Chapter 1 Nuclear physics and radioactivity

1.1 Atoms, isotopes and radioisotopes

1 a 20 protons, 25 neutrons, 45 nucleons
b 79 protons, 118 neutrons, 197 nucleons
c 92 protons, 143 neutrons, 235 nucleons
d 90 protons, 140 neutrons, 230 nucleons
2 a 27 protons, 33 neutrons **b** 94 protons, 145 neutrons
c 6 protons, 8 neutrons
3 A radioisotope is an unstable isotope. At some time, it will spontaneously eject radiation in the form of alpha particles, beta particles or gamma rays from the nucleus. Three isotopes that are not radioisotopes could be any three stable isotopes, e.g. carbon-12, lead-206 and bismuth-209.
4 Yes, a natural isotope can be radioactive. For example, every isotope of uranium is radioactive.
5 Polonium-210 and uranium-238. These have atomic numbers of 84 and 92 respectively; and every isotope beyond bismuth ($Z = 83$) in the periodic table is radioactive.
6 a 88 protons, 138 neutrons, 226 nucleons
b 88 protons, 140 neutrons, 228 nucleons
c Ra-228 is slightly denser.
7 1.1×10^{-13} **8** 210 m
9 a There are no differences.
b ^{89}Kr has 5 more neutrons in its nucleus.
10 ^{28}Al

1.2 Radioactivity and how it is detected

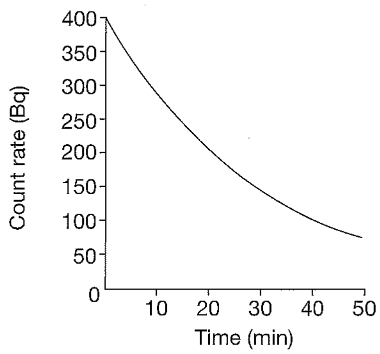
1 a the nucleus **b** the nucleus **c** the nucleus
2 α is a helium nucleus, β is an electron, γ is electromagnetic radiation.
3 a beta particle **b** proton **c** alpha particle **d** neutron
4 a $Z = 82$, $A = 214$, lead **b** $Z = 90$, $A = 231$, thorium
c $Z = 89$, $A = 228$, actinium **d** $Z = 80$, $A = 198$, mercury
5 a α **b** β^- **c** β^- **d** α **e** γ **6** lithium-7
7 a proton **b** neutron **c** neutron **d** alpha particle
8 a 7 protons, 7 neutrons, 1 electron, 1 antineutrino
b A neutron has decayed. **c** $^{1}_{0}\text{n} \rightarrow ^{1}_{1}\text{p} + ^{0}_{-1}\text{e} + \overline{\nu}$
d Kinetic energy carried by the beta particle, antineutrino and nitrogen-14 nucleus.
9 a ^{40}Ca, ^{42}Ca, ^{43}Ca, ^{44}Ca, ^{46}Ca, ^{48}Ca **b** one **c** beta
d $^{48}_{19}\text{K} \rightarrow ^{48}_{20}\text{Ca} + ^{0}_{-1}\beta$, $^{48}_{20}$Ca is stable
e K: 1.53, Ca: 1.40 **f** alpha emitter
g $^{217}_{87}\text{Fr} \rightarrow ^{213}_{85}\text{At} + ^{4}_{2}\alpha \rightarrow ^{209}_{83}\text{Bi} + ^{4}_{2}\alpha$; bismuth-209 is stable
10 a $^{197}_{79}\text{Au} + ^{1}_{0}\text{n} \rightarrow ^{198}_{79}\text{Au}$ **b** $^{198}_{79}\text{Au} \rightarrow ^{198}_{80}\text{Hg} + ^{0}_{-1}\beta$

1.3 Properties of alpha, beta and gamma radiation

1 a α, β, γ **b** γ, β, α **2** B
3 Gamma radiation is most suitable since its penetrating ability will enable it to reach the tumour.
4 A beta emitter would be best suited because its penetrating ability would enable it to irradiate a small volume of tissue around the source. Alpha radiation would not penetrate the tumour at all, and gamma radiation would pass out of the body irradiating some healthy cells along the way.
5 a 5.3×10^{7} eV **b** 4.0×10^{8} eV **c** 2.9×10^{8} eV
6 a 1.4×10^{-12} J **b** 6.7×10^{-14} J **c** 8.0×10^{-14} J
7 a 3.4×10^{6} eV **b** 1.65 cm
8 D **9** A **10** D

1.4 Half-life and activity of radioisotopes

1 C **2 a** 10 g **b** 5 g **c** 2.5 g **d** 0.31 g
3 a



b ~235 Bq **c** 20 min **d** 50 Bq **4** 15 min **5** 0.5
6 192 μg **7 a** 10 half-lives **b** ~240 000 years
8 a uranium-235 **b** It has a much shorter half-life than uranium-238 and so has decayed much more rapidly since the formation of the Earth.
9 a From the activity graph, the time that the activity takes to halve from 800 Bq to 400 Bq is 10 minutes. This is the half-life. **b** 50 Bq
10 a Over time, the radioisotopes transmute by a series of decays to form lead-206, which is stable. The percentage of lead in the sample will increase over time.
b ^{214}Po has such a short half-life (160 μs) that when ^{214}Bi nuclei decay to ^{214}Po, they almost instantaneously transmute to ^{210}Pb.