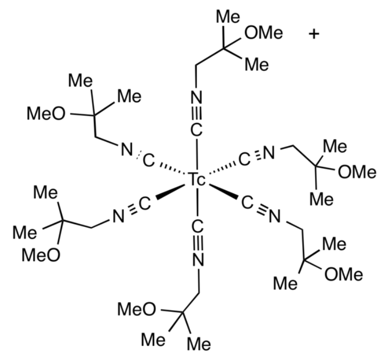
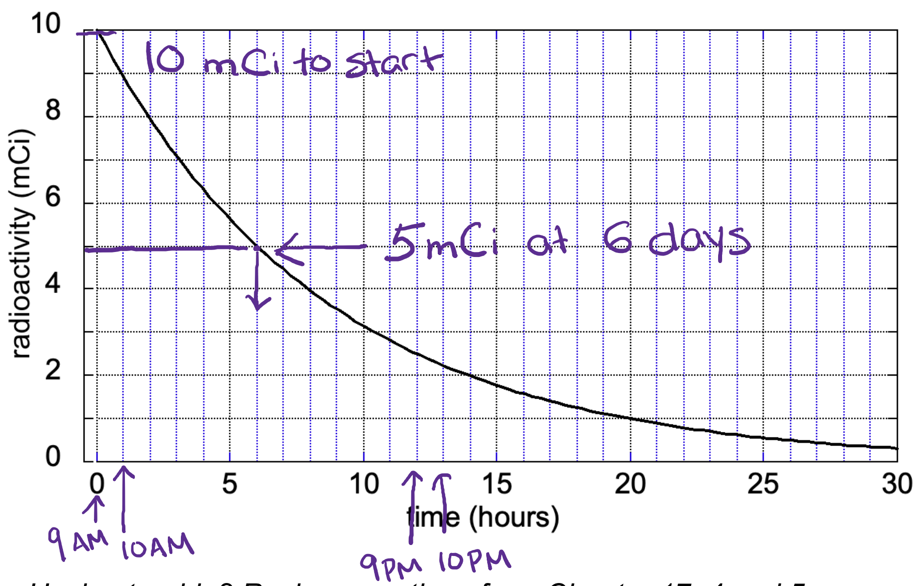
What are the kinetics of radioactive treatments?

For those interested, Chapter 20 of your book covers Nuclear Chemistry in more detail but it is not necessary to answer these questions!

A. The radioimaging agent Cardiolite (see structure at right) is widely used for cardiac stress tests. A typical patient dose is on the order of 10 milliCuries (mCi), which works out to less than 2 ng of technetium metal. You dose your patient with 10 mCi at 9 AM on Monday and monitor how radioactive they are until Tuesday at noon. From the data below, what is the average rate of Tc radioactive decay between 9 AM and 10 AM on Monday? What is the average rate of decay between 9 PM and 10 PM on Monday? (Two significant figures are fine here.)





Having trouble? Review questions from Chapter 17: 4 and 5.

at 9 AM ($t = 0h$), 10.0 mCi

at 10 AM ($t = 1h$), 9.0 mCi

$$\text{average rate} = \frac{10.0\,\text{mCi} - 9.0\,\text{mCi}}{1h} = 1.0\ \text{mCi/h}$$

at 9 PM ($t = 12h$), 2.5 mCi

at 10 PM ($t = 13h$), 2.2 mCi

$$\text{average rate} = \frac{2.5\,\text{mCi} - 2.2\,\text{mCi}}{1h} = 0.3\ \text{mCi/h}$$

B. Radioactive decays are first order reactions. Use the data above to determine the half-life for radioactive decay of Tc.

Having trouble? Review questions from Chapter 17: 36, 37, 38, and 39.

radioactivity decreases from 10 mCi to 5 mCi in 6 hours

so $t_{1/2}$ = 6 hours

C. How did you use these data to determine your answer? Based on part B, write the rate law and determine the rate constant for the radioactive decay of Tc.

Having trouble? Review questions from Chapter 17: 32, 36, 37, 38, and 39.

I read the radioactivity at t=0 and determined when the radioactivity was 1/2 that value

for first order, $k = 0.693/t_{1/2} = 0.693/6h = 0.116 h^{-1}$

so rate law = $k[^*Tc] = 0.116 h^{-1} [^*Tc]$

(using *Tc to designate radioactive Tc)

D. Use your rate law and rate constant to calculate the initial rate of radioactive decay you'd predict for that patient you dosed with 10 mCi of radioactivity on Monday morning at 9 AM. How does your number compare to the average rate you estimated in part A from 9 AM to 10 AM? Explain the similarity or difference.

Having trouble? Review questions from Chapter 17: 46, 47, and 48.

initial rate = $0.116\ h^{-1}$ (10 mCi) = 1.16 mCi/h

This value is just a little bit larger/faster than the average rate between 0 and 1 hour. That's what we would expect because this reaction slows down as it goes and the initial rate (the instantaneous rate at t=0) is the fastest it will ever be.

E. Suppose that hospital policy says your patient can be discharged when only 0.1 mCi of radiation remains. How many hours after the original dose will that be true? (You can assume no excretion.)

Having trouble? Review questions from Chapter 17: 41 and 45.

$$\ln \frac{[A]_t}{[A]_0} = -kt$$

$$\ln \frac{0.1\ mCi}{10\ mCi} = -(0.116 h^{-1})(t)$$

$$-4.60517 = -0.116\ h^{-1}\ (t)$$

$$t = 40\ h^{-1}$$

note: you could make a close guess by

t=0	10 mCi
6h	5 mCi
12h	2.5 mCi
18h	1.25 mCi
24h	0.625 mCi
30h	0.3125 mCi
36h	0.1563 mCi
42h	0.0781 mCi

← somewhere between these times