Research Notes - Xenon-133

What to submit:

1. Works Cited in APA Format
2. Infographic - (Canva)
3. Research Notes (Current File)

Note

Chosen Isotope: Xenon-133 (Medical Purposes)

Important

Criterion:

- A brief description of what your isotope is used for
- The % abundance of your isotope (try to explain how the % abundance was determined by showing a calculation, a graph, or some other data...)
- How stable is your isotope? Is it prone to undergo radioactive decay? Why or Why not? If it decays, what is the half-life?
- Explain how your isotope works (e.g. if it is a medical isotope - how does it fight against cancer?)
- What positive impacts does your isotope have on the human body/environment/an industrial process?
- What negative impacts does your isotope have on the environment or human health?
- Any other pertinent information about your isotope that you think relates to our unit?

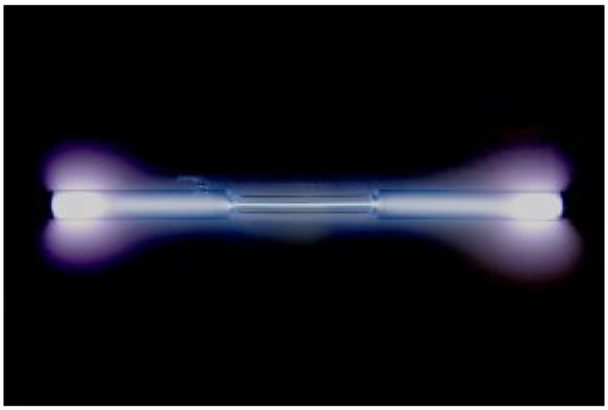
After conducting your research, summarize your information:

- Chosen format: **INFOGRAPHIC (ONE PAGE)**

First, what is Xenon-133?

Xenon-133 is a **radioactive isotope** of the noble gas xenon. It is also known as a Radiopharmaceutical. These are used as radioactive agents to treat diseases and complications in the body.

- Xenon-133 is a specific isotope of xenon, a chemical element with the atomic number 54. (Theodore Gray et al., 2017)
- It is a radioactive isotope, which means it undergoes spontaneous radioactive decay.
- Xenon-133 is commonly used in medical imaging, specifically in lung ventilation/perfusion scans. (National Library of Medicine - National Institute of Health, 2022)
- It is a safe and inert gas, making it suitable for inhalation by patients during diagnostic procedures. (Tres - tres.nl, 2023)
- Xenon-133 goes through beta minus decay and gamma emissions, which can be detected by specialized equipment to create images of lung ventilation and blood flow. (National Library of Medicine - National Institute of Health, 2022)



Important properties of Xenon-133:

Info

- (Xenon) Year Discovered: 1898 by *William Ramsay and Morris Travers* - Xe133 discovered 1940
- Appearance: Colourless
- Odor: No distinctive odor
- Isotope Mass: 132.9059107 u (unified atomic mass unit)
- No. of Neutrons: 78.9059107 -> 79n
- No. of protons / Atomic Number: 54p
- No. of electrons / Not ion therefore equal #. of electrons: 54e
- Oxidation States: 0
- Atomic Radius (Approx.): 216 pm (Van der Waals)
- Covalent Atomic Radius: 140(9) (Covalent)
- Electronegativity: 2.6 (Pauling Scale) | 2.582 (Allen Scale)
- Electron Affinity: 0eV
- Spin: 3/2
- Parity: 1

- Half-life: 5.243 days
- Electronic Configuration: (Kr)5s24d105p6 (Same as Xenon)
- Abundance % = None -> reactor-produced
- Decay Type (Significant Radiations): Most prevalent -> Beta-minus decay, Gamma-2 emissions
- Branching/Probability %: 100% -> Will decay
- Yield: 100% will yield new element after decay

(Theodore Gray et al., 2017), (National Center for Biotechnology Information, 2019), (National Accelerator Facility - Office of Science Education, 2023)

Going through each of the criterion and rubric respectively we have:

1. A brief description of what your isotope is used for:

- Xenon-133 is used for the medical diagnosis of different lung problems (specifically these tests are called lung perfusion tests). Usage of this type of method only used in North America. (Tres - tres.nl, 2023)
- Single Photon Emission Computed Tomography (SPECT) is used to image the lungs, heart and brain by utilizing the gamma radiation that is given off in during decay from Xenon-133. (Chemistry Learner, 2011)
- Also used for patients with severe respiratory complaints and pulmonary/cardiovascular problems and disorders such as embolisms. (Tres - tres.nl, 2023)
- It also helps in the identification and measurement of cerebral blood flow
- Only doctors who are trained in nuclear medicine are allowed to administer this medicine (Mayo Clinic, 2023).

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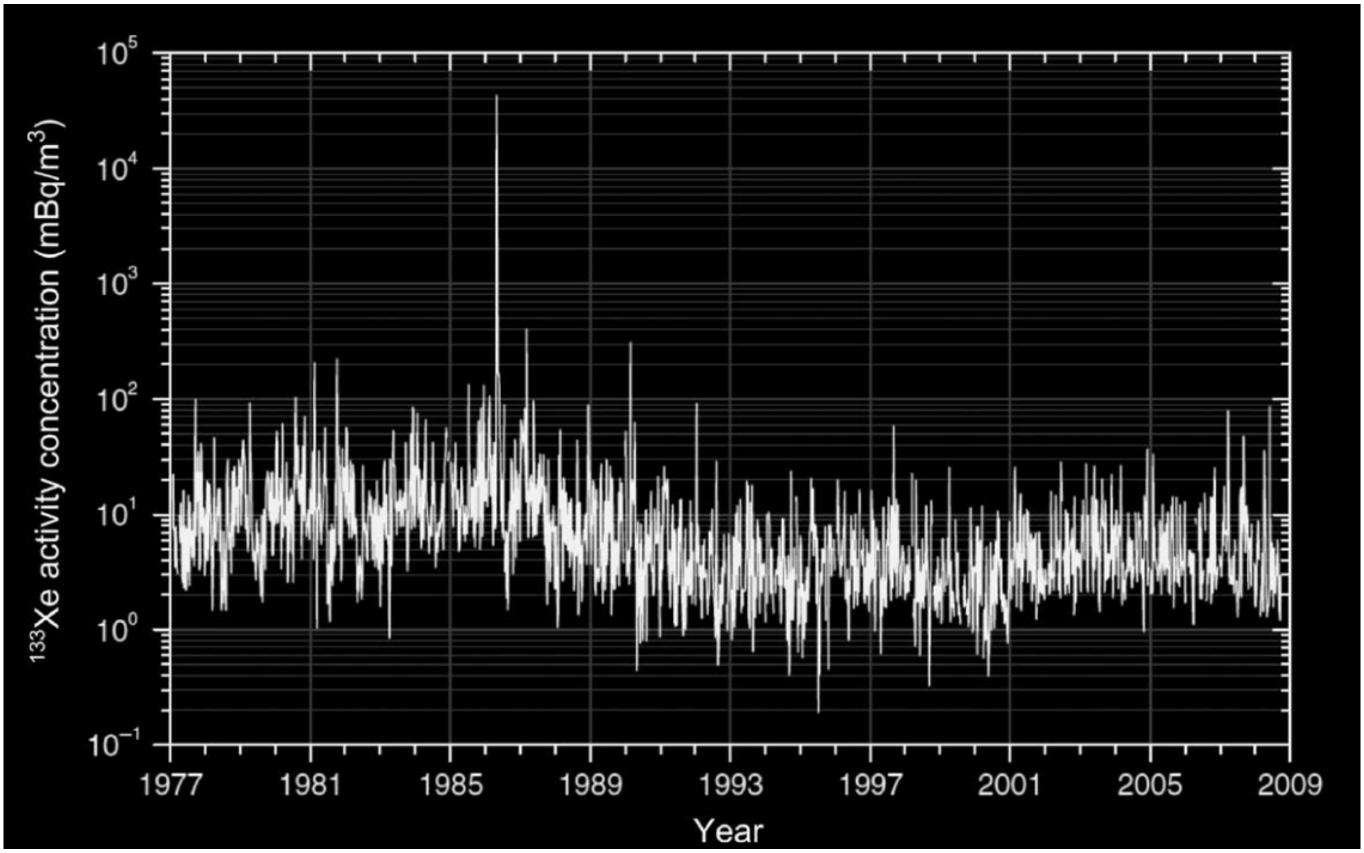
2. The % abundance of your isotope (try to explain how the % abundance was determined by showing a calculation, a graph, or some other data...)

There is no natural abundance of this isotope recorded. There is expected to be a very small amount in the atmosphere or surface that scientists may have not measured yet. Mostly, This is because this isotope is reactor-produced. Xe133 is produced through neutron irridation in air cooled nuclear reactors (National Center for Biotechnology Information, 2019). It is reactor-produced it occurs as a by-product of U-235 or Pu-239 fission. (National Library of Medicine - National Institute of Health, 2022). Finding these isotopes in the natural world would be evidence of a nuclear bomb reaction. Xe-133 is released in the atmosphere through multiple nuclear power plant reactions throughout the years. (National Center for Biotechnology Information, 2019) shows the releases throughout the years in a graph, and where it spiked during the Chernobyl accident. Xe-133 is not toxic, but its compounds are.



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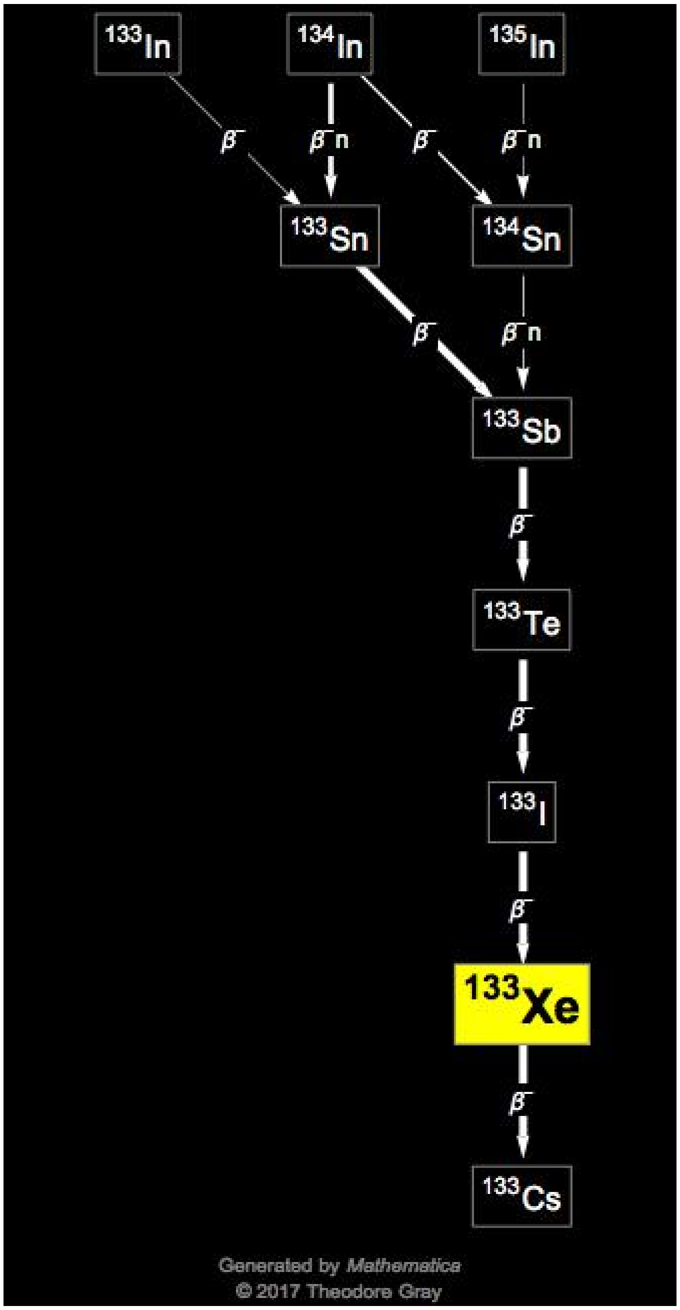
3. How stable is your isotope? Is it prone to undergo radioactive decay? Why or Why not? If it decays, what is the half-life?

- Xenon-133 is unstable and slightly radioactive (Tres - tres.nl, 2023). Xenon Xe 133 decays by beta and gamma emissions with a half-life of 5.245 days (National Library of Medicine - National Institute of Health, 2022). It has a decay energy of 0.427 MeV (Chemistry Learner, 2011).
- Xenon-133, an unstable radioactive gas, releases ionizing particles to shed energy and attain stability (Chemistry Learner, 2011) . It undergoes Beta decay, emitting energetic Beta Rays (β) with a decay energy of 0.427 MeV. Additionally, small amounts of Gamma (γ) rays are also emitted by this radioisotope (Chemistry Learner, 2011).

But why ***beta minus*** decay?

Due to an imbalance between the number of protons and neutrons in its nucleus (excess of neutrons relative to protons) it undergoes beta minus decay. One of the neutrons in the nucleus transforms into a proton. This process is accompanied by the emission of a beta particle (an electron) and an antineutrino. By undergoing beta-minus decay, Xe-133 can reach a more balanced state with a reduced neutron-to-proton ratio, resulting in a more stable nucleus.

- The decay probability is 100%, and it's daughter *decay product* is Cesium-133 (Theodore Gray et al., 2017). The decay chain of Xenon-133 is relatively short, as the subsequent element produced in the decay chain is a stable substance. Here is the decay chain:



Here is the decay equation from (Chemistry Learner, 2011) :

$$^{133}_{54}Xe \rightarrow {}^{0}_{-1}\beta + {}^{133}_{55}Cs$$

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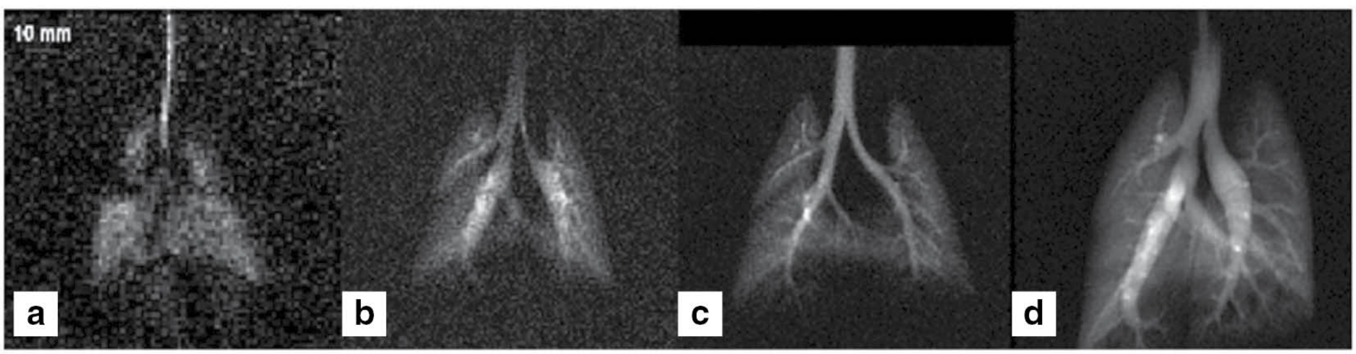
5. Explain how your isotope works

- Xenon Xe-133 is a diffusible gas not produced or utilized by the body (National Library of Medicine - National Institute of Health, 2022).
- It freely moves through cell membranes and exchanges between blood, tissue, and body fat (National Library of Medicine - National Institute of Health, 2022).

- It has a higher concentration in body fat than in blood, plasma, water, or protein solutions. (National Center for Biotechnology Information, 2019)
- Physiologically, at recommended diagnostic concentrations, it is inactive. (National Center for Biotechnology Information, 2019)
- When inhaled, Xenon Xe-133 enters the alveolar wall and pulmonary venous circulation via capillaries (Chemistry Learner, 2011).
- The majority of the gas inhaled in a single breath is returned to the lungs and exhaled after passing through the peripheral circulation once (Chemistry Learner, 2011).
- Xenon isotopes are used in numerous ways to investigate the movement of inhaled gases in lungs and other parts of the body (Chemistry Learner, 2011).
- If radioactive isotopes of xenon are inhaled, they can be tracked throughout the body by externally monitoring their decay products using magnetic resonance microscopy (National Center for Biotechnology Information, 2019).
- This imaging technique is used to assess how well oxygen is taken up and transported by the blood (National Center for Biotechnology Information, 2019).

For fighting against cancer any sort of anomaly or mass in the body can be spotted using this imaging technique with Xe-133. This prevents any mass or tumor from becoming malignant and allows doctors to reduce further complications. If tumors are spotted then eradication methods can be applied. Spotting cancer is very useful with Xe-133.



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6. What positive impacts does your isotope have on the human body/environment/an industrial process?

Xe-133 has numerous positive impacts. As an inert gas, Xe-133 does not affect the human body and is not toxic for medical use. Medicine has flourished because of new imaging techniques that involve this gas. Due to the relatively short half life, the environment is not impacted negatively which means that the environment is not affected. This is primarily due to the relatively short half life discussed before. The radioactive emissions and exposure are limited in duration. Once released in the environment it quickly disperses.

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7. What negative impacts does your isotope have on the environment or human health?

There aren't any direct negative effects, but the common sources of error that might create complications if not controlled are:

1. Radiation Exposure: Xe-133 emits gamma radiation, which can be harmful to living organisms if they are exposed to high levels for extended periods. However, Xe-133 is typically used in controlled and regulated settings where radiation doses are kept within safe limits.
2. Radioactive Waste: After Xe-133 is used for medical or research purposes, the disposal of any remaining radioactive material should follow proper procedures to ensure the safe management of radioactive waste.

Also the industrial process and production of Xe-133 might need substantial amounts of energy and power to be able to produce Xe-133. There are methods being used to optimize the process of producing such radioisotopes in nuclear-reactors and particle accelerators however.

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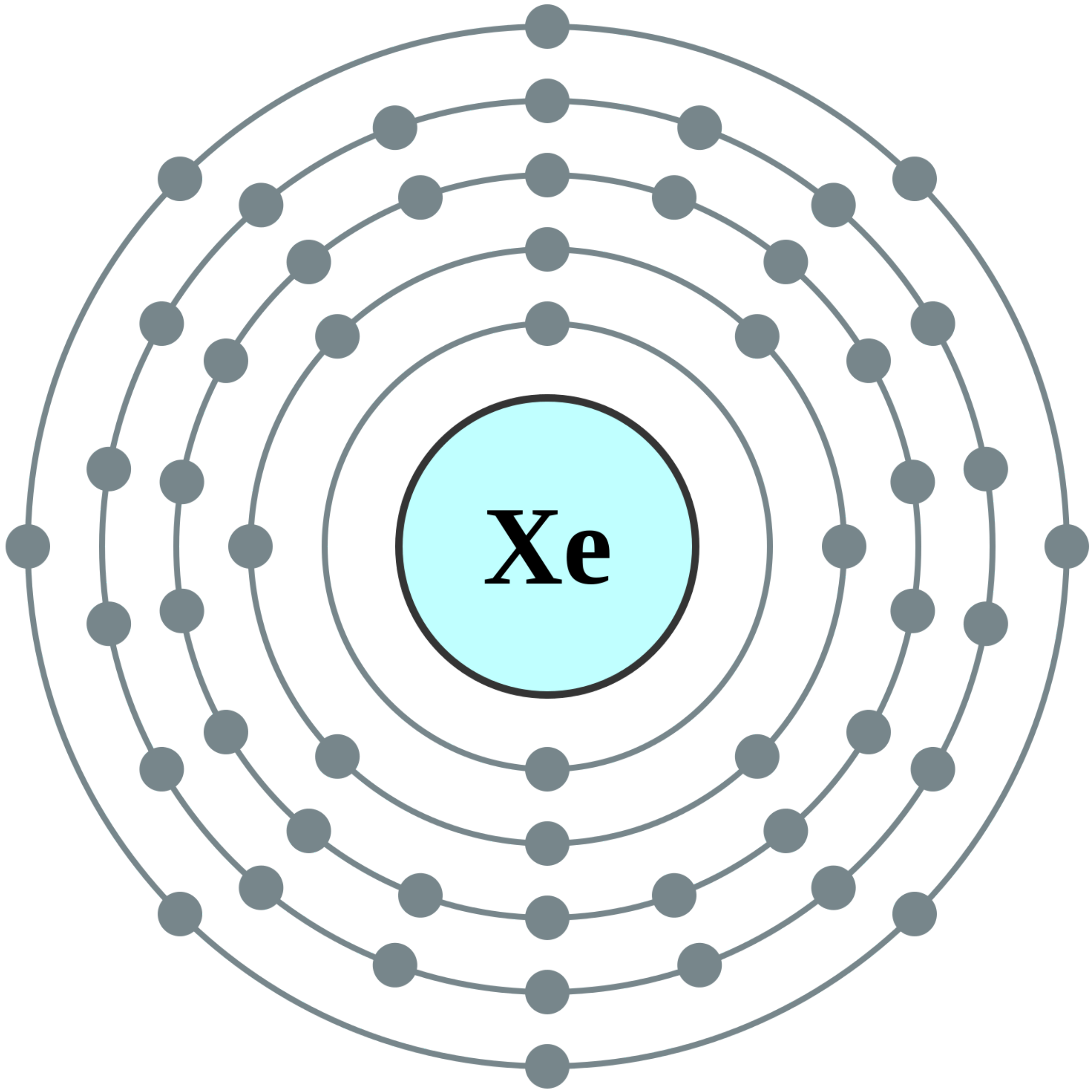
8. Any other pertinent information about your isotope that you think relates to our unit?

Yes, we have not discussed yet about the precautions of using this gas:

- Pregnant women should avoid administering this radiopharmaceutical due to limited research on its effects on fertility.
- Individuals with hypersensitivity to this radioactive agent should not use it.
- Radiopharmaceuticals should only be used under the guidance of qualified physicians experienced in the safe use of radionuclides.
  (Chemistry Learner, 2011)

More diagrams:

Bohr Model: - Here the nucleus contains 79 neutrons and 54 protons which make 133 as the total mass. The electrons do not change, because this isotope is not an ion - although it can bond with other elements just like how Xenon bonds with other elements even though it is an inert gas. The number of electrons are the same as the protons which is 54. This is because 54 defines the element, and this element is Xenon - but an isotope therefore Xe-133.



Lewis Dot Diagram - shows 8 valence electrons:


Xe