Electron Configuration and Chemical Periodicity

The Periodic Table

- Periodic law (Mendeleev, Meyer, 1870) – periodic reoccurrence of similar physical and chemical properties of the elements arranged by increasing atomic mass
  - Periodic table included the 65 known elements
  - Mendeleev left blank spaces for the undiscovered elements and was able to predict their properties
  - The true basis of periodicity is the atomic number not the atomic mass (Mosley, 1913)

8.1 Many-Electron Atoms

- Only approximate solutions of the Schrödinger equation are available
- Electron-electron interactions are important
- The same tree quantum numbers \( n, l \) and \( m_l \) are used to describe the solutions (the orbitals are hydrogen-like)

The Electron Spin

- The electron can be viewed as a ball of spinning charge – has a magnetic moment
- The magnetic moment is quantized – only two orientations of the spin are allowed in a magnetic field

⇒ Spin quantum number \( m_s \) – two possible values of \( m_s \) (+1/2 and -1/2)
- Each electron in an atom is described by four quantum numbers – \( n, l, m_l, m_s \)
The Pauli exclusion principle – no two electrons in an atom can have the same set of four quantum numbers

⇒ Each orbital can hold no more than two electrons and they must have opposite spins (paired spins, ↑↓)

Orbital Energies
• Orbital energies depend on both \( n \) and \( l \)
  \[ n \uparrow \rightarrow E \uparrow \quad l \uparrow \rightarrow E \uparrow \]
  ⇒ Orbitals in different subshells of a given principal shell have different energies
– Evidence – many-electron atoms have more complex atomic spectra (splitting of \( E \)-levels)

Electrons are attracted by the nucleus and repelled by each other
– The effect of nuclear charge \((Z)\) – higher \( Z \) lowers the orbital energy
– The effect of electron repulsion – an additional \( e^- \) in the same orbital raises the orbital energy

Electron shielding – electrons shield each other from the nuclear charge
– Inner electrons shield outer electrons more effectively than electrons in the same orbital or subshell

Effective nuclear charge \((Z_{\text{eff}})\) – smaller than the actual nuclear charge \((Z)\) due to electron shielding

Penetration – electrons on orbitals in different subshells of a given shell are shielded to a different extent depending on their penetration (closeness) to the nucleus

More penetration → less shielding → higher \( Z_{\text{eff}} \)

The \( s \)-orbitals have the greatest penetration to the nucleus

Least shielded → highest \( Z_{\text{eff}} \) → lowest energy

The \( p \)-orbitals have a node at the nucleus and lower penetration than the \( s \)-orbitals

More effectively shielded → lower \( Z_{\text{eff}} \) → higher energy
- Penetration decreases with increasing $l$
  - More effective shielding $\rightarrow$ lower $Z_{\text{eff}}$ $\rightarrow$ higher energy
  - Energy order of the subshells in a given shell:
    - $s < p < d < f < g ...$
  - This leads to a much greater number of energy levels compared to one-electron species like H