Radon Management Throughout the Life Cycle of an Underground Mine

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Properties of Radon

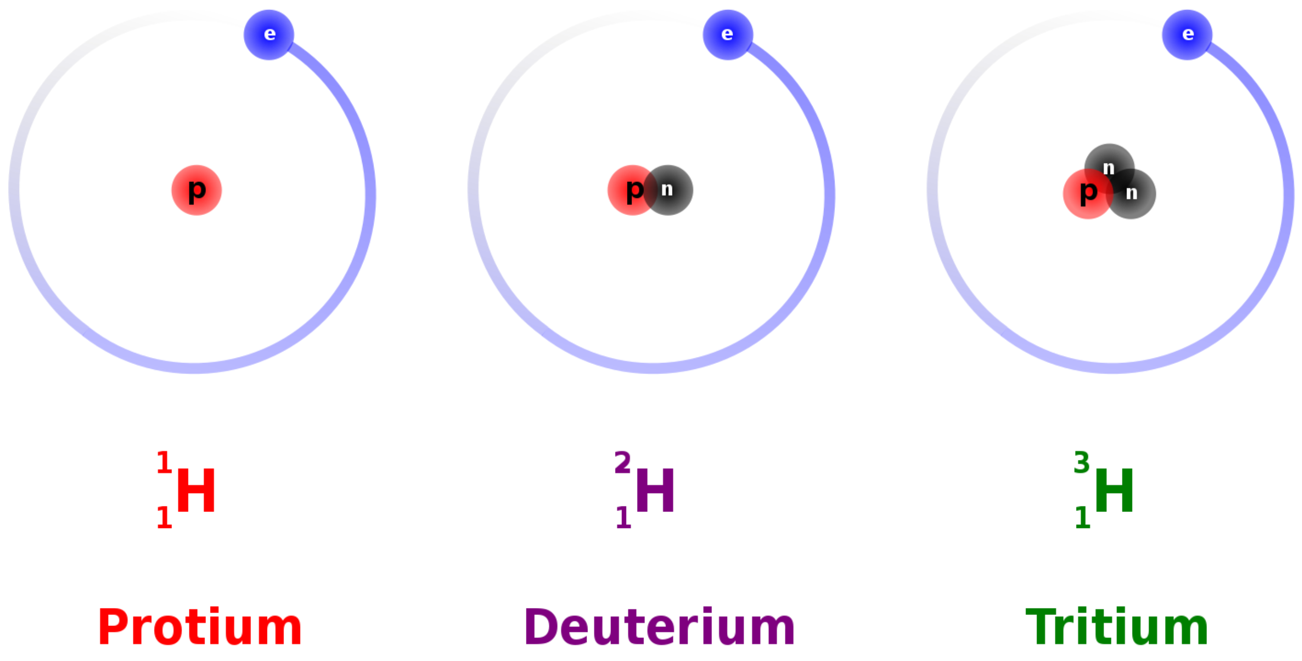
- Radon is a naturally occurring, ubiquitous gas produced through the radioactive decay of uranium
- Toxic gas; lung carcinogen
- A noble gas with atomic number 86 (Group VIIIA/18)
- Chemically inert; oxidation potential of zero
- Four naturally occurring isotopes; all of which are radioactive

Nuclear Chemistry 101

- Matter is comprised of atoms
- Atoms are comprised of a nucleus (containing protons and neutrons of equal mass) and orbiting electrons (no mass)
- Protons have a charge of +1; electrons have a charge of -1; neutrons have no charge
- Protons and electrons remain in balance; number of neutrons can vary
- Number of protons represents the atomic number; radon has an atomic number of 86
- Number of protons and neutrons represents the atomic mass
- Isotopes are the various configurations of atomic nuclei in combination with various numbers of isotopes

Nuclear Chemistry 101

- Example – hydrogen has an atomic number of 1
- Three naturally occurring isotopes with corresponding atomic masses of 1, 2 and 3



Nuclear Chemistry 101

- As atomic mass increases, nuclei become more complex and they tend to build up more energy

- Some isotopes become predictably unstable (radioactive isotopes or radioisotopes) and start to emit subatomic particles (radioactive decay), resulting in a different isotope or atom (‘daughters’ or progeny)

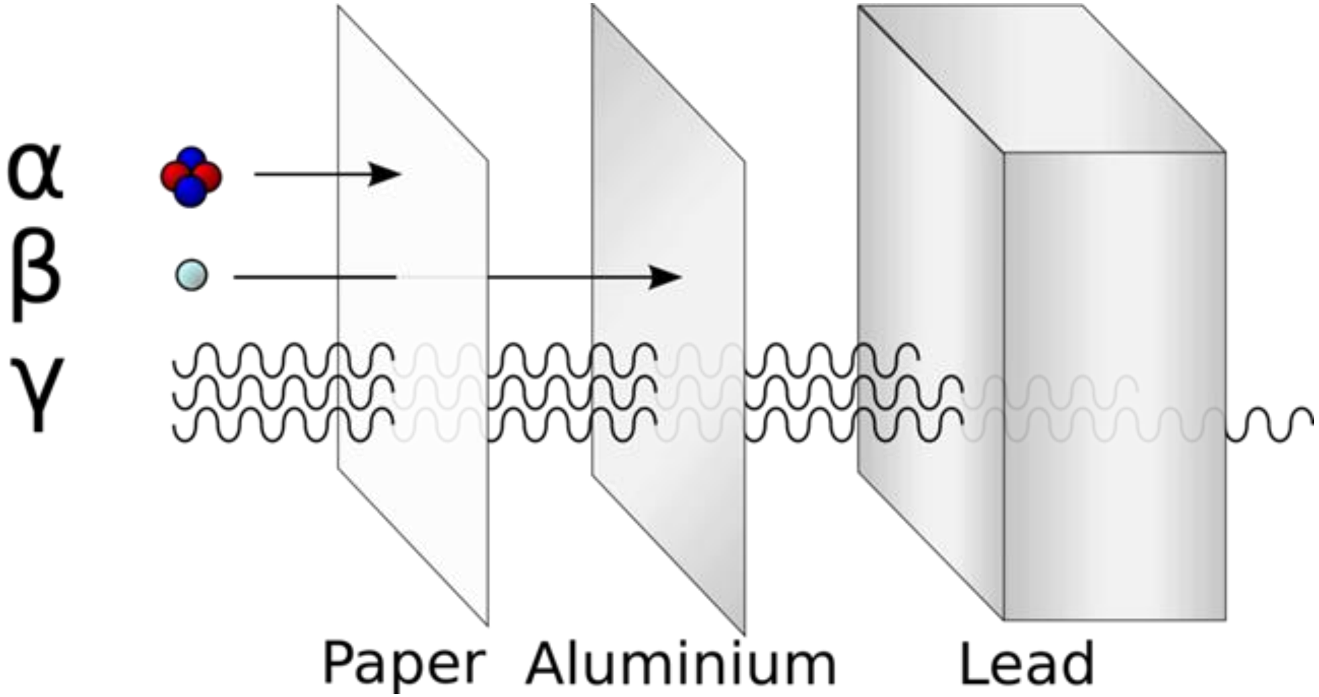
- Emitted particles (radiation) have varying levels of energy

- The rate of decay of any given radioisotope is predictable and is measured in terms of half-life (duration required for the decay of 50% of the isotopes)

- Half-lives can vary from billions of years to milliseconds

Radiation

- Radiation from an isotope is in one of three forms:
  - alpha particle – consists of two protons and two neutrons
  - beta particle – an electron
  - gamma particle – a high energy photon



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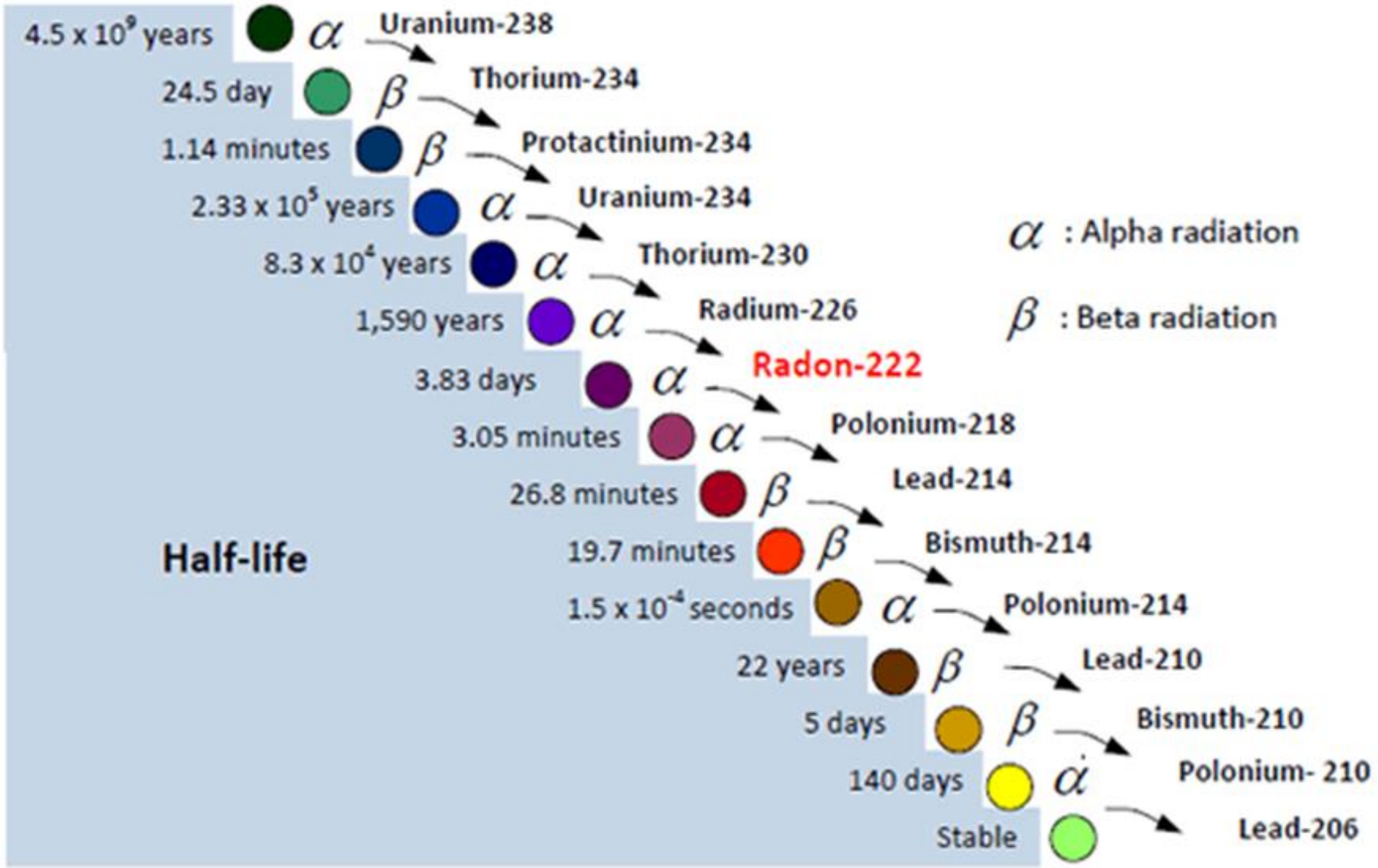
Radon Formation

- Radon formation is one step in the decay chain of naturally occurring uranium-238 isotope (99.2% abundance)



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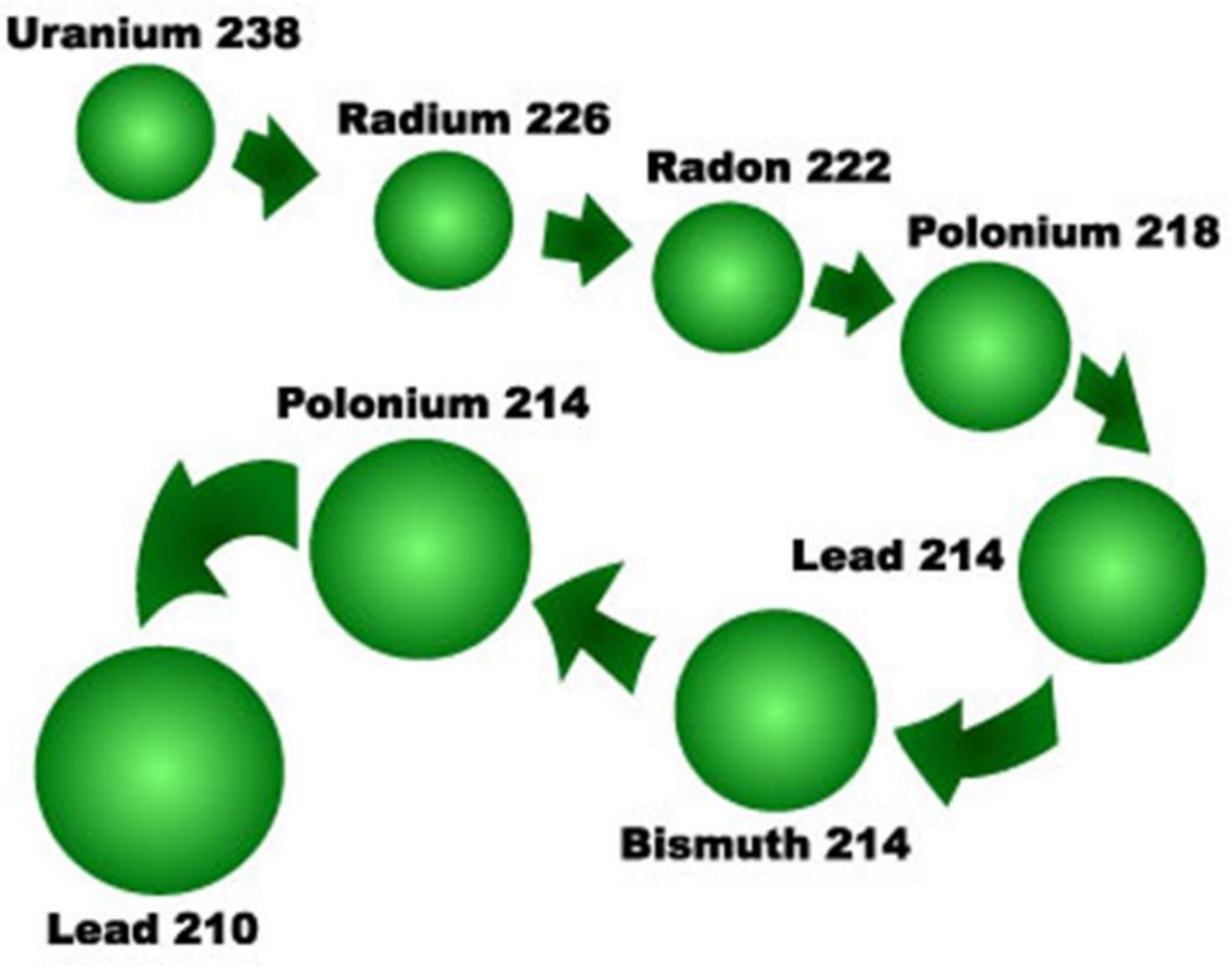
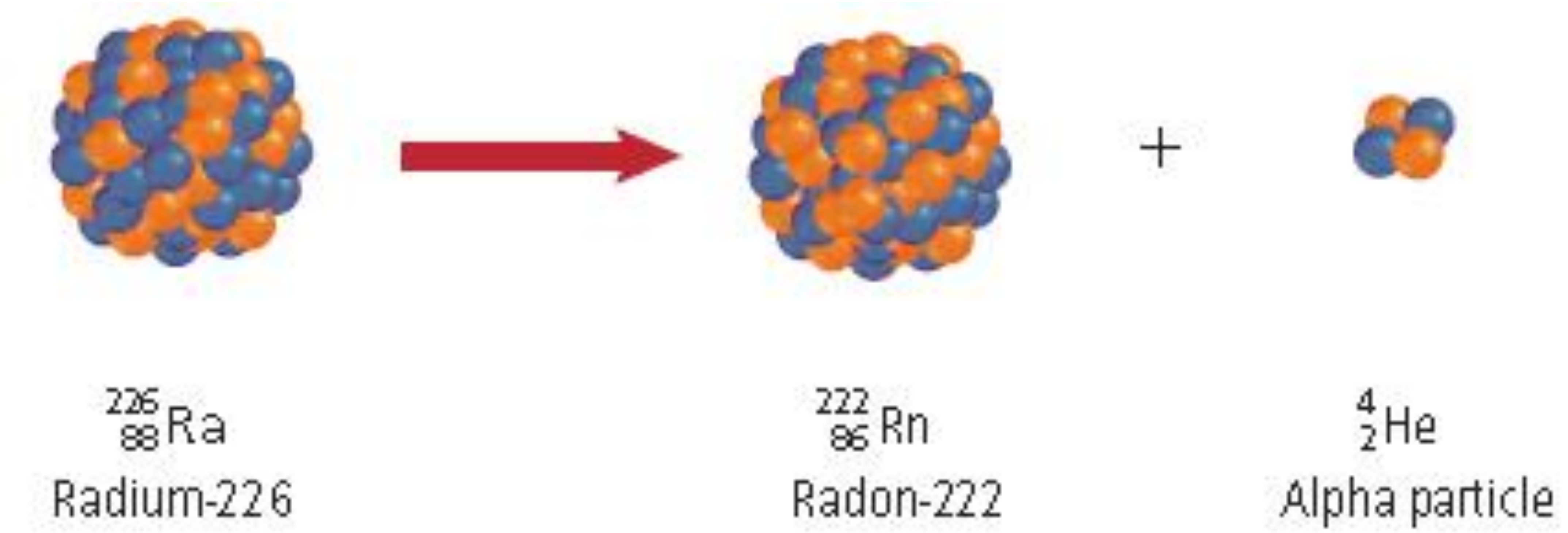
Radon Formation

- The half-lives of the precursor isotopes in the uranium-238 decay chain from uranium to radium are predominantly measured in thousands to billions of years.



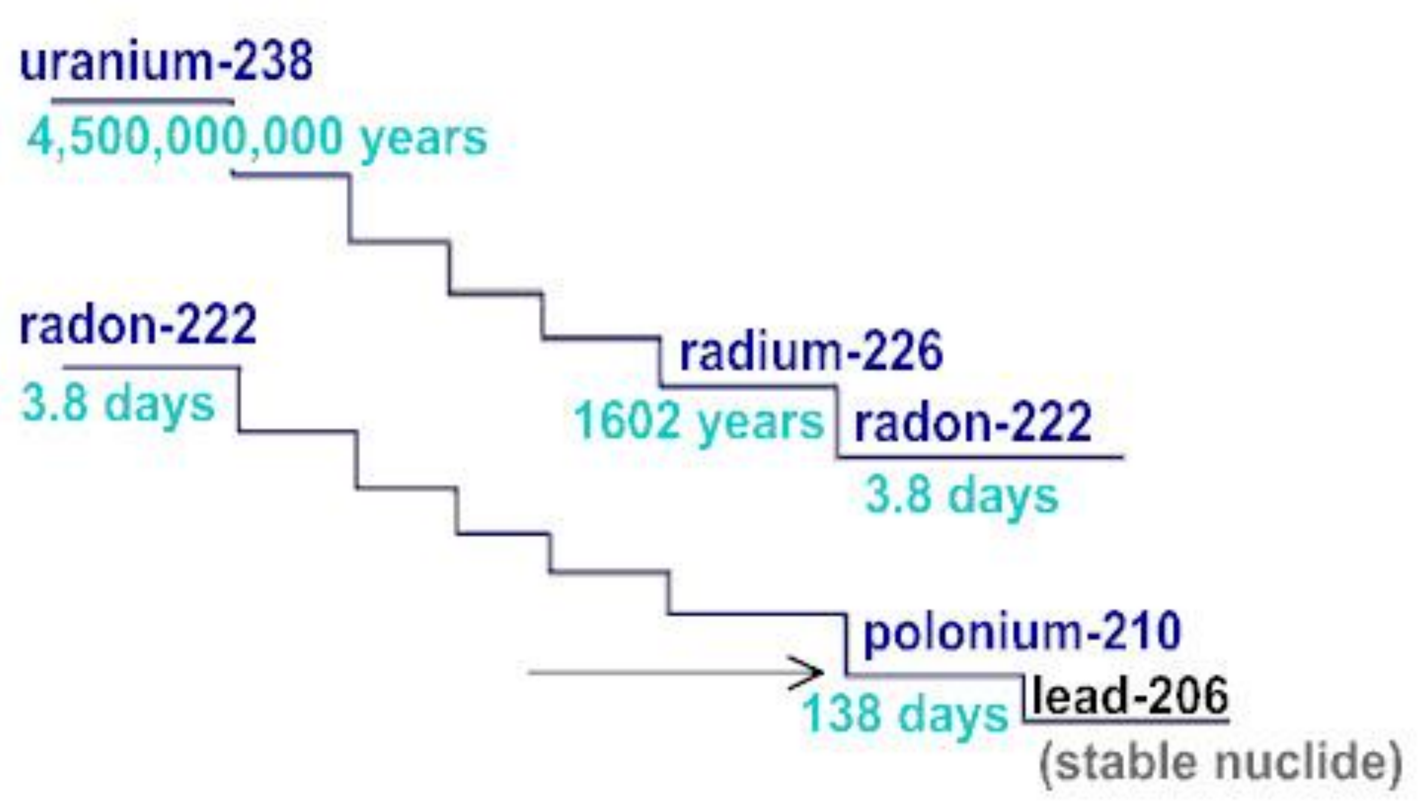
Radon Formation

- When radium decays into radon, it produces an alpha particle



Radon Formation

- The decay chain from radon-222 to polonium-210 is a series of short half-lives measured predominately in days, producing alpha and beta radiation



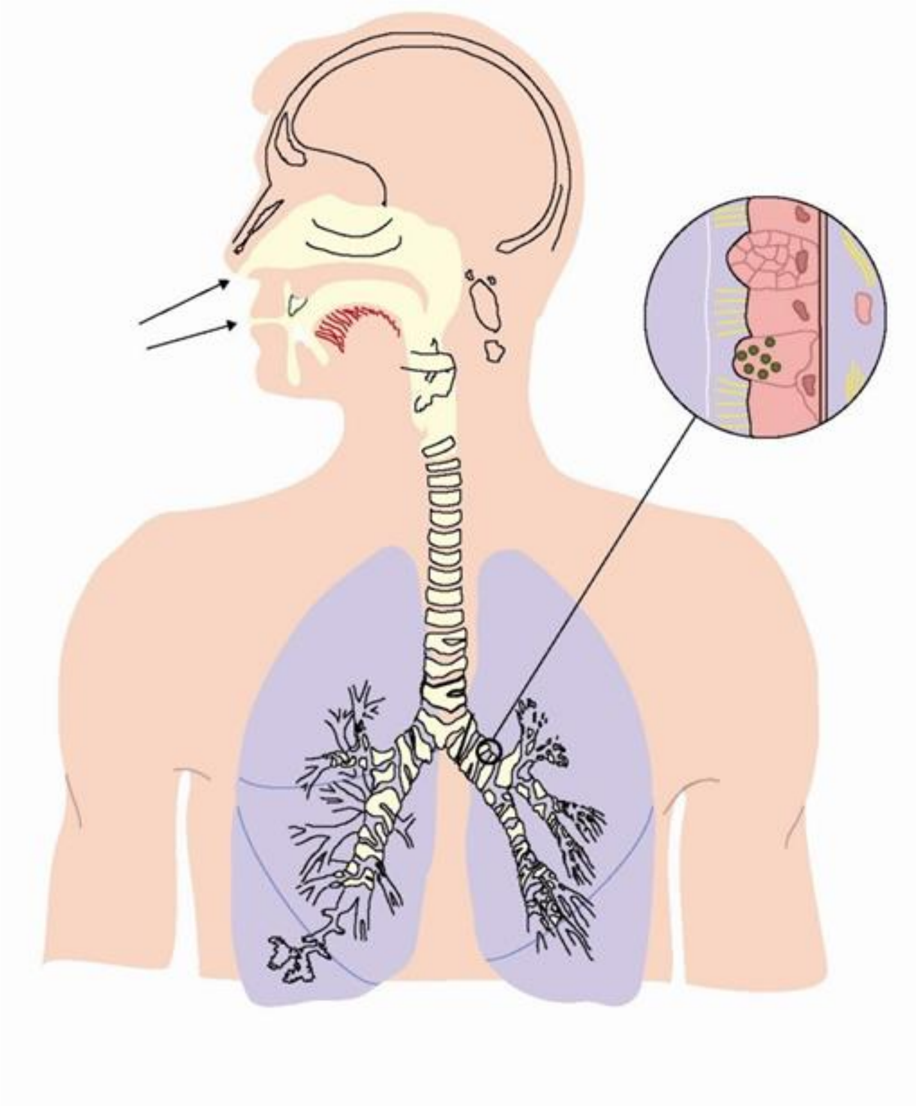
Radon Toxicity

- The relatively short half-life decay chain from radon-222 to polonium-210 produces alpha and beta particles, and a chemical phase change from gas to solid

- The solid progeny of radon (lead, polonium and bismuth) are attracted to dust particles and then inhaled as both free particles as well as adhered to dust particles

Radon Toxicity

- Particles deposit on the surface of the lung, which then undergo decay to produce alpha radiation at a rapid pace while in direct contact with lung tissue



Radon Toxicity

- Alpha radiation damages the genetic material of the cells lining the respiratory tract, leading to cancer
- Preferential deposit is in the bronchi, where successive transformations of the progeny produces several times the radiation produced by the initial decay of radon
- No associated acute symptomatology or irritancy
- Additional chronic health effects include emphysema, chronic pneumonia and pulmonary fibrosis
- Synergistic effect with cigarette smoke

Factors Affecting Radon Emission Levels Underground

- Concentration of uranium in ore body
- Geological formations
- Water flow and accumulation
- Barometric pressure and air flow
- Mine layout, complexity and evolution
- Blasting

Radon Exposure Assessment

- Radon and radon progeny levels underground can vary significantly over time and space
- Exposure assessment requirements under O. Reg. 854/90
- Requires ‘off-the-shelf’ capacity for real time measurements
- Grab sampling
  - Short term integrative particulate sampling followed by field scintillation counter assessment of progeny alpha radiation
  - CNSC Guide G-4 – *Measuring Airborne Radon Progeny at Uranium Mines and Mills*

Controls

- Ventilation
  - Parallel versus series ventilation
  - Strategic use of auxiliary ventilation
  - Changing air delivery requirements

- Mining practices
  - Underground ore storage and handling
  - Location of ore transfer points relative to fresh air intakes/raises
  - Number of working faces

Respiratory Protection

- Air purifying respirators with P100 will provide protection from exposure to radon progeny but not radon gas

- Must consider periods of usage versus non-usage

- NIOSH respirator ‘credit’ formula

Respiratory Protection

NIOSH Credit for Respirator Use

$$P_t = 1/CF = t_w/APF + t_n$$

Where: P_t is total penetration of radon progeny
APF is the assigned protection factor of the respirator
CF is the respirator credit factor
P_w penetration of radon progeny while wearing the respirator
t_w is the fraction of time respirator is worn (0 to 1)

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Key Summary Points

- Radon never sleeps

- Radon levels are in constant flux

- Radon levels are subject to numerous factors and change as the mine evolves

- Radon levels can increase dramatically as the underground mine moves toward closure

References

NIOSH (1987). *A Recommended Standard for Occupational Exposures to Radon Progeny in Underground Mines.*

CNSC (2003). *Regulatory Guide G-4 – Measuring Airborne Radon Progeny at Uranium Mines and Mills (under revision).*

Agency for Toxic Substances and Disease Registry (ASTDR, 2010). *Case Studies in Environmental Medicine – Radon Toxicity.*

RADON GAS