B.Sc. (Honours) Part-I
Paper-IB

Topic: The Pauli Exclusion Principle

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Subject-Chemistry

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The Pauli Exclusion Principle

Pauli exclusion principle is one of the important principles along with Aufbau's Principle and Hund's Rule in chemistry. Learning about it is crucial for students especially when they are studying about electrons. It basically helps us to understand the electron arrangements in atoms and molecules and it also gives an explanation for the classification of elements in the periodic table. In this section, we shall study the Pauli exclusion principle in detail and learn about all the underlying concepts. We discussed the fact that it takes four quantum numbers to completely specify the state of an electron. We examine how these four quantum numbers determine the structure of the periodic table. To understand how these four numbers can determine a structure as complex as the periodic table, we begin with the Pauli exclusion principle, which is a simple statement with far-reaching consequences.

The Pauli exclusion principle: No two electrons can simultaneously occupy the same electron state in an atom. In other words, no two electrons in an atom can simultaneously have the same set of four quantum numbers.

Pauli exclusion principle states that in a single atom no two electrons will have an identical set or the same quantum numbers (n, l, m_l, and m_s). To put it in simple terms, every electron should have or be in its own unique state (singlet state). There are two salient rules that the Pauli Exclusion Principle follows:

- Only two electrons can occupy the same orbital.
- The two electrons that are present in the same orbital must have opposite spins or it should be antiparallel.

The exclusion principle is named for the Austrian physicist Wolfgang Pauli (1900–1958), shown in the picture in Figure 28.7. Pauli was awarded the Nobel Prize in Physics in 1945 for the exclusion principle.

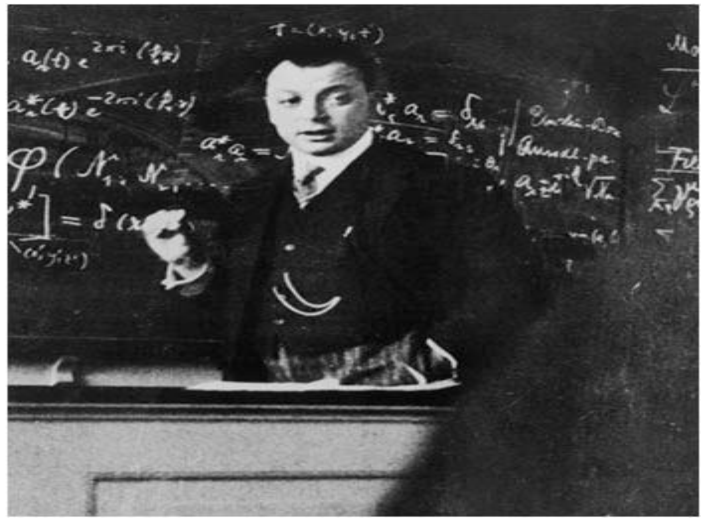


Figure 1: A photograph of Wolfgang Pauli, a colorful character who came up with the exclusion principle.

With the exclusion principle in mind, let's examine the ground-state (lowest energy) configurations of various atoms. In general, equation 28.3, in which the energy of an electron state is determined solely by the principal quantum number, is inadequate. The energy is also determined by the electron's orbital angular momentum. In general, for a given value of the principal quantum number, *n*, the higher the value of the orbital quantum number, l, the higher the energy of that

Atomic number	Name (symbol)	Ground-state configuration
2	Helium (He)	$1s^2$
6	Carbon (C)	$1s^2 2s^2 2p^2$
10	Neon (Ne)	$1s^2 2s^2 2p^6$
15	Phosphorus (P)	$1s^2 2s^2 2p^6 3s^2 3p^3$
20	Calcium (Ca)	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$
26	Iron (Fe)	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^4$

Table 28.1: Ground-state configurations for selected atoms.

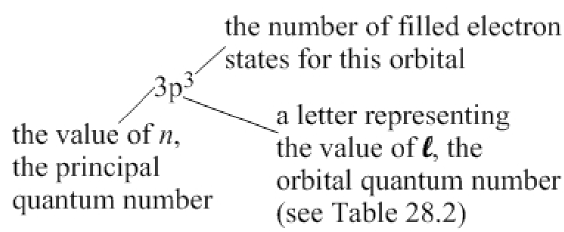


Figure 2: Explaining the number-letter-number notation.

state. Let's begin by looking at the ground state configurations of a few elements in the periodic table. These are shown in Table 28.1. An explanation of what the number-letter-number notation means is given in Figure 2.

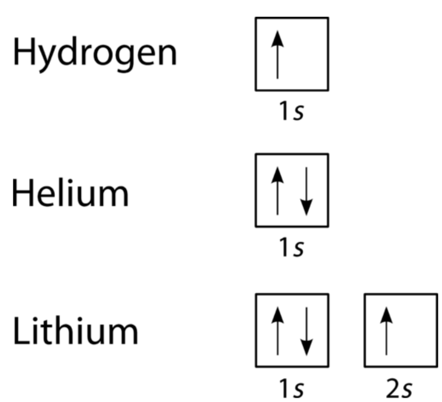
Referring to Table 28.1, we see that helium, with only two electrons, can have both electrons in the *n* = 1 shell, which can only fit two electrons. For atoms that have more than 2 electrons, two electrons are in the *n* = 1 level, and then the others are in states that have larger n values. The *n* = 2 level can fit eight electrons (two with l = 0 and six with l = 1). Thus, for elements up to and including neon, which has 10 electrons in its ground-state configuration, the electrons are in the *n* = 1 and *n* = 2 levels. Beyond this, electron state with higher *n* values come into play.

Pauli Exclusion Principle Example

We can take a neutral helium atom as a common Pauli Exclusion Principle example. The atom has 2 bound electrons and they occupy the outermost shell with opposite spins. Here, we will find that the two electrons are in the 1s subshell where n = 1, l = 0, and m_l = 0.

Their spin moments will also be different. One will be m_s = -1/2 and the other will be +1/2. If we draw a diagram then the subshell of the helium atom will be represented with 1 "up" electron and 1 "down" electron. In essence, 1s subshell will consist of two electrons, which have opposite spins.

Similarly, if we take Hydrogen it will have 1s subshell with 1 "up" electron ($1s_1$). Lithium will have the helium core (1s2) and then one more "up" electron ($2s_1$). What we are trying to depict here is that the electron configuration of the orbitals is written in this manner.



Importance And Applications Of Pauli Exclusion Principle

- The Pauli exclusion principle helps to explain a wide variety of physical phenomena.
- It helps in describing the various chemical elements and how they participate in forming chemical bonds.
- The periodic table can also be defined with the help of this principle.
- Apart from chemistry, the principle is a fundamental principle in quantum mechanics which is mainly studied in physics.
- It is also used in astrophysics.