NUC 2018

Question 2 (3 pt)

Give the shell model spin and parity assignment for the ground state of $^{23}_{11}Na$ using the shell ordering given below.

Shell ordering: $1s_{1/2}$; $1p_{3/2}$; $1p_{1/2}$; $1d_{5/2}$; $1d_{3/2}$; $2s_{1/2}$; $1f_{7/2}$; $2p_{3/2}$; $1f_{5/2}$; $2p_{1/2}$; $1g_{9/2}$; $1g_{7/2}$; $2d_{5/2}$.

Question 3 (5 pt)

Predict how the radioisotope ^{55}Co will decay, supported by calculations. Write the balanced equations for each decay (5 pt). In table B.1 you can find the atomic masses of radionuclides related to the decay of ^{55}Co.

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

N	Z	A	El	Atomic Mass (μu)
29	18		Ar	46 972190
28	19		K	46 961678
27	20		Ca	46 954546.5
26	21		Sc	46 952408.0
25	22		Ti	46 951763.8
24	23		V	46 954906.9
23	24		Cr	46 962907
22	25		Mn	46 976100
21	26		Fe	46 992890
32	16	48	S	48 012990
31	17		Cl	47 994850
30	18		Ar	47 975070
29	19		K	47 965513
28	20		Ca	47 952534
27	21		Sc	47 952235
26	22		Ti	47 947947.1
25	23		V	47 952254.5
24	24		Cr	47 954036
23	25		Mn	47 968870
22	26		Fe	47 980560
21	27		Co	48 001760
33	16	49	S	49 022010
32	17		Cl	48 999890
31	18		Ar	48 982180
30	19		K	48 967450
29	20		Ca	48 955673
28	21		Sc	48 950024
27	22		Ti	48 947870.8
26	23		V	48 948516.9
25	24		Cr	48 951341.1
24	25		Mn	48 959623
23	26		Fe	48 973610
22	27		Co	48 989720
33	17	50	Cl	50 007730
32	18		Ar	49 985940
31	19		K	49 972780
30	20		Ca	49 957518
29	21		Sc	49 952187
28	22		Ti	49 944792.1
27	23		V	49 947162.8
26	24		Cr	49 946049.6
25	25		Mn	49 954244.0
24	26		Fe	49 962990
23	27		Co	49 981540
22	28		Ni	49 995930
34	17	51	Cl	51 013530
33	18		Ar	50 993240
32	19		K	50 976380
31	20		Ca	50 961470
30	21		Sc	50 953603
29	22		Ti	50 946616.0
28	23		V	50 943963.7
27	24		Cr	50 944771.8
26	25		Mn	50 948215.5
25	26		Fe	50 956825
24	27		Co	50 970720
23	28		Ni	50 987720
34	18	52	Ar	51 998170

N	Z	A	El	Atomic Mass (μu)
33	19		K	51 982610
32	20		Ca	51 965100
31	21		Sc	51 956650
30	22		Ti	51 946898
29	23		V	51 944779.7
28	24		Cr	51 940511.9
27	25		Mn	51 945570.1
26	26		Fe	51 948117
25	27		Co	51 963590
24	28		Ni	51 975680
23	29		Cu	51 997180
35	18	53	Ar	53 006230
34	19		K	52 987120
33	20		Ca	52 970050
32	21		Sc	52 959240
31	22		Ti	52 949730
30	23		V	52 944343
29	24		Cr	52 940653.8
28	25		Mn	52 941294.7
27	26		Fe	52 945312.3
26	27		Co	52 954225
25	28		Ni	52 968460
24	29		Cu	52 985550
35	19	54	K	53 993990
34	20		Ca	53 974680
33	21		Sc	53 963000
32	22		Ti	53 950870
31	23		V	53 946444
30	24		Cr	53 938884.9
29	25		Mn	53 940363.2
28	26		Fe	53 939614.8
27	27		Co	53 948464.1
26	28		Ni	53 957910
25	29		Cu	53 976710
24	30		Zn	53 992950
36	19	55	K	54 999390
35	20		Ca	54 980550
34	21		Sc	54 967430
33	22		Ti	54 955120
32	23		V	54 947240
31	24		Cr	54 940844.2
30	25		Mn	54 938049.6
29	26		Fe	54 938298.0
28	27		Co	54 942003.1
27	28		Ni	54 951336
26	29		Cu	54 966050
25	30		Zn	54 983980
36	20	56	Ca	55 985790
35	21		Sc	55 972660
34	22		Ti	55 957990
33	23		V	55 950360
32	24		Cr	55 940645
31	25		Mn	55 938909.4
30	26		Fe	55 934942.1
29	27		Co	55 939843.9
28	28		Ni	55 942136
27	29		Cu	55 958560
26	30		Zn	55 972380

N	Z	A	El	Atomic Mass (μu)
25	31		Ga	55 994910
37	20	57	Ca	56 992360
36	21		Sc	56 977040
35	22		Ti	56 962900
34	23		V	56 952360
33	24		Cr	56 943750
32	25		Mn	56 938287
31	26		Fe	56 935398.7
30	27		Co	56 936296.2
29	28		Ni	56 939800
28	29		Cu	56 949216
27	30		Zn	56 964910
26	31		Ga	56 982930
37	21	58	Sc	57 983070
36	22		Ti	57 966110
35	23		V	57 956650
34	24		Cr	57 944250
33	25		Mn	57 939990
32	26		Fe	57 933280.5
31	27		Co	57 935757.6
30	28		Ni	57 935347.9
29	29		Cu	57 944540.7
28	30		Zn	57 954600
27	31		Ga	57 974250
26	32		Ge	57 991010
38	21	59	Sc	58 988040
37	22		Ti	58 971960
36	23		V	58 959300
35	24		Cr	58 948630
34	25		Mn	58 940450
33	26		Fe	58 934880.5
32	27		Co	58 933200.2
31	28		Ni	58 934351.6
30	29		Cu	58 939504.1
29	30		Zn	58 949270
28	31		Ga	58 963370
27	32		Ge	58 981750
38	22	60	Ti	59 975640
37	23		V	59 964500
36	24		Cr	59 949730
35	25		Mn	59 943190
34	26		Fe	59 934077
33	27		Co	59 933822.2
32	28		Ni	59 930790.6
31	29		Cu	59 937368.1
30	30		Zn	59 941832
29	31		Ga	59 957060
28	32		Ge	59 970190
27	33		As	59 993130
39	22	61	Ti	60 982020
38	23		V	60 967410
37	24		Cr	60 954090
36	25		Mn	60 944460
35	26		Fe	60 936749
34	27		Co	60 932479.4
33	28		Ni	60 931060.4
32	29		Cu	60 933462.2
31	30		Zn	60 939514

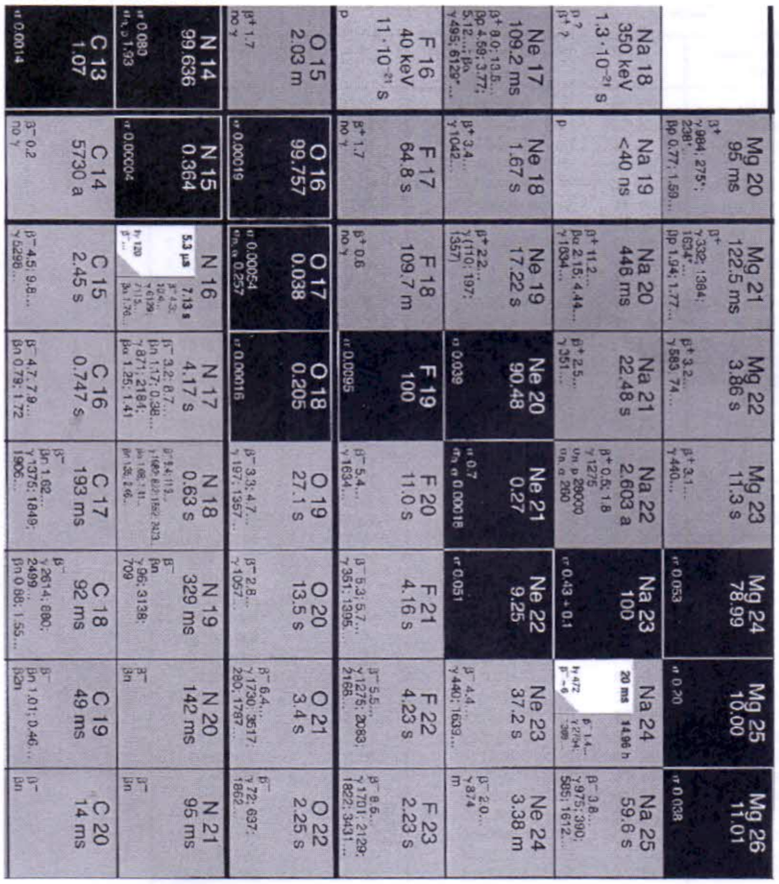
Production of Isotopes

Question 4 (5 pt)

Consider you want to make ^{18}F for PET studies

a) What would be the maximum specific activity (Bq/g F) of the ^{18}F made by irradiating 1g of $K^{19}F$ (100% abundance of ^{19}F) in a flux of 10^{10} fast neutrons/($cm^2 \cdot s$). You may assume the $^{19}F(n,2n)$ cross section is 300 mb.

b) Imagine you want to produce ^{18}F carrier-free (i.e., with no stable fluorine present). Suggest one nuclear reaction for producing the carrier-free ^{18}F (by irradiating e.g. with neutrons, protons, or deuterons). Defend your choice of nuclear reaction.



Radioanalytics

Question 5 (3 pt)

To determine the ^{226}Radium content in a mineral (10 g), Rn is separated from the mineral, and the activity of ^{222}Rn in equilibrium is measured. The counting rate is 4300 cpm, the total counting efficiency of the measuring setup is 80%. How much is the Radium content of the mineral (in mass%)?

Ac 223 2.10 m α 6.647; 6.662; 6.564...; ε γ (99; 191; 84...)	Ac 224 2.9 h ε α 6.142; 6.060; 6.214... γ 216; 132	Ac 225 10.0 d α 5.830; 5.793; 5.732...; C 14 γ 100; (150; 188; 63...); e⁻	Ac 226 29 h β⁻ 0.9; 1.1 ε; α 5.34 γ 230; 158; 254; 186...	Ac 227 21.773 a β⁻ 0.04... α 4.953; 4.941... γ (100; 84...); e⁻ σ 880; σ_f <0.00035	Ac 228 6.13 h β⁻ 1.2; 2.1... α 4.27 ?... γ 911; 969; 338; 965...
Ra 222 38 s α 6.559; 6.237... γ 324; (329; 473...) C 14	Ra 223 11.43 d α 5.7162; 5.6067... γ 269; 154; 324... C 14; σ 130 σ_f <0.7	Ra 224 3.66 d α 5.6854; 5.4486... γ 241...; C 14 σ 12.0	Ra 225 14.8 d β⁻ 0.3; 0.4 γ 40 e⁻	Ra 226 1600 a α 4.7843; 4.601... γ 186...; C 14 σ ~13 σ_f <7E-6	Ra 227 42.2 m β⁻ 1.3... γ 27; 300; 303...
Fr 221 4.9 m α 6.341; 6.126... γ 218; (101; 411...) C 14	Fr 222 14.2 m β⁻ 1.8... γ 206; 211; 242... α ?	Fr 223 21.8 m β⁻ 1.1... α 5.34 γ 50; 80; 235...	Fr 224 3.3 m β⁻ 2.6; 2.8... γ 216; 132; 837; 1341...	Fr 225 4.0 m β⁻ 1.6... γ 182; 32; 225; 200...	Fr 226 48 s β⁻ 3.2; 3.5... γ 254; 186; 1323...
Rn 220 55.6 s α 6.288... γ (550) σ <0.2	Rn 221 25 m β⁻ 0.8; 1.1... α 6.037; 5.788; 5.778 γ 186; 150...	Rn 222 3.825 d α 5.48948... γ (510) σ 0.74	Rn 223 23.2 m β⁻ γ 593; 417; 636; 655...	Rn 224 1.78 h β⁻ γ 261; 266...	Rn 225 4.5 m β⁻ γ 29–207...
At 219 0.9 m α 6.27 β⁻	At 220 3.71 m β⁻ α 5.493 γ 241; 293; 422...	At 221 2.3 m β⁻	At 222 54 s β⁻	At 223 50 s β⁻	

Radionuclide generators

Question 6 (4 pt)

a) Describe the principles of a radionuclide generator.

b) List the ideal characteristics of a radionuclide generator.

c) A 1350-mCi (50-GBq) ^{99}Mo–^{99m}Tc generator was calibrated on Wednesday at 8:00 a.m. and was eluted daily at the same time. What would be the ^{99m}Tc activity in the generator at 12:00 am on the fifth day after calibration? 6h

Chemical effects of nuclear transformations and Mossbauer

Question 7 (8 pt)

The nucleus ^{57}Fe has an excited state at 14.4 keV that decays with a half-live of 10^{-7} s under emission of a γ-photon

a) What is the recoil energy of the free ^{57}Fe nucleus? If that atom were part of a molecule, would you expect bond rupture due to the emission of that γ-photon. (Chemical bonds energies are in the order of few eV)

b) Why can the emitted γ not be absorbed by a second free ^{57}Fe nucleus at rest?

c) Explain why the recoilless emission and absorption (Mossbauer effect) of a γ-photon only takes place in solids and how that effect can be utilized to characterize solids.

Radiodating

Question 8 (2 pt)

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.

Radiobiology

Question 9 (2 pt)

For which type of radiation would you expect clustered DNA damage and why does this damage lead often to cell death?

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