Nucl Chem Exam
1/21/15

Answer key.

Q1 $\frac{N_1^t}{N_1^0} = e^{-\lambda_1 t}$; $t = T_{1/2} = \frac{\ln 2}{\lambda_1}$; $\frac{N_1^t}{N_1^0} = e^{-\lambda_1\left(\frac{\ln 2}{\lambda_1}\right)} = e^{-\ln 2} = \boxed{\frac{1}{2}}$

Q2 $\frac{N_1^t}{N_1^0} = 0.01 = e^{-\lambda_1 t}$; $\lambda_1 = \frac{\ln 2}{T_{1/2}}$; $0.01 = e^{-\left(\frac{\ln 2}{T_{1/2}}\right)t}$; $\ln 0.01 = -\ln 2\left(\frac{t}{T_{1/2}}\right)$

$t = \frac{-\ln 0.01}{\ln 2} T_{1/2} = \frac{4.605}{0.693} T_{1/2} = \boxed{6.64\ T_{1/2}}$

Q3 $A = \lambda N$ $\lambda = \frac{\ln 2}{T_{1/2}} = \frac{0.693}{14.95\,h} = 0.04635\ hr^{-1}$

$N = \frac{0.114 \times 10^{-9}\,g}{24\,g/mol} \times 6.02 \times 10^{23} \frac{nuclei}{mol} = 2.85 \times 10^{12}$ nuclei

$A = (0.04635\ hr^{-1})(2.85 \times 10^{12}\ nuclei) = \boxed{1.385 \times 10^{11}\ dph}$

or $1.325 \times 10^{11}\ dph \times \frac{1\,h}{3600\,s} = \boxed{3.68 \times 10^{7}\ dps}$

Q4 specific activity $= \frac{A}{\text{total weight}} = \frac{1.325 \times 10^{11}\ dph}{\text{total weight}}$

total weight = moles $(MW_{Na} + MW_{Cl})$

$mol = \frac{0.114 \times 10^{-9}\,g}{24\,g/mol} = 4.75 \times 10^{-12}$ mol.

total weight $= 4.75 \times 10^{-12}\,mol\,(24\,g/mol + 35.5\,g/mol)$

$= 2.82 \times 10^{-10}\,g$

Specific activity $= \frac{1.325 \times 10^{11}\ dph}{2.82 \times 10^{-10}\,g} = \boxed{4.68 \times 10^{20} \frac{dph}{g}}$

$= \boxed{1.302 \times 10^{20} \frac{dps}{kg}}$

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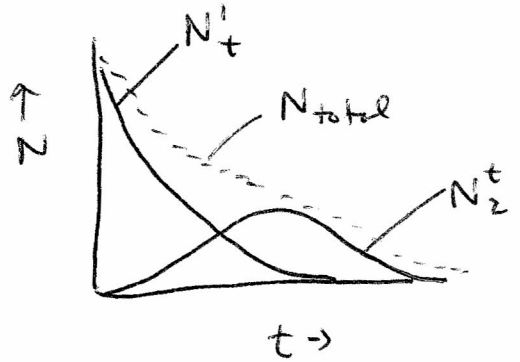
Answer Key

Q5



Q6 $N_1^t = N_1^\circ$ when $e^{-\lambda_1 t} = 1$, $\boxed{t=0}$

Q7 assuming $N_2^\circ = 0$ and $\lambda_1 >> \lambda_2$

$$N_2^t = \frac{\lambda_1}{\lambda_1} - N_1^\circ\left(e^{-\lambda_1 t} - e^{-\lambda_2 t}\right)$$

$$\frac{dN_2^t}{dt} = 0 = \frac{d\left(N_1^\circ\left(e^{-\lambda_1 t} - e^{-\lambda_2 t}\right)\right)}{dt} = N_1^\circ\left[\frac{d\left(e^{-\lambda_1 t}\right)}{dt} - \frac{d\left(e^{-\lambda_2 t}\right)}{dt}\right]$$

$$0 = -\lambda_1 e^{-\lambda_1 t} + \lambda_2 e^{-\lambda_2 t}$$

$$+\lambda_1 e^{-\lambda_1 t} = \lambda_2 e^{-\lambda_2 t}$$

$$\ln \frac{\lambda_1}{\lambda_2} = e^{(-\lambda_2 t + \lambda_1 t)} \qquad \ln \frac{\lambda_1}{\lambda_2} = (-\lambda_2 + \lambda_1)t$$

$$\boxed{t = \frac{\ln \lambda_1/\lambda_2}{(\lambda_1 - \lambda_2)}}$$

Q8 $N_1 t = N_1^\circ e^{-\lambda_1 t} = N_2^t = -N_1^\circ\left(e^{-\lambda_1 t} - e^{-\lambda_2 t}\right)$

$$-1 = \frac{\left[e^{-\lambda_1 t} - e^{-\lambda_2 t}\right]}{e^{-\lambda_1 t}} = \frac{e^{-\lambda_1 t}}{e^{-\lambda_1 t}} - \frac{e^{-\lambda_2 t}}{e^{-\lambda_1 t}}$$

$$+2 = + \frac{e^{-\lambda_2 t}}{e^{-\lambda_1 t}}$$

$$2e^{-\lambda_1 t} = e^{-\lambda_2 t}$$

$$\ln 2 + (-\lambda_1 t) = -\lambda_2 t$$

$$\ln 2 = t(\lambda_1 - \lambda_2) \qquad \boxed{t = \frac{\ln 2}{(\lambda_1 - \lambda_2)}}$$

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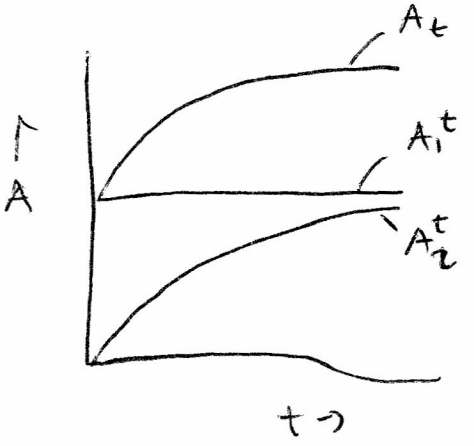
Answer Key

Q9



Q10 $N_1^t = N_1^0$ when $e^{-\lambda_1 t} = 1$, $\boxed{t=0}$

Q11 assuming $N_2^0 = 0$ and $\lambda_2 >> \lambda_1$

$$N_2^t = \frac{\lambda_1}{\lambda_2} N_1^0 \left(e^{-\lambda_1 t} - e^{-\lambda_2 t}\right)$$

$\frac{dN_2^t}{dt} = 0$ at long t (asymptotically approaches max.)

$$0 = \frac{d\, e^{-\lambda_1 t}}{dt} - \frac{d\, e^{-\lambda_2 t}}{dt}$$

$$= -\lambda_1 e^{-\lambda_1 t} + \lambda_2 e^{-\lambda_2 t}$$

$$\ln \frac{\lambda_1}{\lambda_2} = e^{(-\lambda_2 t + \lambda_1 t)}$$ when $\lambda_2 >> \lambda_1$, $\ln(0) \rightarrow$ error

Q12 assume $N_2^0 = 0$ and $\lambda_2 >> \lambda_1$

$$A_1^t = \lambda_1 N_1^t = A_2^t = \lambda_2 N_2^t = \frac{\lambda_2 \lambda_1}{(\lambda_2 - \lambda_1)} N_1^0 \left(e^{-\lambda_1 t} - e^{-\lambda_2 t}\right)$$

$$N_1^t = \frac{\lambda_2}{(\lambda_2 - \lambda_1)} N_1^0 \left(e^{-\lambda_1 t} - e^{-\lambda_2 t}\right)$$

$$N_1^t = N_1^0 \left(e^{-\lambda_1 t} - e^{-\lambda_2 t}\right)$$ ($e^{-\lambda_2 t} \rightarrow 0$)

$N_1^t = N_1^0 e^{-\lambda_1 t}$ ✓ for long t.

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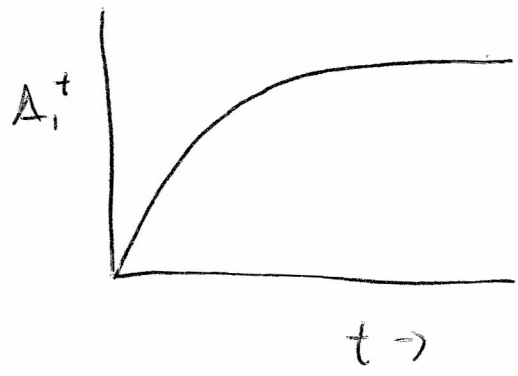
Answer Key

Q 13



Q14

$A_1^t{}_{max} = R(1 - e^{-\lambda_1 t})$ and for long t $e^{-\lambda_1 t} \to 0$

for long t $A_1^t{}_{max} = R$

for $t = 3T_{1/2}$ $e^{-\lambda_1 t} = e^{-\lambda_1 (3) \ln 2/\lambda_1} = e^{-3\ln 2}$

$= 0.125$

A_1^t @ $t = 3T_{1/2} = R(1 - 0.125)$

$\boxed{= 0.85\,R}$

have 85% of max activity.

Q15 at end of irradiation

$N_1^t = N_1^{max}(e^{-\lambda_1 t})$

$\frac{N_1^t}{N_1^{max}} = 0.01 = e^{-\lambda_1 t}$

$\ln(0.01) = -\lambda_1 t$

$-4.605 = -t\left(\frac{\ln(2)}{T_{1/2}}\right)$

$\frac{4.605}{\ln(2)}(T_{1/2}) = t = \boxed{6.64\,T_{1/2}}$