9 On 11 March 2011, Japan suffered a Magnitude 9.0 Earthquake off the eastern coast of Japan. One of the consequences of the Earthquake was a tsunami that crippled the Fukushima Daiichi nuclear power plant, which subsequently released significant amounts of radioactive materials and by-products into the atmosphere and environment.

Tables 9.1 and 9.2 show the surface activities of several radionuclides measured on 31 March 2011 from soil samples at several locations in and around the Fukushima district, their half-lives and decay modes.

	Surface Activity (Bq m^{-2})					
Location	Tellurium-129m	Tellurium-132 / Iodine-132	Iodine-131	Caesium-134	Caesium-137	Barium-140 / Lanthanum-140
A	208 370	111 960	824 150	205 260	211 480	8 397
B	388 600	195 640	1 163 120	477 040	479 720	22 244
C	754 920	382 120	1 887 300	894 720	922 680	35 416
D	71 928	35 478	481 140	77 031	78 489	2 527

Table 9.1 Surface Activities of Radionuclides

Radio-nuclide	Tellurium-129m	Tellurium-132	Iodine-132	Iodine-131	Caesium-134	Caesium-137	Barium-140	Lanthanum-140
Half-life (Days)	33.6	3.20	2.30	8.02	755	11 000	12.8	1.68
Decay Constant (s^{-1})	2.39×10^{-7}	2.51×10^{-6}	3.49×10^{-6}		1.06×10^{-8}	7.29×10^{-10}	6.27×10^{-7}	4.78×10^{-6}
Decay Mode	γ	β^-	β^-	β^-	β^-	β^-	β^-	β^-

Table 9.2 Half-lives and Decay Modes of Radionuclides

34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8
52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3
84 Po polonium –	85 At astatine –	86 Rn radon –

Notations

A: Mass/Nucleon Number

Z: Atomic/Proton Number

X: Chemical Symbol

Chemical Name

Relative Atomic Mass

Example of Nuclide Representation: ${}^{A}_{Z}X$

Fig. 9.1   Elements Around Iodine on the Periodic Table

(a) Using the data from **Table 9.1**, **Table 9.2** and **Fig. 9.1**,

(i) calculate A_β, the total activity per m^2 due to beta decay, of the most contaminated location.

A_β = ... Bq m^{-2} [1]

(ii) for the location C,

1. calculate the decay constant of Iodine-131,

decay constant = ... s^{-1} [1]

2. calculate N_i, the number of Iodine-131 nuclei present per m^2,

N_i = ... [2]

3. calculate M_i, the mass of Iodine-131 nuclei present per m^2,

M_i = ... kg [1]

4. calculate $A_{T,i}$, the total activity present due to Iodine-131 in 7.5 km^2 of the location.

A_i = ... Bq [1]

(v) write down the decay equation for:

1. Tellurium-129m

....
[1]

2. Tellurium-132

....
[1]

(b) Explain why after 16.1 days, another sample taken at the same location had significantly more than a quarter of the original activity due to Iodine-131.

....

....

....

....

....

....
[2]

(c) Among the radioactive fallout, Iodine-131 and Caesium-137 are major concerns as both elements can be absorbed by the human body through inhalation as well as through the consumption of contaminated food and water.

(i) Even though the activity of Iodine-131 is significantly greater than that of Caesium-137 in all locations tested, Caesium-137 will present a greater hazard in the long term. Explain why this is so.

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....
[2]

(ii) Iodine is absorbed by the body and accumulates in the thyroid. Explain why Iodine-131 is dangerous when ingested.

....

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....

....
[2]

(iii) Suggest why the consumption of potassium iodide pills before Iodine-131 exposure may help reduce the chances of irreparable damage to the thyroid or contracting thyroid cancer.

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[2]

(d) Radioactive materials are often considered dangerous due to its high energy output with a relatively small mass and its hazardous nature to living things.

(i) By considering the decay constants of the radioactive materials listed that undergoes beta decay, suggest and explain which material could be the most dangerous.

....

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....
[2]

(ii) Suggest and explain another physical factor that contributes to the dangers of radioactive material.

....

....

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.... [2]

[Total: 20]

End of Paper