

# Nuclear Chemistry Test: Study Guide - Answers

Z, a) Nuclide	Nuclear Charge	Mass Number	Symbol
Alpha particle	+2	4	$\alpha$ or ${}^4_2\text{He}$
$\beta^-$ particle	-1	0	$\beta^-$ or ${}^0_{-1}e$
Positron	+1	0	${}^0_{+1}e$
Gamma ray	0	0	${}^0_0\gamma$
Neutron	0	1	${}^1_0n$

b) Reaction	General Equation
Alpha Decay	${}^A_ZX \rightarrow {}^{A-4}_{Z-2}Y + {}^4_2\text{He}$
$\beta^-$ Decay	${}^A_ZX \rightarrow {}^A_{Z+1}Y + {}^0_{-1}e$
Positron Emission	${}^A_ZX \rightarrow {}^A_{Z-1}Y + {}^0_{+1}e$
Electron Capture	${}^A_ZX + {}^0_{-1}e \rightarrow {}^A_{Z-1}Y$

~~3.~~ ~~3.~~  $C = C_0 e^{-kt} = C_0 e^{-\frac{\ln 2}{t_{1/2}} t}$

At  $t = 24.6$  years,  $C = 0.25 C_0$  (75% has decayed)

$$C = C_0 e^{-\frac{\ln 2}{t_{1/2}} t}$$

$$0.25 C_0 = C_0 e^{-\frac{\ln 2}{t_{1/2}} (24.6)}$$

$$\ln(0.25) = -\frac{\ln 2}{t_{1/2}} (24.6)$$

$$t_{1/2} = 12.3 \text{ years}$$

4.  $t_{1/2} = 8.05 \text{ days}$ ;  $C_0 = 2.4 \text{ mL}$ ;  $C(t) = 1.0 \text{ mL}$ ;  $t = ?$

$$C(t) = C_0 e^{-\frac{\ln 2}{t_{1/2}} t}$$

$$1 = 2.4 e^{-\frac{\ln 2}{8.05} t}$$

$$\ln\left(\frac{1}{2.4}\right) = -\frac{\ln 2}{8.05} t$$

$$t = 10.167 \text{ days}$$

$$= 10 \text{ days, } 4 \text{ hours, } 1 \text{ minute, } 5.7 \text{ seconds}$$

M T W Th F S Su  
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Thursday at 7:01 <sup>pm</sup> and 5.7 seconds

S.	$\text{Cr-60}$	$\text{Cr-45}$	$\text{Cr-44}$	$\text{Cr-52}$
	${}_{24}^{60}\text{Cr}$	${}_{24}^{45}\text{Cr}$	${}_{24}^{44}\text{Cr}$	${}_{24}^{52}\text{Cr}$
$\frac{N}{Z} =$	$\frac{60-24}{24}$	$\frac{45-24}{24}$	$\frac{44-24}{24}$	$\frac{52-24}{24}$
	"	"	"	"
	$\frac{36}{24} = 1.5$	$\frac{21}{24} = 0.875$	$\frac{20}{24} = 0.833$	$\frac{28}{24} = 1.167$

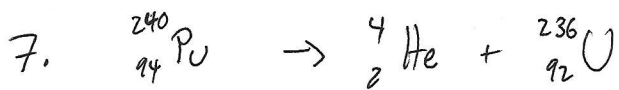
Stable nuclei tend to have  $N/Z$  between 1 + 2.5.

$\beta^-$  decay increases  $Z$  and decreases  $N$ .

Since  $\text{Cr-60}$  has the highest  $N/Z$  ratio, it is most likely to decay by  $\beta^-$  decay.

6. Oxygen-14  $\Rightarrow$   ${}_{8}^{14}\text{O} \Rightarrow \frac{N}{Z} = \frac{14-8}{8} = \frac{6}{8} = 0.75$

$\frac{N}{Z}$  too low. Most likely to decay by  $\alpha$  process that increases  $N$ , decreases  $Z$ , or both: ~~both~~ (prove to yourself that  $\alpha$ -decay won't work)  
 ${}_{+1}^0\text{e}$  emission



$$m({}_{94}^{240}\text{Pu}) = 240.0538 \text{ amu}$$

$$\Delta m = [4.0026 + 236.0456] - [240.0538]$$

$$m({}_2^4\text{He}) = 4.0026 \text{ amu}$$

$$= \del{4.0026} - 0.0056 \text{ amu}$$

$$m({}_{92}^{236}\text{U}) = 236.0456 \text{ amu}$$

$$= -9.299 \times 10^{-30} \text{ kg}$$

$$\Delta E = \Delta mc^2 = (-9.299 \times 10^{-30} \text{ J}) (3 \times 10^8)^2 = -8.3689 \times 10^{-13} \text{ J/rxn}$$

$$= (-8.3689 \times 10^{-13}) \times 10^{-3} / (6.022 \times 10^{23}) = -5.0398 \times 10^8 \text{ kJ/mol rxn}$$

$$= (-5.0398 \times 10^8) / 240.0538 = -2.0994 \times 10^6 \text{ kJ/g } {}_{94}^{240}\text{Pu}$$



$$m({}_{18}^{40}\text{Ca}) = 39.9626$$

$$\Delta m = [5.4858 \times 10^{-4} + 39.9626] - [39.9640]$$

$$m({}_{19}^{40}\text{K}) = 39.9640$$

$$= -0.0008514 \text{ amu}$$

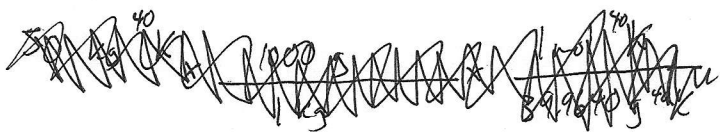
$$m({}_{-1}^0\text{e}) = 5.4858 \times 10^{-4}$$

$$= -1.4138 \times 10^{-30} \text{ kg}$$

$$\Delta E = \Delta mc^2 = -1.2724 \times 10^{-13} \text{ J/rxn}$$

$$= -7.6624 \times 10^7 \text{ kJ/mol rxn}$$

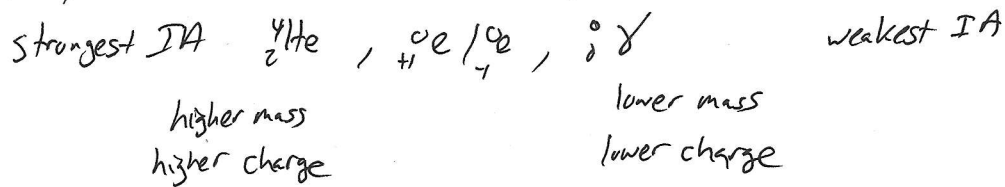
$$= \del{-7.6624 \times 10^7} -1.9173 \times 10^6 \text{ kJ/g } {}_{19}^{40}\text{K}$$



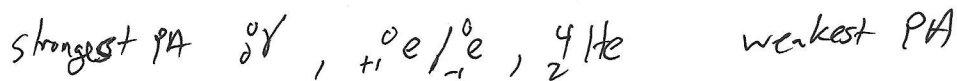
$$50 \text{ kg } {}_{19}^{40}\text{K} \times \frac{1000 \text{ g } {}_{19}^{40}\text{K}}{1 \text{ kg } {}_{19}^{40}\text{K}} \times \frac{-1.9173 \times 10^6 \text{ kJ}}{1 \text{ g } {}_{19}^{40}\text{K}} = -9.5865 \times 10^{10} \text{ kJ}$$

## 9. Factors Determining Toxicity of Radioactive particles (Products of Nuclear Reactors)

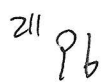
1. Ionizing Ability: the relative ability of a particle to ionize other molecules



2. Penetrating Ability: the relative ability of a particle to penetrate a material



3. Biocompatibility: the similarity of a radioactive, unstable nucleus to other elements in the human body; also related to half-life of nucleus, life-cycle of nucleus in body, organ/tissue which it affects



Time in body:

10 years

40 years

Location in body:

Bones

Liver

Particles emitted:



Half-life:

36 minutes

88 years

Convincing arguments could be made for the relative toxicity of either nuclide.

Good arguments will be specific, comparing each ~~nuclide~~ nuclide based on the four categories listed above. One sentence in a good argument might be:

"Though the half-life of  ${}^{238}_{94}\text{Pu}$  is much longer than that of  ${}^{211}_{82}\text{Pb}$ , the significantly higher ionization activity of  ${}^4_2\text{He}$  compared to  ${}^{-1}_0\text{e}$  makes  ${}^{238}_{94}\text{Pu}$  the more toxic radioactive nucleus."