**2.4 Limitations of this Model.**

While the shell picture represented a great advance in the understanding of the atom there were certain limitations and scientists began to ask:

* Why do electrons move in circular orbits rather than elliptical ones?
* Why do shells have particular energies?
* Why do we need a special rule that limits the number of electrons in the outer shell to eight, even when the maximum number possible can be greater than eight?

**1926 –** Erwin Schrödinger proposes that electrons behave as waves around the nucleus. Hi description is known as wave or quantum mechanics and is the most popular description of the atom we have at present. Scientists now believe that small particles such as protons, electrons and neutrons behave according to the laws of quantum mechanics.

Quantum mechanics is extremely complex and we will only look at a descriptive account of the more important features.

* The electron is now a vague, elusive object that behaves like a cloud of negative charge.
* There are no definitive orbits for electrons in this model.
* Electrons move in regions of space surrounding the nucleus called orbitals.



The electron in a hydrogen atom acts like a cloud of negative charge around the nucleus. The density of the cloud gives an indication of the amount of time and electron spends there.

**Shells and Subshells**

Quantum mechanics show the following:

* Within an atom, there are major energy levels, which for historical reasons, we call shells. These shells can be regarded as equivalent to the earlier model and are numbered 1, 2, 3 etc.
* Within the shells are energy levels of similar energy called subshells. These are labelled by the letters s, p, d and f.
* In atoms containing more than one electron, the energies of the subshells within a shell increase in the orders s < p < d < f.
* Subshells are made up of orbitals (the regions in which the electrons move). Orbitals within a particular subshell are of equal energy.
* The s-subshells contain one orbital, p-subshells contain three orbitals, d-subshells contain five orbitals and the f-subshells seven orbitals.

|  |  |  |  |
| --- | --- | --- | --- |
| Shell Number | Number of subshells in shell | Subshell in shell | Number of orbitals in subshell |
| 1 | 1 | 1s | 1 |
| 2 | 2 | 2s2p | 13 |
| 3 | 3 | 3s3p3d | 135 |
| 4 | 4 | 4s4p4d4f | 1357 |
| 5 | 5 | 5s5p5d5f | 1357 |

**Electronic Structures of Elements**

The Pauli Exclusion Principle states that: An atomic orbital may hold a maximum of two electrons.

*Maximum number of electrons in subshells*

|  |  |  |
| --- | --- | --- |
| *Type of subshell* | *Number of orbitals* | *Maximum number of electrons* |
| *s* |  |  |
| *p* |  |  |
| *d* |  |  |
| *f* |  |  |



The order of the energies of the subshells can be remembered using the above geometric pattern. Notice that some subshells are higher in energy than other subshells of the next shell. For example the 3-d subshell is higher in energy than the 4-s subshell.

We can now determine how the electrons in a particular element are arranged.

**Example 1: Sodium**

**Atomic Number:**

**Uncharged sodium atom has \_\_\_\_\_ electrons.**

Under normal circumstances, these electrons will occupy the lowest energy levels possible. When electrons are in the lowest energy state possible the atom is said to be in its electronic ground state. If an atom is given sufficient energy the outer electrons can move to a higher energy level. For example hydrogen has 1 electron in the 1s-subshell. Given the right amount of energy the electron could move to the 2s-subshell or 2p-subshell, the 3s-subshell an so on. These higher energy states are known as excited states.

**Write the electronic configuration of sodium in both shell and subshell models.**

**Example 2: Iron**

**Key Terms.**

Alpha particle ionisation energy Pauli exclusion principle

Atomic number isotope photon

Electron mass number proton

Electronic configuration neutron quanta

Emission spectrum nucleus quantum mechanics

Excited state orbit shell

Ground state orbital subshell

**Text Questions: 14.**

**Workbook: 2 and 4**

**Chapter Review Questions: 16, 17, 21 – 26, 28 - 33.**

**Extension: 18, 27, 34, 35**