Nuclear Physics

Set 7: Half Life

7.1	(a)	22 hours
	(b)	since ½ have decayed, then there will be ½ unchanged
	(c)	44 hours is two half lives and in this time ¾ of the atoms will have decayed
7.2	(a)	half life is the time taken for 500 MBq to become 250 MBq = 6 hours
	(b)	after each half life: 500 → 250 → 125 → 62.5 → 31.1 → 15.65 → 7.83 → 3.9 → 1.95 (approximately 2) This is eight half lives = 8 x 6 hrs = 48 hours
7.3		The sample becomes a sixteenth of its original value after four half lives = 4 x 30 yrs = 120 years
7.4		number of half lives elapsed $= \dfrac{42.9 \text{ days}}{14.3 \text{ days}} = 3$ half lives after three half lives there will be(2^{-3}) = ⅛ of the original sample remaining and therefore ⅛ the original activity, so the new activity = ⅛ x 2.4 MBq = 0.3 MBq (or 300 kBq)
7.5	(a)	after each half life: 2048 → 1024 → 512 → 256 → 128 = four half lives 4 x $t_{½}$ = 150 mins, then half life, $t_{½} = \dfrac{150 \text{ minutes}}{4} = 3.75$ minutes
	(b)	Each half life, a half of the original number of atoms decay into other products by emitting either alpha particles, beta particles or gamma rays (or a combination of them). This occurs because the original atoms are unstable and randomly and spontaneously decay in an attempt to become more stable.
7.6	(a)	After 24 hrs, it has gone through two half lives and therefore decayed into ¼ of its original amount. Therefore, in order for a sample with an activity of 800 kBq to be injected, the technician would need to prepare a sample with an activity 4 x 800 kBq = 3200 kBq (or 3.2 MBq)
	(b)	24 hrs after injection, it has gone through two half lives and therefore decayed into ¼ of its original amount. So the new activity = ¼ x 800 kBq = 200 kBq
7.7	(a)	A half will decay in one half life so atoms decaying = ½ x 1 x 10^{24} = 5.0 x 10^{23}
	(b)	Activity, A = λ x N $\lambda = \dfrac{\ln(2)}{t_{½}} = \dfrac{0.693}{2.41 \times 10^{4}\text{ y}} = 2.88 \times 10^{-5}\text{ y}^{-1}$ so $A = 2.88 \times 10^{-5}\text{ y}^{-1} \times 1 \times 10^{24} = 2.9 \times 10^{-19}$ Bq
	(c)	${}^{239}_{94}\text{Pu} \rightarrow {}^{239-4=235}_{94-2=92}\text{U} + {}^{4}_{2}\text{He}$
7.8	(a)	$\dfrac{A}{A_0} = 0.5^{n}$

		where n is the number of half lives which have elapsed = $\left(\frac{t}{t_{½}}\right)$ and A_o is the original activity so the new activity, $A = 0.5^{\left(\frac{26\ y}{5.3\ y}\right)} x\ 800\ GBq = 26.8\ GBq$
	(b)	to reduce to $\frac{1}{1000}$ of original value requires n half-lives such that $(0.5)^n = \frac{1}{1000}$ as $2^{10} = 1024$ then n is approximately equal to 10 10 half-lives is 10 x 5.3 = 53 years "safe" in approximately (2008 + 53) = 2061 (or 6th decade of 21st century)
7.9		At the point where they have the same number of undecayed atoms X is decaying faster (half will have decayed in 8 seconds) and has the higher activity. (Activity is measured as the number of disintegrations per second.)
7.10	(a)	$\frac{A}{A_0} = 0.5^n$ so the new activity, $A = 0.5^{\left(\frac{7\ d}{2.7\ d}\right)} x\ 8\ \ MBq = 1.33\ MBq$
	(b)	$^{198}_{79}Au \rightarrow ^{228-0=198}_{79-(-1)=80}Hg + ^{0}_{-1}e$
7.11		The fact that the ratio of carbon-12 to carbon-14 is the same in the atmosphere and in the new bone is an indication that the living animal is continuously absorbing carbon from the atmosphere. When the bone is dead, no interchange occurs and because carbon-14 is radioactive, the amount of it slowly declines (due to decay).
7.12		12.5% is ⅛of the original sample which accounts for three half lives. So, three half lives = 3 x 5730 y = 17 190 years
7.13	(a)	The value of the half life will vary depending on the graph plot, but take at least three readings from the graph to estimate an average value. It should be about 20±2 minutes.
	(b)	It must be a beta particle since aluminium would absorb virtually all alpha particles and gamma rays would pass through the foil almost unaffected. Sine some particles emerge and there is a noticeable change, only beta particles are possible.
7.14	(a)	$^{24}_{12}Mg + ^{1}_{0}n \rightarrow ^{24}_{11}Na + ^{24+1-24=1}_{12-11=1}p$ or $^{1}_{1}H$ $^{24}_{11}Na \rightarrow ^{24-0=24}_{11-(-1)=12}Mg + ^{0}_{-1}e + ^{0}_{0}\gamma$
	(b)	if 90% has decayed, then 10% remains, so $\frac{A}{A_0} = 0.5^n = 0.10$ then $n = \frac{\ln(0.10)}{\ln(0.5)} = 3.32$ Since n = $n = \frac{t}{t_{½}}$ then $t = n\ x\ t_{½} = 3.32\ x\ 15\ h = 49.8$ hours

7.15	(a)	Radon undergoes $\frac{20\text{ days}}{4\text{ days}} = 5\text{ half lives}$ During 5 x $t_{½}$, there will be ($\frac{1}{32}$) of the original radon remaining so the new activity, A = $\frac{1}{32}$ x 3.8 kBq = 0.12 kBq (or 120 Bq)
	(b)	Both are alpha emitters so once ingested or absorbed could cause significant cell damage through ionisation. The blood organs would particularly be affected and harmed. However, since the half life of polonium is only 3 minutes, it will decay and effectively disappear within hours, so this would be less harmful than radon which has a relatively much larger half life and will therefore hang about longer.
7.16		if 95% has decayed, then 5% remains, so $\frac{A}{A_0} = 0.5^n = 0.05$ then $n = \frac{\ln(0.05)}{\ln(0.5)} = 4.32$ Since n = $n = \frac{t}{t_{½}}$ then t = n x $t_{½}$ = 4.32 x 28.9 y = 125 years
7.17	(a)	Since the activity of 50 g is 200 min^{-1}, then 1 g would have an activity $A = \frac{200}{50} = 4\text{ min}^{-1}$ $\frac{A}{A_0} = 0.5^n$ so $\frac{A}{A_0} = \frac{4\text{ min}^{-1}}{15\text{ min}^{-1}} = 0.267 = 0.5^n$ then $n = \frac{\ln(0.267)}{\ln(0.5)} = 1.91$ Since $n = \frac{t}{t_{½}}$ then $t = n \times t_{½} = 1.91 \times 5730\text{ y} = 10\,940\text{ y}$
	(b)	This value assumes that the ration of carbon-12 to carbon-14 in living things, being the same as the ratio in the earth's atmosphere, has remained constant over a very long period of time.
7.18	(a)	Artificially produced radioisotopes, being man-made, which decay very quickly have not had the opportunity to influence nature, something that has become established over millions of years.
	(b)	Naturally occurring radioisotopes however have adapted to the environment and have been absorbed into many of nature's resources, perhaps producing products which themselves have longer half lives.