UNIT 2 PERFORMANCE TASK: A STUDY OF AN ELEMENT

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A STUDY OF ARGON

History

The English scientist, Henry Cavendish, was shy and reclusive to the point of phobia, and, consequently, never took examinations for his degree at Cambridge, which would have involved personal contact with the examiners. Nonetheless, his contributions to science guarantee his place in history. He is most famous for the physics experiment in which he determined the value of G, the universal gravitational constant; but in 1785, he performed chemical experiments with air which eventually led to the discovery of argon. When he chemically combined all of the oxygen and nitrogen in a sample of dry air, he found that a small bubble of gas, about 1% of the total volume, remained no matter what he did to get it to react. He speculated at the time that air contains an unknown gas that is resistant to chemical reaction. This was correct—he had discovered a new element.

The Cavendish experiment was ignored for more than a century until it was repeated by Sir William Ramsay in 1892 in an attempt to solve a problem publicized by Lord Rayleigh. Rayleigh had found that nitrogen obtained from air had a slightly higher density than did nitrogen obtained from its compounds. Ramsay and Rayleigh used a spectroscope to analyze the bright-line spectrum emitted by the unreacted gas from an air sample, and found it to be an unknown element. They named the new element argon, from the Greek word for "inert." Discovery of the other inert gases followed quickly from this research. In 1904, Ramsay won the Nobel Prize for Chemistry and Rayleigh the Nobel Prize for Physics, for their discovery and determination of the properties of argon.

Structure and Bonding

An atom of argon is theoretically described as having atomic number 18, meaning a nuclear structure made up of 18 protons, and, most commonly, 22 neutrons. About 0.34% of argon atom nuclei have 20 neutrons, and about 0.07% have 18 neutrons. There are at least 12 other unstable (radioactive) isotopes of argon known to exist. The atomic volume is occupied by 18 electrons, described by a quantum mechanical configuration of $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$. (See diagram below.)

$3p$ ↑↓ ↑↓ ↑↓
$3s$ ↑↓

$2p$ ↑↓ ↑↓ ↑↓
$2s$ ↑↓

$1s$ ↑↓

Ground-state electron configuration for an argon atom, Ar

The octet of electrons of the highest energy level results in a particularly stable (low) energy configuration. Notice that all orbitals contain a pair of electrons and that there are no half-filled orbitals. Theoretically then, argon should exist as a monatomic element with very low melting and boiling points because the attraction between atoms is limited to London forces. These forces should not be very strong because the total number of electrons per atom is low. By the same argument, argon should be extremely unlikely to combine chemically with other atoms because there are no half-filled orbitals to overlap with half-filled orbitals of other atoms to form a covalent bond or to transfer electrons to achieve a more stable configuration.

Physical Properties

Argon is a colourless, odourless gas at SATP and has a molar mass of 39.95 g/mol. The gas condenses to a colourless, odourless liquid at –186°C, and freezes to a solid at –189°C (both values measured at 1 atm pressure). The density of argon gas is 1.78 g/L at STP, and the solubility in water at 0°C is 56 mL/L, slightly more than oxygen. In rare instances, argon is found to be combined with other substances in a fixed-mass ratio. Argon forms a hydrate with water under very high pressure and low temperature, and a clathrate with ß-hydroquinone, but in these cases the scientific community assumes that the argon atoms are trapped within the crystals and held in place by van der Waals forces, and not by chemical bonds.

Chemical Properties

Argon has no known chemical compounds, which agrees very well with the prediction from the theoretical atomic structure. This evidence strongly supports the quantum mechanical and bonding theories. I am not sure why one or more valence electrons of an argon atom could not be promoted to the 3*d* level to perhaps form some covalently bonded compounds. These compounds are obviously unstable since no one has found any but maybe some could be formed at very low temperatures.

Technological Applications

Most of the technological uses of argon in society are based on three factors. It is readily available since it makes up nearly 1% of the atmosphere of the Earth. It is inexpensive because it is easily extracted in high purity from air. And finally, it is chemically inert. There are many situations where technology requires that chemical reaction not take place, and in these situations argon finds its primary uses. Some common examples include the following:

- Argon is placed in incandescent and fluorescent light bulbs at about 400 Pa pressure, which inhibits the tendency of metal atoms to boil off the surface of very hot filaments, thus prolonging filament life. Other gases would react with the hot metals themselves, but argon does not.
- Argon is widely used in welding and torch-cutting systems to create an inert blanketing atmosphere around the high-temperature area. This gaseous blanket prevents the metal from oxidizing while it is very hot.
- Argon is used as the atmosphere in metallurgy vessels where reactive elements, such as titanium, are produced. An argon atmosphere keeps them from reacting the instant they are formed.
- Silicon and germanium crystals—which are critical for production of semiconductors and microchip circuits—may be grown in an argon atmosphere to ensure high purity and evenness of atomic arrangement in such crystals.

Argon produces a bluish light when present at low pressure in a glass tube connected to a high potential difference (voltage). This has been used for decades as a way to produce a blue colour in commercial display signs, just as neon is used to produce a red-orange colour. Modern technology has developed many new uses for the light emitted by argon.

The emission of light by excited argon atoms is presumed to be due to electron energy-level shifts—consistent with atomic structure theory from Bohr through to quantum mechanics. The argon atoms' electrons are raised to various excited states, and then emit several characteristic frequencies (wavelengths) of monochromatic light as they drop back to a ground state. An examination of argon's spectrum for light emitted by a low-pressure, high-voltage tube shows it to be a typical "bright-line" spectrum. An application of quantum mechanical technology allows lasers to be created that operate using argon as one of the gases producing the desired monochromatic light. Following are two special examples of this technology:

- Laser eye surgery commonly uses argon-fluorine "excimer" lasers to produce a coherent beam at 193 nm wavelength to vaporize corneal tissue, allowing reshaping of the eye surface to improve vision acuity.
- Laser "light show" systems are becoming common in the world of entertainment. Argon lasers produce bright blue and green colour wavelengths, and krypton lasers produce vivid red colour, so a laser using a mixture of these two gases can be constructed to produce all three primary colours. This means that, just as on a television screen, these three colours can be combined to produce all apparent colours of the visible spectrum. The very bright laser beams can be projected separately onto a screen, and moved at high speed to produce stunning visual effects.

Careers Involving Argon

Some careers directly involving argon include:

- Gas Plant (Liquid Air) Operator/Technician

  Individuals working in plant operations involving the extraction of argon from the atmosphere; usually operating compression and fractionation equipment and control systems.

- Inert Gas Welder

  Individuals using modern technology and equipment to perform inert gas welding and cutting operations on metals.

- Light Bulb Manufacturing Plant Operator/Technician

  Individuals working in plant operations involving the placement of argon into light sources using specialized equipment and control systems.

- Semiconductor Production Plant Operator/Technician

  Individuals working in plant operations involving the growing and doping of crystals in special argon atmospheres, and associated technology and quality control.

- Laser Eye Surgeon

  Medical doctors specially trained to use excimer lasers to perform corrective eye-surface restructuring.

- Surgical Optical Laser Technician

  Individuals specially trained to service and adjust precise tolerance lasers for eye surgeries.

- Light Show Operators/Technicians

  Individuals specially trained to operate, program, service, and adjust light show lasers.

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Web Sites

http://lasereye.net/laser_eye_surgery_hawaii_kw.htm#Laser%20Types
http://www.laserist.org/Laserist/showbasics_laser.html

UNIT 2 SELF-QUIZ

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1. False: The term orbital refers to the volume of space an electron occupies near a nucleus.
2. True
3. True
4. True
5. False: The ground state electron configuration for all alkali metals shows that the highest energy electron~~s~~ are in an *s* sublevel.
6. False: There are thought to be five *d* energy sublevels.
7. True
8. False: Schrödinger became famous by developing wave equation mathematics to describe electrons as wave functions.
9. True
10. True
11. False: VSEPR theory predicts that a central atom with three bonded atoms and one lone pair of electrons should have a pyramidal shape.
12. True
13. True
14. False: VSEPR and Lewis theories are complete enough to explain the structure and shape of the molecules in gaseous silane, $SiH_{4(g)}$, which is used as a doping agent in the manufacture of semiconductors for solid-state devices.
15. True
16. True
17. True
18. False: Ionic bonding involves three-dimensional structures with positive and negative ions attracting each other.
19. True
20. (a)
21. (b)
22. (c)
23. (a)
24. (a)
25. (a)
26. (c)
27. (d)
28. (b)
29. (d)
30. (b)