GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff School of Mechanical Engineering

NRE/HP Qualifier Exam

Fall Semester 2000

___________Your ID Code

Day 4 – Radiation Protection

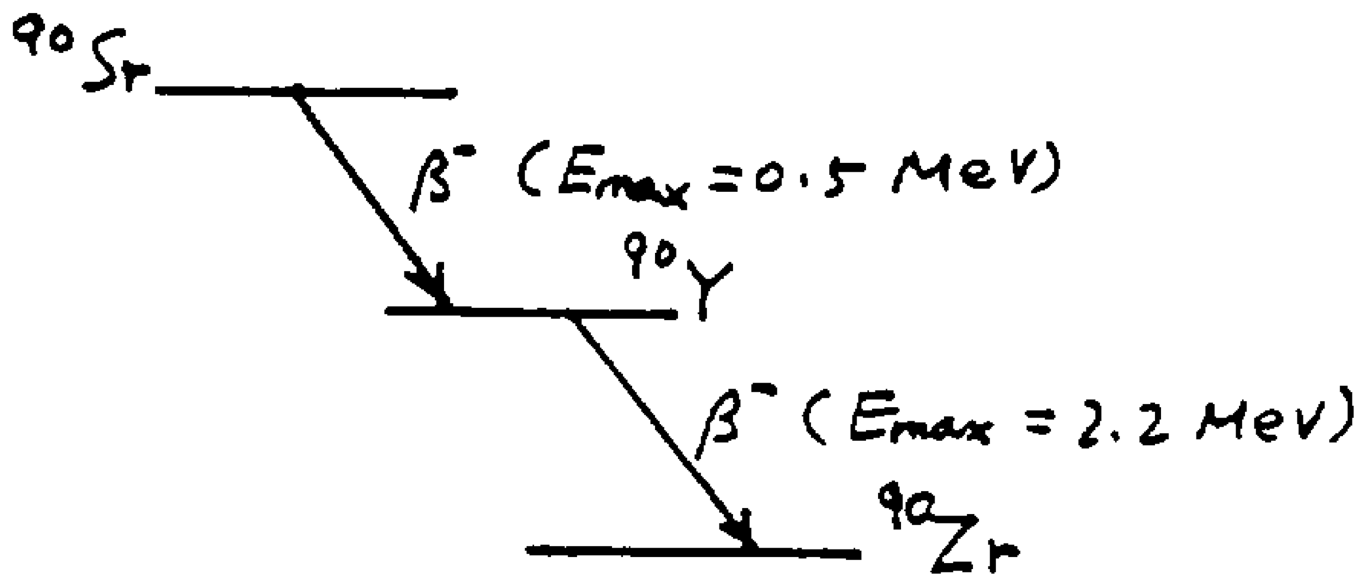
Instructions

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 the 6 questions attached.
4. Staple your question sheet to your answer sheets and turn in.

1. a. Describe the detailed physical, chemical, and biological mechanisms about how ionizing radiation transforms a normal cell into a cancerous form.

   b. Explain why (in terms of the physical, chemical, and biological mechanisms), for the same absorbed dose, neutrons are more effective than gamma rays in causing cancer.

2. In a radiological accident, a significant quantity of ^{90}Sr became airborne, and several workers are believed to have had some intake via inhalation. If you are the health physicist assigned to assess the committed effective dose equivalent ($H_{E,50}$) for each exposed worker, what will be the technical steps involved in your dose assessment?



3. A tissue-equivalent gas proportional chamber (simulating an 8-μm-dia. tissue sphere) recorded the following Gaussian shape for single-event specific energy distribution:

$$f_1(z) = \frac{1}{\sqrt{2\pi z}} e^{-\frac{(z-\bar{z})^2}{2z}}, \qquad \text{where } \bar{z} = 25 \text{ keV}$$

Assume a cell nucleus is an 8-μm-dia. tissue sphere, use the $f_1(z)$ given above to construct the distribution of specific energy $f(z)$ for cell nuclei that have received an absorbed dose of 5 Gy.

4. Graphite (carbon) containing 2 part per million by mass of ^{151}Eu is exposed to a thermal neutron flux of 10^8 n/cm^2-sec for 35 years.

   a. Calculate the activity (Bq/kg) of ^{152}Eu present due to thermal neutron capture in the ^{151}Eu.

   b. What is the dose rate at 1 m from a 10 kg sample of the graphite?

   c. How much lead is required to reduce the dose at 1 meter to 10 μSv/hr?

Data:

$\rho_{graphite}$	$= 1.8\ g/cm^3$
A_{carbon}	$= 12.00$ amu
σ_c (Eu-151)	= 5935b
$T_{1/2}$ (Eu-152)	= 12.7 years
Γ (Eu-152)	$= 2.012\left(10^{-4}\right)\frac{mSv}{hr-MBq}$ at 1 meter
μ_{Pb}	$= 0.831\ cm^{-1}$
Assume B(μt)	= 1 + 0.3·μt for Pb where *t* is the lead thickness

5. ^{213}Bi is created in the decay chain of ^{233}U. ^{213}Bi is an isotope being considered for use in creating compounds that will concentrate in a tumor. If 50 kg of pure ^{233}U was created in 1950, how much ^{213}Bi activity (in Bq) is present in that material in the year 2000? The decay chain and associated information is shown on the following page. **(1 sheet attached.)**

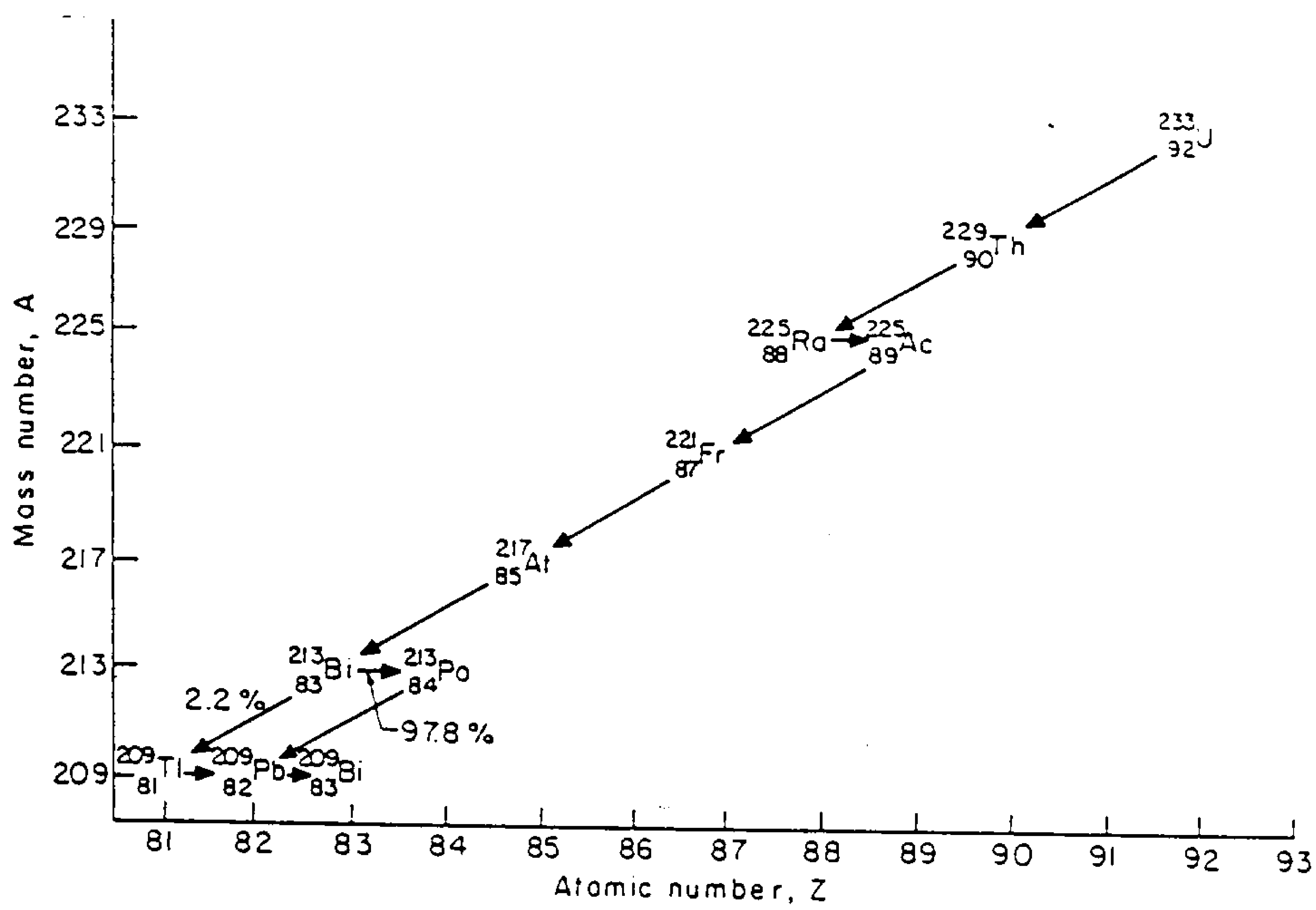


Figure 5.3 Radioactive decay of ^{237}U and ^{233}U.

Table 5.4 Principal radioactive decay products of ^{237}U, ^{237}Np, and ^{233}U

Nuclide	Half-life	Radiation
$^{233}_{92}U$	1.62E5 yr	$\alpha(\gamma)$
$^{229}_{90}Th$	7340 yr	α
$^{225}_{88}Ra$	14.8 days	$\beta(\gamma)$
$^{225}_{89}Ac$	10.0 days	α, γ
$^{221}_{87}Fr$	4.8 min	α, γ
$^{217}_{85}At$	0.032 s	α
$^{213}_{83}Bi^{\dagger}$	47 min	α, β, γ
$^{213}_{84}Po$	4.2 μs	α
$^{209}_{81}Tl$	2.2 min	β, γ
$^{209}_{82}Pb$	3.30 h	β
$^{209}_{83}Bi$	2E18 yr	α

†2.2% of decays of ^{213}Bi go to ^{209}Tl, 97.8% to ^{213}Po.

6. a. What is the effective dose for an individual who received the following exposures:

   1 mGy of alpha to the lung.
   2 mGy of thermal neutrons to the whole body.
   5 mGy of gamma rays to the whole body.
   200 mGy of beta rays to the thyroid.

   b. The annual limit on intake (ALI) for inhalation of ^{32}P is 10^7Bq. What is the committed effective dose per Bq of activity for the radionuclide?

   c. Ingestion of a certain radionuclide results in a committed effective dose of $5.2\ (10^{-5})$ mSv/Bq. What is the ALI?

(Attached page – 2 figures)

TABLE 14.1. Radiation Weighting Factors, w_R, from NCRP Report No. 116

Radiation	w_R
X and γ rays, electrons, positrons, and muons	1
Neutrons, energy <10 keV	5
10 keV to 100 keV	10
>100 keV to 2 MeV	20
>2 MeV to 20 MeV	10
>20 MeV	5
Protons, other than recoil protons and energy >2 MeV	2[a]
Alpha particles, fission fragments, and nonrelativistic heavy nuclei	20

[a] ICRP Publication 60 recommends $w_R = 5$.

TABLE 14.2. Tissue Weighting Factors, w_T

Tissue or Organ	w_T
Gonads	0.20
Bone marrow (red)	0.12
Colon	0.12
Lung	0.12
Stomach	0.12
Bladder	0.05
Breast	0.05
Liver	0.05
Esophagus	0.05
Thyroid	0.05
Skin	0.01
Bone surface	0.01
Remainder	0.05

Note: The data refer to a reference population of equal numbers of both sexes and a wide range of ages. In the definition of effective dose, they apply to workers, to the whole population, and to either sex. The w_T are based on rounded values of the organ's contribution to the total detriment.