Georgia Institute of Technology

The George W. Woodruff School of Mechanical Engineering
Nuclear & Radiological Engineering/Medical Physics Program

Ph.D. Qualifier Exam

Spring Semester 2007

_______________ Your ID Code

Radiation Physics (Day 1)

Instructions

1. Use a separate page for each answer sheet (no front to back answers).
2. The question number should be shown on each answer sheet.
3. ANSWER 4 OF 6 QUESTIONS ONLY.
4. Staple your question sheet to your answer sheets and turn in.

NRE/MP Radiation Physics

Answer any 4 of the following 6 questions:

1. Alpha particles of energy 6.50 MeV are Coulomb scattered by a gold foil. (a) What is the impact parameter when the scattered particles are observed at 90^0? (b) Again for scattering at 90^0, find the smallest distance between the α particles and the nucleus, and also find the kinetic and potential energies of the α particle at that distance. (c) At what scattering angle is the scattering rate (per unit solid angle) an order of magnitude larger than it is at 90^0?

2. (a) A beam of deuterons of non-relativistic energy is elastically scattered by a hydrogen target. Show that according to classical mechanics the scattering angle cannot exceed 30° in the laboratory system. However, if a beam of protons is incident on a deuterium target show that there is no such limit to the angle at which elastic scattering can occur; (b) Again treating the system classically show that if the neutron-neutron scattering is elastic, the angle between their final directions in the laboratory frame is always 90°.

Attachment A

Nuclide ($_zXA$)	Mass excess (μu)	Abundance or half-life
$_0$n1	8665	β^-614.6 s
$_1$H1	7825	99.985%
2	14102	0.015%
3	16049	β^-12.33 y
$_2$He3	16029	0.000137%
4	2603	99.99986%

Nuclide ($_zXA$)	Mass excess (μu)	Abundance or half-life
$_3$Li6	15122	7.5%
7	16004	92.5%
8	22487	β^-838 ms
9	26789	β^-178.3 ms
$_4$Be7	16929	ε53.29 d
8	5305	α67 as
9	12182	100%

Nuclide ($_zXA$)	Mass excess (μu)	Abundance or half-life
10	13534	β^-1.51 My
11	21658	β^-13.81 s
12	26920	β^-21.3 ms
$_5$B8	24607	β^+770 ms
9	13329	p 800 zs
10	12937	19.9%
11	9305	80.1%

Nuclide ($_zXA$)	Mass excess (μu)	Abundance or half-life
236	45562	α23.42 My
237	48724	β^-6.75 d
238	50783	99.2745%
239	54288	β^-23.45 m
$_{93}$Np234	42888	β^+4.4 d
235	44056	ε396.1 d
236	46560	ε154 ky
237	48167	α2.144 My
238	50940	β^-2.117 d
239	52931	β^-2.3565 d
$_{94}$Pu236	46048	α2.858 y
237	48404	ε45.2 d
238	49553	α87.7 y
239	52157	α24.11 ky
240	53807	α6.564 ky
241	56845	β^-14.35 y
242	58737	α373.3 ky
243	61997	β^-4.956 h
244	64198	α80.8 My
$_{95}$Am240	55288	β^+50.8 h
241	56823	α432.2 y
242	59543	β^-16.02 h
243	61373	α7.37 ky
244	64279	β^-10.1 h
$_{96}$Cm242	58829	α162.8 d
243	61382	α29.1 y
244	62746	α18.10 y
245	65486	α8.5 ky
246	67218	α4.73 ky
247	70347	α15.6 My
248	72342	α340 ky

Nuclide ($_zXA$)	Mass excess (μu)	Abundance or half-life
249	75947	β^-64.15 m
250	78350	f 9 ky
$_{97}$Bk245	66355	ε4.94 d
246	68664	β^+1.80 d
247	70299	α1.38 ky
248	73076	α9 y
249	74980	β^-320 d
$_{98}$Cf250	76400	α13.08 y
251	79580	α900 y
252	81619	α2.645 y
253	85127	β^-17.81 d
254	87317	f 60.5 d
255	91037	β^-85 m
256	93441	f 12.3 m
$_{99}$Es251	79983	ε33 h
252	82974	α471.7 d
253	84818	α20.47 d
254	88016	α275.7 d
255	90267	β^-39.8 d
$_{100}$Fm251	81567	β^+5.30 h
252	82460	α25.39 h
253	85176	ε3.00 d
254	86848	α3.240 h
255	89955	α20.07 h
256	91767	f 157.6 m
257	95099	α100.5 d
$_{101}$Md255	91075	β^+27 m
256	94053	β^+78.1 m
257	95535	ε5.52 h
258	98426	α51.50 d

NRE/MP Radiation Physics-Cont'd.

3. In an alloyed Am(Be) neutron source, neutrons are produced from the interactions of 5.5-MeV alpha particles (emitted from ^{241}Am) with the ^{9}Be nuclei. That is,

$$ {}^{9}_{4}Be + {}^{4}_{2}He \rightarrow {}^{1}_{0}n + {}^{12}_{6}C $$

   a. Use the mass table (attachment A) to calculate the kinetic energy of the alpha particle.

   b. Given that the nuclear radius obeys the formula, $R = 1.25 \times A^{1/3}$ *fm* and that $\frac{e^2}{4\pi\varepsilon_0} = 1.44$ *MeV fm*, use the classical approach to estimate the coulomb barrier (in *MeV*) for the above (α,n) reaction.

   c. Use the classical approach to estimate the cross section (in barns) for the above (α,n) reaction, and discuss how the cross section should be modified by the quantum-mechanical approach.

4. As a follow-up question of problem 1, use the mass table (attachment A) to calculate the energy range of neutrons emitted in the LAB system.

5. Answer the following:

   a. What is the kinetic energy of the Compton electron for photons scattered at 45^{o} during a Compton interaction if the energy of the incident photon is 150 keV?

   b. What effect does an increase in the photon scattering angle have on the scattered photon?

6. An assay of uranium ore at equilibrium shows an atom ratio for ^{235}U/^{231}Pa of 3.04(10^{6}). Calculate the half-life of ^{235}U from the assay data and the known half-life of ^{231}Pa (3.28 x 10^{4} years).