614.3
49	39		Y	87 909503.4
48	40		Zr	87 910226
47	41		Nb	87 917960
46	42		Mo	87 921953
45	43		Tc	87 932830
44	44		Ru	87 940420
56	33	89	As	88 949230
55	34		Se	88 936020
54	35		Br	88 926390
53	36		Kr	88 917630
52	37		Rb	88 912280
51	38		Sr	88 907452.9
50	39		Y	88 905847.9
49	40		Zr	88 908889
48	41		Nb	88 913500
47	42		Mo	88 919481
46	43		Tc	88 927540
45	44		Ru	88 936110
44	45		Rh	88 949380
56	34	90	Se	89 939420
55	35		Br	89 930630
54	36		Kr	89 919524
53	37		Rb	89 914809
52	38		Sr	89 907737.6
51	39		Y	89 907151.4
50	40		Zr	89 904703.7
49	41		Nb	89 911264
48	42		Mo	89 913936
47	43		Tc	89 923560
46	44		Ru	89 929780
45	45		Rh	89 942870
57	34	91	Se	90 945370
56	35		Br	90 933970
55	36		Kr	90 923440
54	37		Rb	90 916534
53	38		Sr	90 910210
52	39		Y	90 907303
51	40		Zr	90 905645.0
50	41		Nb	90 906991
49	42		Mo	90 911751
48	43		Tc	90 918430
47	44		Ru	90 926380
46	45		Rh	90 936550
45	46		Pd	90 949480
58	34	92	Se	91 949330
57	35		Br	91 939260