Ri Christmas Lectures 2012®: The Modern Alchemist

Teaching Resource - Group 8 (18) The Noble Gases

Overview:

This resource contains an overview of the Group 8 (18) elements; the Noble Gases. Interesting applications of these elements are considered through the use of video clips from the Royal Institution Christmas Lectures® 2012.

Structure and Reactivity:

The Noble gases get their name from the fact that they are mostly unreactive. This property comes about due to their electronic distribution (i.e. the number, and positioning of their electrons).

At a basic level, the Noble Gases are unreactive as they have full outer shells of electrons. This is an energetically stable configuration, and therefore they are unreactive as losing or gaining extra electrons would increase their energy, and decrease their stability.

At a greater level of detail, it can still be shown that the Noble gases have completely filled orbitals, up to their outermost set (See teaching resource Atomic Structure and the Periodic Table for more information on orbitals). For example, Neon has ten electrons as a neutral atom, making its electronic configuration $1s^2$, $2s^2$, $2p^6$. This means that if an electron was gained, it would have to be placed in a higher energy 3s orbital, thus increasing the energy of the whole atom. In a similar way, losing an electron will be energetically disfavoured, as it would lead to an unpaired electron, again increasing the energy of the whole atom.

The effect of having full outermost electron energy levels means that the Noble gases are able to be found as single atoms (He, Ne, Ar, etc...), as opposed to molecules (i.e. O_2, Br_2, H_2). This is extremely rare, and in fact, the Noble Gases are the only example of this in the ground state.

Explanation of why the Noble gases can be seen as single atoms:

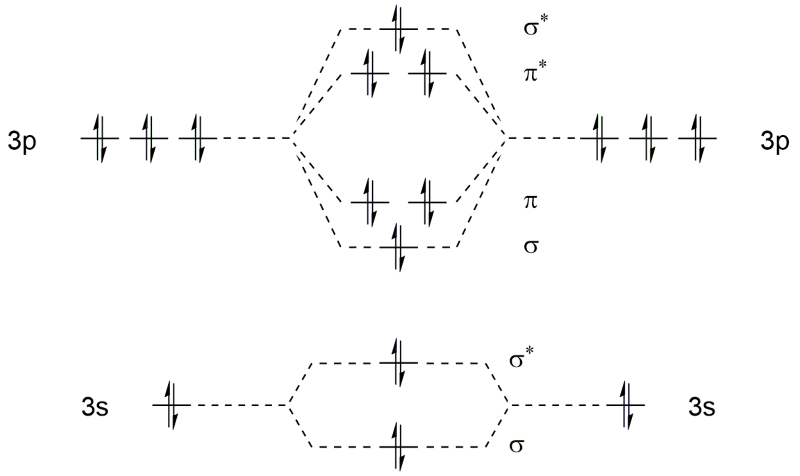
The reason for the Noble gases being found as single atoms can be demonstrated by considering Molecular Orbital Theory (this is a highly advanced treatment, and is not part of the current GCSE, or A-Level curriculum).

When two atoms join together to form a bond, their atomic orbitals (s, p, d, and f) combine to form molecular orbitals. If we consider an atom of argon, it has 1 s orbital, and 3 p orbitals in its outermost shell; a total of 4 orbitals. Therefore, if we combine two atoms of argon, we have 8 atomic orbitals which will combine to form 8 molecular orbitals.

Half of these 8 orbitals will be bonding (ie. if electrons are placed into them, the atoms are more strongly held together, shown as σ and π), and half will be *anti* -

bonding (meaning electrons placed in these orbitals actively pull the atoms apart, weakening the bond; these are shown as σ* and π*).

We can show these molecular orbitals in a molecular orbital (MO) diagram (See below).



If we complete the diagram with the 8 electrons from each argon atom (a total of 16) we can see that all orbitals (including the anti - bonding orbitals) are occupied, leading to a net bond of 0; i.e. no bond - explaining why we see the noble gases as individual atoms.

Video Clip: Properties of the Noble Gases

In this clip, Dr Peter Wothers and several members of the audience demonstrate the differences in density between the Noble gases, how their electronic properties can affect their reaction to electricity, and shows how dense Xenon actually is...

The Noble Gases - Properties

Running Time: 3 min 37 secs

Explanation of the differences in colour of Noble gas lamps:

- The light that is seen when the Noble gases are exposed to electricity (i.e. in 'Neon' type lamps) comes about due to electrons within the atoms that make up the gas.
- When electricity is passed through the gas, electrons from the outer energy levels (shells) of the atoms of gas are 'excited', and move to higher energy, 'excited' states - they are promoted.
- The energy that is required to promote an electron to an excited state is a precise amount, and when the electron returns to its ground state, the energy is released as light - the light that we observe.

- The colour of the light is related to the energy required to promote the outer electrons in the gas - i.e. the different amounts of energy required to promote an electron in each noble gas leads to light of different wavelengths (and therefore colours) being emitted.

Applications of the Noble Gases:

Helium:

- Helium: RSC Visual Elements
- The main industrial use of helium is in the form of liquid helium for cooling superconducting magnets within nMRI and NMR machines.
- There is some debate as to if helium should be allowed to be used in party balloons, due to its rarity. When helium is released it escapes the atmosphere, meaning once it is used, unless recaptured, it is gone forever.
- An interesting research project could be the uses of the Noble gases, and in particular, the uses of Helium - how should we use and protect this precious resource?

Neon:

- Neon: RSC Visual Elements
- The main industrial use of neon is within neon signs; however, recently liquid neon has been gaining interest as a cryogen.

Argon:

- Argon: RSC Visual Elements
- Argon is mainly used as an inert 'blanket' gas for protecting reactive elements and materials from interaction with the relatively reactive other gases in the atmosphere (such as oxygen).

Krypton:

- Krypton: RSC Visual Elements
- Krypton has found use in high speed flash photography, as the discharge produces a white light
- Krypton is also used in high powered lasers for both research (krypton fluoride lasers are being used in nuclear fusion research), and laser shows.

Xenon:

- Xenon: RSC Visual Elements

Video Clip: Hyperpolarised Xenon MRI, and Xenon Therapy

In this clip, Dr Peter Wothers explores some of the remarkable uses that Xenon is finding in the world of medicine - more specifically, the use of hyperpolarised Xenon in MRI imaging of the lungs, and in the prevention of brain injuries in newborns suffering from hypoxia.

The Noble Gases - Xenon - Applications

Running Time 7 min 20 secs

Radon:

- Radon: RSC Visual Elements
- Radon is a highly radioactive gas, and has been used to produce radon 'seeds' (gold tubes in which radon is sealed) which have been implanted into tumours as radiotherapy.

Ununoctium:

- Ununoctium: RSC Visual Elements
- Ununoctium has yet to find any uses outside of the research lab - in fact, IUPAC has yet to confirm the discovery of element 118.

View the full 2012 Ri Christmas Lectures® - The Modern Alchemist, along with behind the scenes footage, and related content, at the Ri Channel[1]

[1] Ri Channel, www.richannel.org