Source term

Small reactors offer significant safety advantages, such as:

Reduced fission product inventory (source term)

After this lecture you will be able to:

- **Discuss the origin of the source term**

Source term

- Severe accidents happen - they are not ”hypothetical”
- Defence in depth strategy to be applied for mitigation.
- Fission product release known to dominate dose to public following failure of barriers and containment functions in nuclear power plants
- ”Source term” consists of highly active, mainly short-lived, nuclides with high propensity for release:
  - Noble gases (Xe, Kr)
  - Volatiles

Volatiles

	T_{boil}	Fission yield
Te	988°C	0.03/fission
I	184°C	0.02/fission
Cs	671°C	0.20/fission

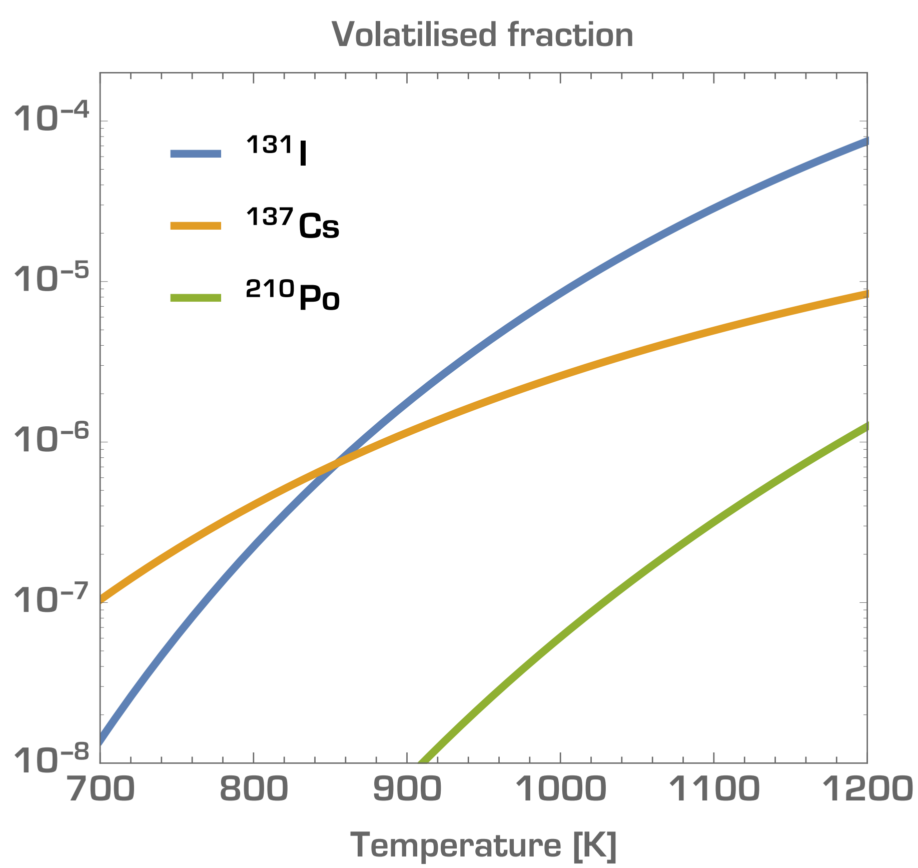
Iodine may be bound to Cs as CsI in the fuel
T_{boil} [CsI] = 1280°C

- What is the temperature of the fuel during a release scenario?

Source term:
Release from cover gas into environment

- In the UK, the radiological consequences of the source term determines the size of the emergency planning zone.
- Failure of barriers for release:
  - Cladding/TRISO coating
  - Primary vessel
  - Containment
- Leakage from cladding is rapid, due to internal pressure.
- Leakage from vessel is rapid in PWRs (high pressure), slower in LFRs.
- Leakage from containment is slower (1% per day assumed for LWRs)

Retention of fission products in lead coolant



- Lead forms compounds with Caesium (Zintl compounds) and Iodine (PbI_2) having much lower vapour pressure than the pure **volatile** elements.
- If volatiles are released from the fuel into the coolant, an equilibrium of concentrations in the coolant and cover gas will be established.
- Volatilised fraction in the cover gas is temperature dependent.

Dose coefficient

A quantity that, when multiplied by a measurement of radionuclide intake, air [kerma], particle [fluence], or environmental radioactivity concentration, will yield an organ equivalent dose or the effective dose to the exposed individual. Sometimes referred to as dose conversion coefficient or factor. **Dose conversion coefficient: A coefficient relating a dose quantity to a physical quantity, both for internal and external radiation exposure. In internal dosimetry, this term is also called a dose coefficient

Nuclide	ε
Sr-90	30 [nSv/Bq]
Te-132	3 [nSv/Bq]
I-131	20 [nSv/Bq]
I-133	4 [nSv/Bq]
Xe-133	0.1 [nSv/d/[Bq/m³]]
Xe-135	1 [nSv/d/[Bq/m³]]
Cs-137	13 [nSv/Bq]
Ba-140	2 [nSv/Bq]

- The dose coefficient (Sv/Bq) is averaged over tissues and exposure time. It is dependent on age, gender and body-size.
- Tabulated values are often given for a 20 year old average person, assuming an integrated dose exposure time of 50 years (ε_{50}).
- For volatiles: inhalation dose coefficients ≈ ingestion dose coefficients
- For noble gases "Cloud shine" is the dominating contribution to exposure. Dose coefficients are in the unit of Sv/d/(Bq/m³).

The equivalent doses in an organ or tissue is given by:

$$H_T = \sum_R w_R D_{R,T}$$

where $D_{R,T}$ is the mean absorbed dose from radiation R in a tissue or organ T, and w_R is the radiation weighting factor. The SI unit of equivalent dose is joule per kilogram (J kg^{-1}), and its special name is sievert (Sv).

Effective dose is calculated as:

$$E = \sum_T w_T \cdot \left[\frac{H_T^M + H_T^F}{2}\right]$$

where H_T^M and H_F^M are the equivalent doses to the tissues or organs r_T of the Reference Adult Male and the Reference Adult Female, respectively and w_T is the tissue weighting factor for target tissue T, with $\sum_T w_T = 1$.

Effective dose is a weighted average of equivalent doses to organs/tissues. The averaging is performed over all organs and tissues of the human body for which radiation detriment can be quantified and for which w_T values are assigned.

As w_R and w_T are dimensionless, the SI unit for effective dose is the same as for absorbed dose J kg^{-1} and its special name is sievert (Sv).

Fission product inventory

- EoL inventory in the SEALER-55 core (average burn-up: 60 GWd/ton)

SEALER-55 fission product inventory

Nuclide	Mass [g]	Activity [PBq]	Half-life	Dose coefficient
Sr-90	1 530	79	29 y	30 [nSv/Bq]
Te-132	17,0	195	78 h	3 [nSv/Bq]
I-131	31,1	143	8 d	20 [nSv/Bq]
I-133	6,7	281	21 h	4 [nSv/Bq]
Xe-133	41,1	285	5 d	0.1 [nSv/d/[Bq/m^3]]
Xe-135	3,1	289	9h	1 [nSv/d/[Bq/m^3]]
Cs-137	32 400	104	30 y	13 [nSv/Bq]
Ba-140	89,6	242	13 d	2 [nSv/Bq]