Part 1: The Branching Fraction

We must determine the probability that an inhaled atom will decay *inside* the lung rather than being cleared biologically.

1. Calculate Decay Constants (λ) The decay constant is defined as $\lambda = \ln(2) / T_{half}$.

- **Physical Constant:** $\lambda_{phys} = 0.693 / 138.4$ days $= 0.00501$ / day
- **Biological Constant:** $\lambda_{bio} = 0.693 / 50$ days $= 0.01386$ / day

2. Calculate the Fraction of Decays (F_{decay}) The fraction of atoms that decay in the lung is the ratio of the physical decay rate to the total removal rate.

$F_{decay} = \lambda_{phys} / (\lambda_{phys} + \lambda_{bio})$

$F_{decay} = 0.00501 / (0.00501 + 0.01386)$

$F_{decay} = 0.265$

Only **26.5%** of the Polonium trapped in the lungs actually emits radiation there, the remaining ~73.5% is cleared by the body before it can decay.

Part 2: Source Term Estimation

1. Daily Activity Inhaled (1 pCi = 0.037 Bq).

A_{daily} = (30 cigs) * (0.516 pCi) * (0.037 Bq/pCi) * 0.50 * A_{daily} = 0.286 Bq/day

2. Convert Activity to Number of Atoms (N_{daily})

- T_{phys} (in seconds) = 138.4 * 86,400 = 11,957,760 s
- λ_{phys} (in seconds) = 5.795×10^{-8} / s

$N_{daily} = 0.286 / (5.795 \times 10^{-8})$ $N_{daily} = 4.935 \times 10^{6}$ atoms/day

1. **Total Atoms Deposited in 1 Year (N_{total})**

   $N_{total} = (4.935 \times 10^{6})$ * 365 days

   $N_{total} = 1.801 \times 10^{9}$ atoms

Part 3: Energy Deposition

We calculate the energy only for the fraction of atoms that actually decay (F_{decay}).

$E_{total} = N_{total} * F_{decay} * E_{alpha}$

$E_{total} = (1.801 \times 10^{9}) * 0.265 * 5.307$ MeV

$E_{total} = 2.53 \times 10^{9}$ MeV

Convert to Joules (1 MeV = 1.602×10^{-13} J):

E_total (J) = (2.53 x 10^9) * (1.602 x 10^-13)

E_total (J) = 4.05 x 10^-4 J

Part 4: Dose Calculation

1. Absorbed Dose (D) Using the specific mass of the bronchial epithelium (0.02 kg).

D = Energy (J) / Mass (kg)

D = (4.05 x 10^-4) / 0.02

D = 20.2 mGy

2. Dose Equivalent (H)

Adjusting for radiation type (Alpha particles, w_R = 20).

H = D * w_R

H = 404 mSv

3. Effective Dose (E)

Adjusting for tissue sensitivity (w_T = 0.12).

E = H * w_T

E = 48.5 mSv