Lecture 3

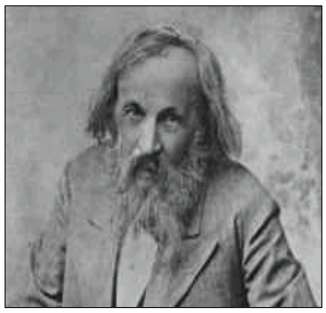
Outline

3.1 Introduction to the Periodic Table

3.2 Structure of the electron shell

3.3 Ionisation energy and electron affinity

Development of the Periodic Table



Dimitrij Mendelejev (1834–1907)

The modern periodic table was developed by the Russian chemist Dimitrij Mendelejev and the German chemist Lothar Meyer.

Around 1869 Mendelejev recognised the periodicity of the elements. Although scientists previously classified the elements, Mendelejev succeeded in interpretating the principles in an adequate way.

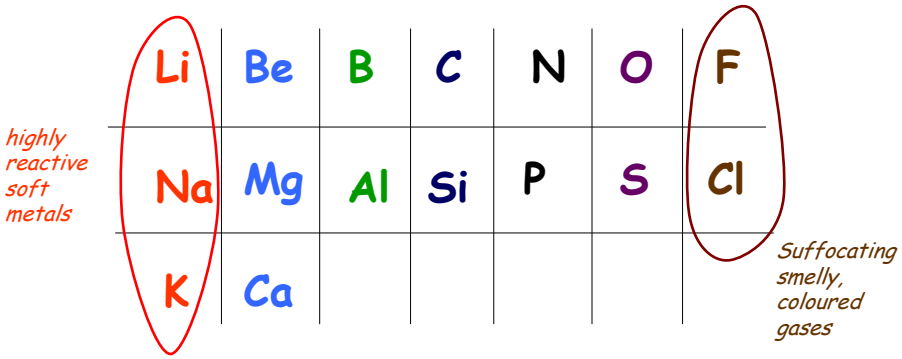
Mendelejev orders the known elements according to their atomic mass.

..... Li Be B C N O F Na Mg Al Si P S Cl K Ca

Development of the Periodic Table

Mendelejev realised that after a certain number of elements similar or related properties appeared again.

He ordered these elements vertically underneath each other, but still ordering the elements according to their atomic mass.



Criteria: (a) increasing atomic mass, (b) chemically similar elements below each other

„Increasing atomic mass"

Is this principle always obeyed??

Argon (Ar_{18}): 39.948 u ⟺ Potassium (K_{19}): 39.0983 u

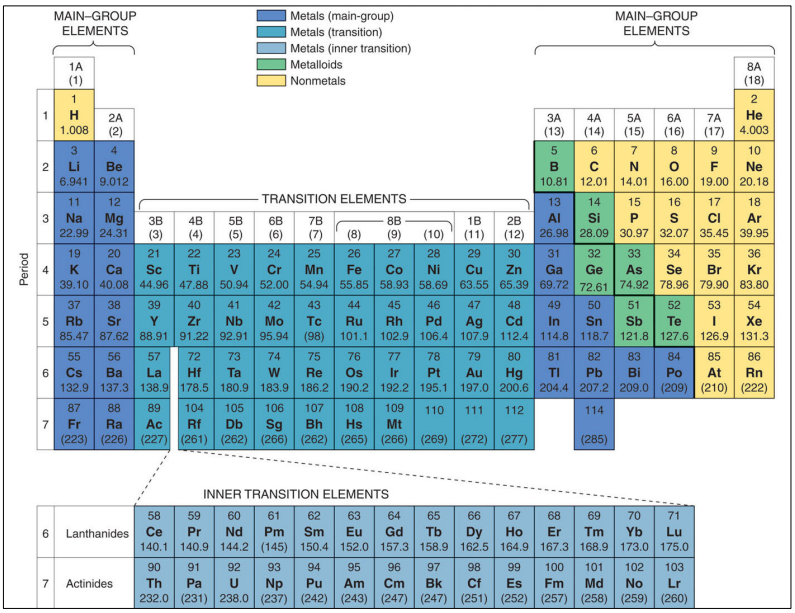
Tellurium (Te_{52}): 127.60 u ⟺ Iodine (I_{53}): 126.90 u

Reasoning:

Potassium is a typical alkali metal which would be completely misplaced in the group of the noble gases. The same applies for the change of telurium and iodine.

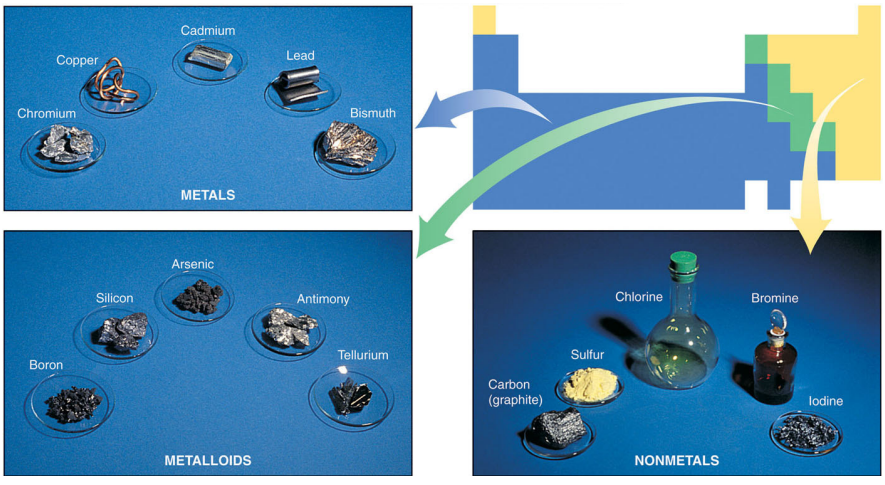
According to Mendelejev: chemical relationship is a more important criteria.

The Modern Periodic Table

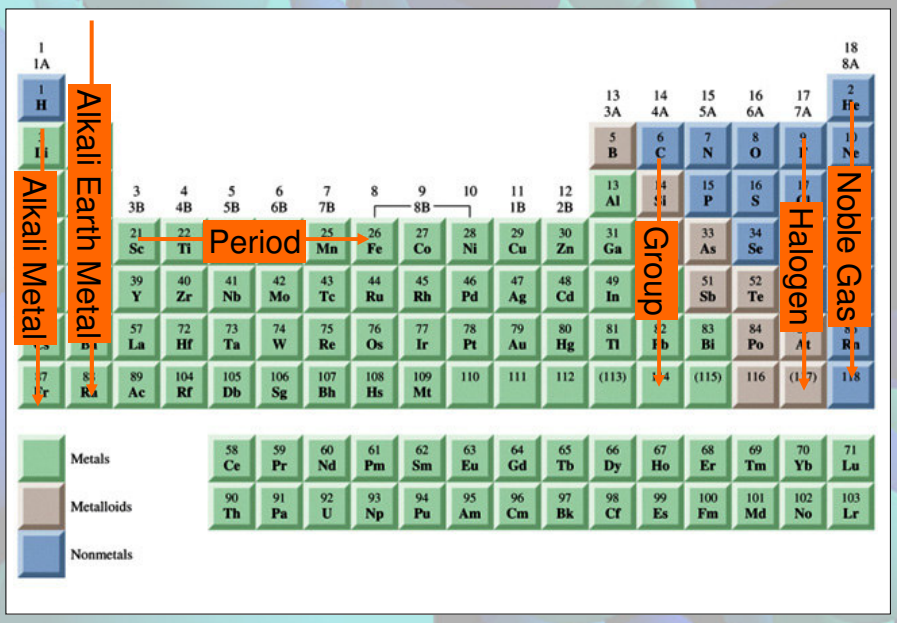


The structure of the Periodic Table

Metals, Metalloids, and Nonmetals



The structure of the Periodic Table



Structure of the Periodic Table

Main Group Elements (Vertical Groups)

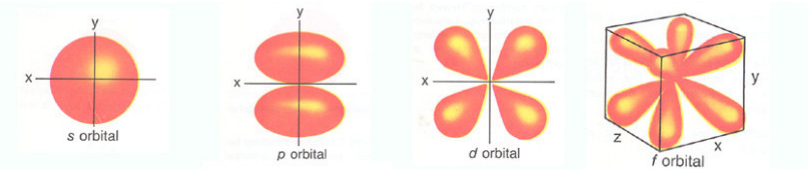
Group 1(IA) - Alkali Metals
Group 2(IIA) - Alkaline Earth Metals
Group 13(IIIA) - Boron Family
Group 14(IVA) - Carbon Family
Group 15(VA) - Nitrogen Family
Group 16(VIA) - Oxygen Family (Chalcogens)
Group 17(VIIA) - Halogens
Group 18(VIIIA) - Noble Gases

Other Groups (Vertical and Horizontal Groups)

Group 3-12(IB - 8B) - Transition Metals
Period 6 Group - Lanthanides (Rare Earth Elements)
Period 7 Group - Actinides

Atoms: Structure of the Electron Shell

- The electrons of an atom “occupy” “discrete” energy states.
- They move around the nuclei in defined orbitals



- The energetic state of an electron is characterised by 4 quantum numbers

1.	Main-quantum number	n
2.	Orbital quantum number	l
3.	Magnetic quantum number	m_l
4.	Spin quantum number	m_s

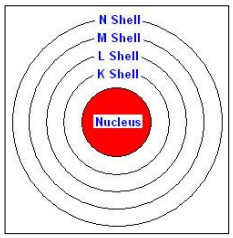
determines the values

- The energetically most stable state is called the ground state

Atoms: Structure of the Electron Shell

n determines the energy level – the shells

n positive, integer



n	shell
1	K
2	L
3	M
4	N
5	O

energy increase

l positive, integer and *l*-value < *n*

Shell	K	L	M	N
n	1	2	3	4
l	0	0 1	0 1 2	0 1 2 3
Orbital	s	s p	s p d	s p d f

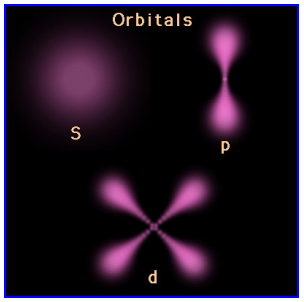
Atoms: Structure of the Electron Shell

1 s-orbitals

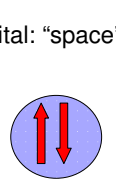
3 p-orbitals

5 d-orbitals

characterised by → m_l number

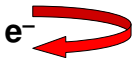


Orbital: "space" for 2 electrons



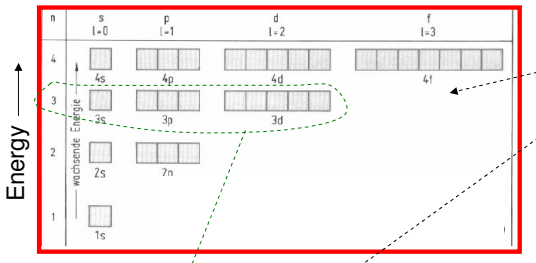
$m_s = +1/2$ 

$m_s = -1/2$ 



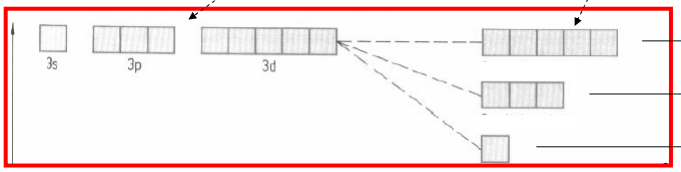
Spin angular moment

Atoms: Structure of the Electron Shell



Atomic orbitals for 1 electron system

Atom that contains more than one electron

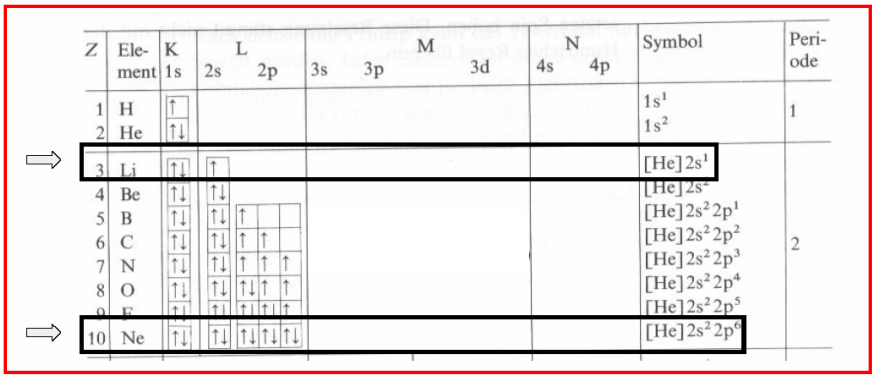


d orbitals

p orbitals

s orbital

Build-up Principle for Electron Shells



Z	Element	K 1s	L 2s	L 2p	M 3s	M 3p	M 3d	N 4s	N 4p	Symbol	Periode
1	H	↑								$1s^1$	1
2	He	↑↓								$1s^2$	
3	Li	↑↓	↑							[He] $2s^1$	2
4	Be	↑↓	↑↓							[He] $2s^2$	
5	B	↑↓	↑↓	↑						[He] $2s^2\,2p^1$	
6	C	↑↓	↑↓	↑ ↑						[He] $2s^2\,2p^2$	
7	N	↑↓	↑↓	↑ ↑ ↑						[He] $2s^2\,2p^3$	
8	O	↑↓	↑↓	↑↓ ↑ ↑						[He] $2s^2\,2p^4$	
9	F	↑↓	↑↓	↑↓ ↑↓ ↑						[He] $2s^2\,2p^5$	
10	Ne	↑↓	↑↓	↑↓ ↑↓ ↑↓						[He] $2s^2\,2p^6$	

Li (Lithium): $1s^2\,2s^1$ or [He] $2s^1$

Ne (Neon): $1s^2\,2s^2\,2p^6$ or [He] $2s^2\,2p^6$

Remember: 4s before 3d

Full shells are very stable (chemically inert): noble gases (group 8; noble gas configuration). Half-full shells are also more stable than other electron configurations.

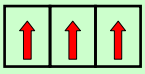
Build-up Principle for Electron Shells

3 basic rules !!!!

1. Pauli Principle: An Atom cannot have two electrons with the same 4 quantum numbers

   → Atomic orbital: 2 electrons must have an opposite spin

2. 'Hund' Rule: Orbitals characterised by / are occupied that the number of electrons with the same spin orientation is maximised



2p orbitals with 3 electrons

3. Lower energy levels are occupied first

……. back to the Periodic Table

- Elements with an analogous electron configuration have similar properties

→ groups – the vertical rows of the periodic table

- The principle of the Periodic Table is based on the increase of the atomic number (number of protons → number of electrons)

→ Successive increase of the valence electrons in the periods – the horizontal rows of the periodic table

- Main group elements: e.g. n = 2, s and p orbitals

  Transition metal elements: e.g. n = 3, s and p and d orbitals

Ionisation Energy (IE)

$$E\,(g) \longrightarrow E^{+}\,(g) + e^{-}\,(g)$$

atom + ionisation energy (I) → $atom^{+}$ (cation) + electron (e^{-})

Is the energy that is necessary to remove an electron from an atom or a molecule. The *Ionisation Energy* is a measure for the force by which an electron is bound in the atom. The Ionisation Energy is a function of the radius and the charge of an atom:

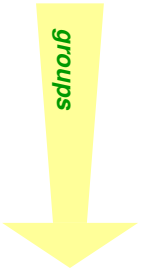
Ionisation Energy (IE)

Tendencies within the Periodic Table

Increase within the periods

<u>Reason:</u> electrostatic attraction between electrons and more positively charged nuclei increases

Decrease within the main groups

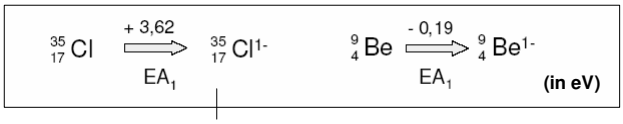


<u>Reason:</u> electrostatic attraction between positively charged nuclei and electrons in far outer shells is reduced

Electron Affinity (EA)

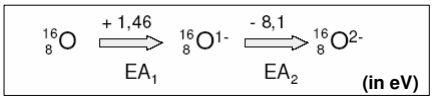
atom + electron (e^-) → atom$^-$ (anion) + electron affinity (EA)

…the electron affinity is the energy that is transferred on acceptance of an electron – it can be positive or negative!



In this case: + EA: Energy is released !

…. in the case of oxygen:



An anion does not like to accept an electron !!! → 2nd EA is always negative !!