Few-Electron Bubbles in Superfluid Helium Gas

Why in News

Recently, Scientists at the **Indian Institute of Science (IISc),** Banglore for the first time discovered **two species of Few-Electron Bubbles (FEBs) in Superfluid** Helium Gas.

Helium

- It is a chemical element with the **symbol He and atomic number 2.** The British chemist **Sir William Ramsay** discovered the **existence of helium on Earth in 1895.**
- It is a **colourless, odourless, tasteless, non-toxic, inert, monatomic gas,** the first in the noble gas group in the periodic table.
- Its **boiling point is the lowest among all the elements.**

Electrons

- **Matter is made up of atoms,** which are the basic units of chemical elements such as hydrogen, helium or oxygen.
- Atoms are **made up of three particles:** Protons, Neutrons and Electrons.
- Hence, **electrons are the subatomic particles that orbit the nucleus of an atom.** They are generally **negative in charge** and are much **smaller than the nucleus of the atom.**

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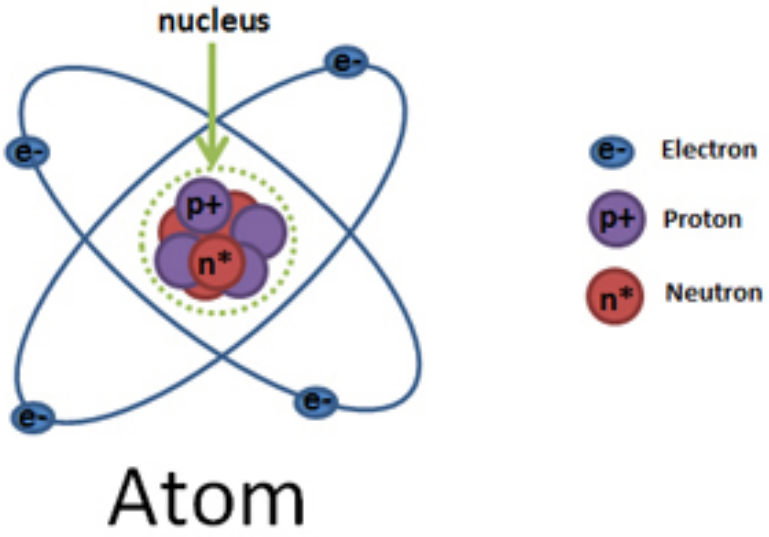

Key Points

- **Electron Bubble:**
    - An electron bubble is the **empty space created around a free electron in a cryogenic gas or liquid,** such as neon or helium. They are typically very small, about **2 nm in diameter** at atmospheric pressure.
    - An electron injected into a **superfluid** form of helium creates a **Single Electron Bubble (SEB) —** a cavity that is free of helium atoms and contains only the electron. The shape of the bubble depends on the energy state of the electron.
        - For instance, the bubble is spherical when the electron is in the ground state (i.e. state of lowest energy). There are also **multiple electron bubbles** that contain **thousands of electrons.**
        - **Superfluidity** is the **frictionless flow and other exotic behaviour observed in liquid helium at temperatures near absolute zero** (−273.15 °C), and similar frictionless behaviour of electrons in a superconducting solid. In each case the **unusual behaviour arises from quantum mechanical effects.**
- **Few-Electron Bubbles:**
    - FEBs, on the other hand, are **nanometre-sized cavities in liquid helium containing just a handful of free electrons.** The number, state, and interactions between free electrons dictate the physical and chemical properties of materials.
        - FEBs form an interesting system that has both **electron-electron interaction and electron-surface interaction.**
        - FEBs were found to be **stable for at least 15 milliseconds** (quantum changes typically happen at much shorter time scales) which would enable researchers to trap and study them.
- **Significance:**
    - **Study Properties:**
        - FEBs can serve as a useful model to study how the energy states of electrons and interactions between them in a material influence its properties.
    - **Decipher Phenomenons:**
        - There are several phenomena that FEBs can help scientists decipher, such as:
            - Turbulent flows in superfluids and viscous fluids, or the flow of heat in superfluid helium.
            - Just like how **current flows without resistance in superconducting materials** at very low temperatures, **superfluid helium also conducts heat efficiently at very low temperatures.**

Source: DTE