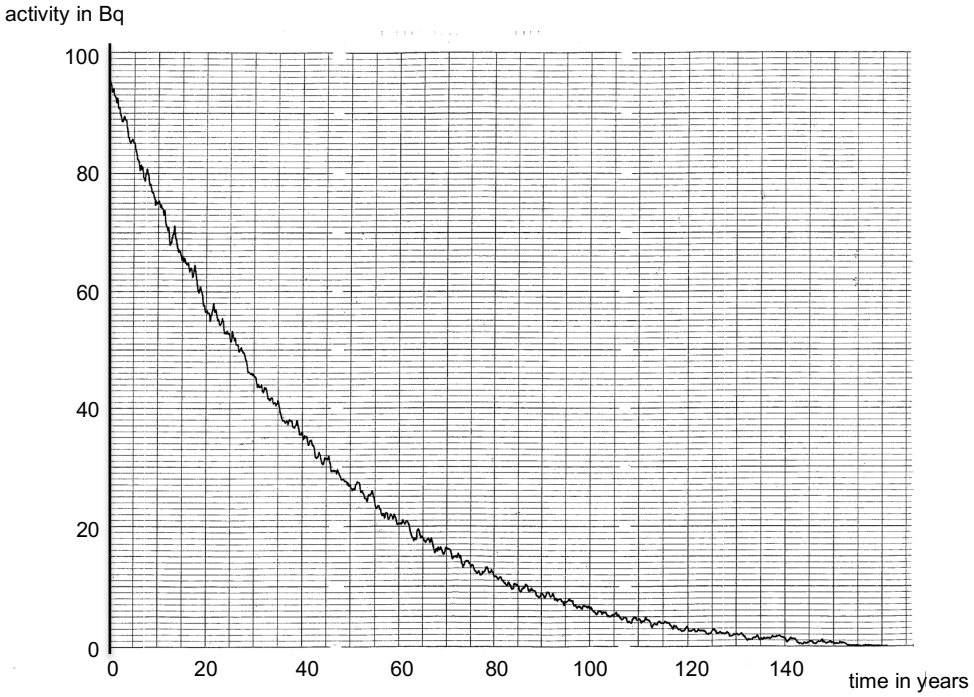
1. The graph shows how the activity of a radioactive sample changes over time.
a) Why is the curve jagged and not even?
b) Determine the half-life. Draw the values used for answering the question in the diagram.



2. A radioactive sample contains $6.24 \cdot 10^{16}$ Caesium-137 nuclides ($T_{1/2}$ = 30.17 years).
a) What is the decay constant?
b) Calculate the activity.
c) Calculate the activity after 4.89 years.
d) How long does it take until $2.75 \cdot 10^{14}$ nuclei have decayed?

3. In a radioactive sample of Uranium-238, each minute 1'000 nuclides decay.
a) How many nuclides are in the sample?
b) Calculate the mass of the sample.

4. A Cu-64 sample is produced and then sealed. Cu-64 is radioactive and its half life is 12.8 h. After 20.0 days the activity is 20.0 Bq.
Determine the number of nuclei that were present initially.

5. A live plant absorbs carbon from the air (air contains CO_2). The stable C-12, as well as the radioactive C-14 is built into the plant, at the same ratio as it is present in the air. After the plant's death no more carbon is absorbed. The amount of C-12 remains constant, while the amount of C-14 decreases, as it decays. 1.00 g of a live plant shows 15.3 C-14 decays per second.
An old piece of wood containing 2.00 g of carbon, shows an activity (from C-14) of 0.250 Bq.
a) How many C-14-atoms are in the piece of wood?
b) How many years ago has the piece of wood died?

6. Radium-226 is used in medicine for the treatment of cancer. It emits gamma rays.
How long does the radium waste need to be stored until the activity is reduced to 10 % of its inital value?

Selected radioactive nuclides

m_a	atomic mass (in u)
$T_{1/2}$	half life (a = year, d = day, h = hour, min = minute, s = second)
decay mode	α-, β-, γ-decay, ε electron capture; • decay *not* accompanied by γ-decay
energy	for β-decay energies maximum value; emissions < 2%of total omitted

nuclide	m_a	$T_{1/2}$		decay mode	energies (MeV)
n	1.008 664 915 7	613.9	s	β^- •	0.7824
H-3	3.016 049	12.32	a	β^- •	0.0186
Be-10	10.013 534	$1.51 \cdot 10^6$	a	β^- •	0.5558
C-14	14.003 242	$5.70 \cdot 10^3$	a	β^- •	0.1565
Na-22	21.994 436	2.6019	a	$\beta^+ \varepsilon$ •	β^+: 0.545 / γ: 1.275
Na-24	23.990 963	14.9590	h	$\beta^- \gamma$	β^-: 1.393 / γ: 1.369; 2.754
P-32	31.973 907	14.263	d	β^- •	1.710
Ar-41	40.964 501	109.61	min	$\beta^- \gamma$	β^-: 1.198 / γ: 1.293 (99%)
K-40	39.963 998	$1.261 \cdot 10^9$	a	$\beta^+ \varepsilon \beta^- \gamma$	β^-: 1.311 / γ: 1.460 (11%)
Fe-55	54.938 293	2.737	a	ε	
Co-60	59.933 817	5.2713	a	$\beta^- \gamma$	β^-: 0.318 / γ: 1.173; 1.332
Kr-85	84.912 527	10.776	a	$\beta^- \gamma$	β^-: 0.687
Rb-87	86.909 181	$4.923 \cdot 10^{10}$	a	β^- •	0.283
Sr-89	88.907 451	50.53	d	$\beta^- \gamma$	β^-: 1.495
Sr-90	89.907 738	28.79	a	β^- •	0.546
Tc-99 m	98.906 255	6.015	h	γ	0.140 (90%)
Ag-108	107.905 956	2.37	min	$\beta^+ \varepsilon \beta^-$	β^-: 1.649
Ag-110	109.906 107	24.6	s	$\beta^- \gamma$	β^-: 2.89 / γ: 0.658 (4.5%)
I-128	127.905 809	24.99	min	$\beta^+ \varepsilon \beta^- \gamma$	β^-: 2.12 / γ: 0.443 (13%)
I-131	130.906 125	8.02070	d	$\beta^- \gamma$	β^-: 0.606 / γ: 0.364 (82%); complex
Xe-135	134.907 227	9.14	h	$\beta^- \gamma$	β^-: 0.90 / γ: 0.250 (90%); 0.608 (3%)
Cs-137	136.907 090	30.1671	a	$\beta^- \gamma$	β^-: 1.176 (6%); 0.514 (94%) / γ: 0.662
Au-198	197.968 242	2.69517	d	$\beta^- \gamma$	β^-: 0.961 / γ: 0.412 (96%) (85%)
Pb-210	209.984 189	22.20	a	$\alpha \ \varepsilon \ \gamma$	β^-: 0.064 / γ: 0.047 (4%)
Bi-208	207.979 742	$3.68 \cdot 10^5$	a	$\varepsilon \ \gamma$	γ: 2.614
Bi-210	209.984 120	5.012	d	$\alpha \ \beta^-$	β^-: 1.162
Po-210	209.982 874	138.376	d	$\alpha \ \gamma$	α: 5.304
Rn-220	220.011 394	55.6	s	$\alpha \ \gamma$	α: 6.29
Rn-222	222.017 578	3.8235	d	$\alpha \ \gamma$	α: 5.49
Ra-226	226.025 410	$1.600 \cdot 10^3$	a	$\alpha \ \gamma$	α: 4.78 (94%); 4.60 (6%) / GRS* complex
Ac-227	227.027 752	21.772	a	$\alpha \ \beta^- \gamma$	β^-: 0.045
Th-230	230.033 134	$7.538 \cdot 10^4$	a	$\alpha \ \gamma$	α: 4.69 (76%); 4.62 (24%)
Th-232	232.038 055	$1.405 \cdot 10^{10}$	a	$\alpha \ \gamma$	α: 4.01 (78%); 3.95 (22%)
Pa-231	231.035 884	$3.276 \cdot 10^4$	a	$\alpha \ \gamma$	α: 5.0 (80%); 4.73 (8%) / GRS* complex
U-233	233.039 635	$1.592 \cdot 10^5$	a	$\alpha \ \gamma$	α: 4.82 (84%); 4.78 (13%) / GRS* complex
U-234	234.040 952	$2.455 \cdot 10^5$	a	$\alpha \ \gamma$	α: 4.77 (71%); 4.72 (28%) / GRS* complex
U-235	235.043 930	$7.04 \cdot 10^8$	a	$\alpha \ \gamma$	α: 4.58 (9%), 4.4 (75%) / GRS* complex
U-238	238.050 788	$4.468 \cdot 10^9$	a	$\alpha \ \gamma$	α: 4.20 (79%); 4.15 (21%)
U-239	239.054 293	23.45	min	$\beta^- \gamma$	β^-: 1.19 / γ: 0.044 (4%); 0.075 (49%)
Np-239	239.052 939	2.356	d	$\beta^- \gamma$	β^-: 0.330 (42%); 0.436 (45%) / GRS* complex
Pu-239	239.052 163	$2.411 \cdot 10^4$	a	$\alpha \ \gamma$	α: 5.16 (71%); 5.14 (17%) / GRS* complex
Am-241	241.056 829	432.2	a	$\alpha \ \gamma$	α: 5.49 (85%); 5.44 (13%) / GRS* complex

* GRS: γ-ray spectrum

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solutions:

1. b) 30 a
2. a) $7.23 \cdot 10^{-10}$ s^{-1} b) $4.55 \cdot 10^7$ Bq c) $4.07 \cdot 10^7$ Bq d) 70.2 days
3. a) $3.39 \cdot 10^{18}$ nuclei b) 1.34 mg
4. $2.59 \cdot 10^{17}$ nuclei
5. a) $6.48 \cdot 10^{10}$ nuclei b) $3.95 \cdot 10^4$ a
6. $5.3 \cdot 10^3$ a