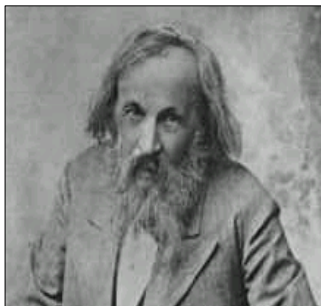


## Lecture 3

### 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 interpreting 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.

	Li	Be	B	C	N	O	F
<i>highly reactive soft metals</i>	Na	Mg	Al	Si	P	S	Cl
	K	Ca					

*Suffocating smelly, coloured gases*

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

„Increasing atomic mass“

*Is this principle always obeyed??*

Argon (Ar<sub>18</sub>): 39.948 u ↔ Potassium (K<sub>19</sub>): 39.0983 u

Tellurium (Te<sub>52</sub>): 127.60 u ↔ Iodine (I<sub>53</sub>): 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 tellurium and iodine.**

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

## The Modern Periodic Table

**MAIN-GROUP ELEMENTS**

**Metals (main-group)**  
**Metals (transition)**  
**Metals (inner transition)**  
**Metalloids**  
**Nonmetals**

**MAIN-GROUP ELEMENTS**

Period	1A (1)	2A (2)	TRANSITION ELEMENTS										3A (13)	4A (14)	5A (15)	6A (16)	7A (17)	8A (18)	
1	H (1) 1.008																	He (2) 4.003	
2	Li (3) 6.941	Be (4) 9.012																	
3	Na (11) 22.99	Mg (12) 24.31	3B (3)	4B (4)	5B (5)	6B (6)	7B (7)	8B (8)	(9)	(10)	1B (11)	2B (12)	Al (13) 26.98	Si (14) 28.09	P (15) 30.97	S (16) 32.07	Cl (17) 35.45	Ar (18) 39.95	
4	K (19) 39.10	Ca (20) 40.08	Sc (21) 44.96	Ti (22) 47.88	V (23) 50.94	Cr (24) 52.00	Mn (25) 54.94	Fe (26) 55.85	Co (27) 58.93	Ni (28) 58.69	Cu (29) 63.55	Zn (30) 65.39	Ga (31) 69.72	Ge (32) 72.61	As (33) 74.92	Se (34) 78.96	Br (35) 79.90	Kr (36) 83.80	
5	Rb (37) 85.47	Sr (38) 87.62	Y (39) 88.91	Zr (40) 91.22	Nb (41) 92.91	Mo (42) 95.94	Tc (43) 98	Ru (44) 101.1	Rh (45) 102.9	Pd (46) 106.4	Ag (47) 107.9	Cd (48) 112.4	In (49) 114.8	Sn (50) 118.7	Sb (51) 121.8	Te (52) 127.6	I (53) 126.9	Xe (54) 131.3	
6	Cs (55) 132.9	Ba (56) 137.3	La (57) 138.9	Hf (72) 178.5	Ta (73) 180.9	W (74) 183.9	Re (75) 186.2	Os (76) 190.2	Ir (77) 192.2	Pt (78) 195.1	Au (79) 197.0	Hg (80) 200.6	Tl (81) 204.4	Pb (82) 207.2	Bi (83) 209.0	Po (84) (209)	At (85) (210)	Rn (86) (222)	
7	Fr (87) (223)	Ra (88) (226)	Ac (89) (227)	Rf (104) (261)	Db (105) (262)	Sg (106) (266)	Bh (107) (262)	Hs (108) (265)	Mt (109) (266)	110	111	112	114						
			<b>INNER TRANSITION ELEMENTS</b>																
6	Lanthanides		Ce (58) 140.1	Pr (59) 140.9	Nd (60) 144.2	Pm (61) (145)	Sm (62) 150.4	Eu (63) 152.0	Gd (64) 157.3	Tb (65) 158.9	Dy (66) 162.5	Ho (67) 164.9	Er (68) 167.3	Tm (69) 168.9	Yb (70) 173.0	Lu (71) 175.0			
7	Actinides		Th (90) 232.0	Pa (91) (231)	U (92) 238.0	Np (93) (237)	Pu (94) (242)	Am (95) (243)	Cm (96) (247)	Bk (97) (247)	Cf (98) (251)	Es (99) (252)	Fm (100) (257)	Md (101) (258)	No (102) (259)	Lr (103) (260)			

## The structure of the Periodic Table

### Metals, Metalloids, and Nonmetals

**METALS**

Copper, Cadmium, Lead, Chromium, Bismuth

**METALLOIDS**

Arsenic, Silicon, Antimony, Boron, Tellurium

**NONMETALS**

Chlorine, Bromine, Carbon (graphite), Sulfur, Iodine

## The structure of the Periodic Table

The periodic table is color-coded as follows:

- Metals:** Green (Groups 1-10, 11-12, 13-16, 17-18)
- Metalloids:** Brown (Groups 13-16)
- Nonmetals:** Blue (Groups 17-18)

Key labels and their corresponding elements:

- Alkali Metal:** Group 1 (IA) - H, Li, Na, K, Rb, Cs, Fr
- Alkali Earth Metal:** Group 2 (IIA) - Be, Mg, Ca, Sr, Ba, Ra
- Transition Metal:** Groups 3-10 (IB-8B) - Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Ge, As, Se, Br, Kr, Rb, Sr, Y, Zr, Nb, Mo, Tc, Ru, Rh, Pd, Ag, Cd, In, Sn, Sb, Te, I, Xe, Ba, La, Hf, Ta, W, Re, Os, Ir, Pt, Au, Hg, Tl, Pb, Bi, Po, At, Rn, Ac, Th, Pa, U, Np, Pu, Am, Cm, Bk, Cf, Es, Fm, Md, No, Lr
- Group:** Vertical columns (e.g., Group 13: B, Al, Ga, In, Tl, Sn, Pb, Bi, Po, At, Fr)
- Period:** Horizontal rows (e.g., Period 2: Li, Be, B, C, N, O, F, Ne)
- Halogen:** Group 17 (VIIA) - F, Cl, Br, I, At
- Noble Gas:** Group 18 (VIIIA) - He, Ne, Ar, Kr, Xe, Rn

## Structure of the Periodic Table

### Main Group Elements (Vertical Groups)

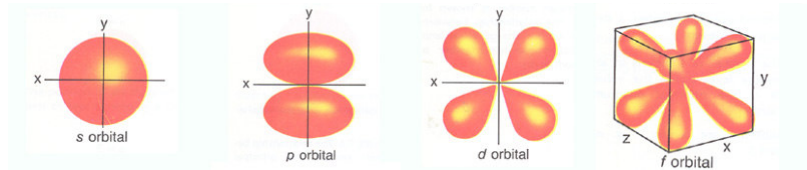
- Group 1(IA) - Alkali Metals**
- Group 2(IIA) - Alkaline Earth Metals**
- Group 13(IIIA) - Boron Family**
- Group 14(IVA) - Carbon Family**
- Group 15(VA) - Nitrogen Family**
- Group 16(VIA) - Oxygen Family (Chalcogens)**
- Group 17(VIIA) - Halogens**
- Group 18(VIIIA) - Noble Gases**

### 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	$m_s$

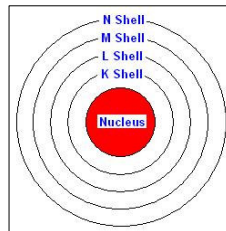
determines the values

- 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

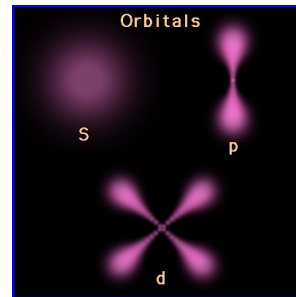
## Atoms: Structure of the Electron Shell

1 s-orbitals

3 p-orbitals

5 d-orbitals

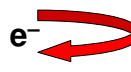
characterised by  $m_l$  number



Orbital: "space" for 2 electrons

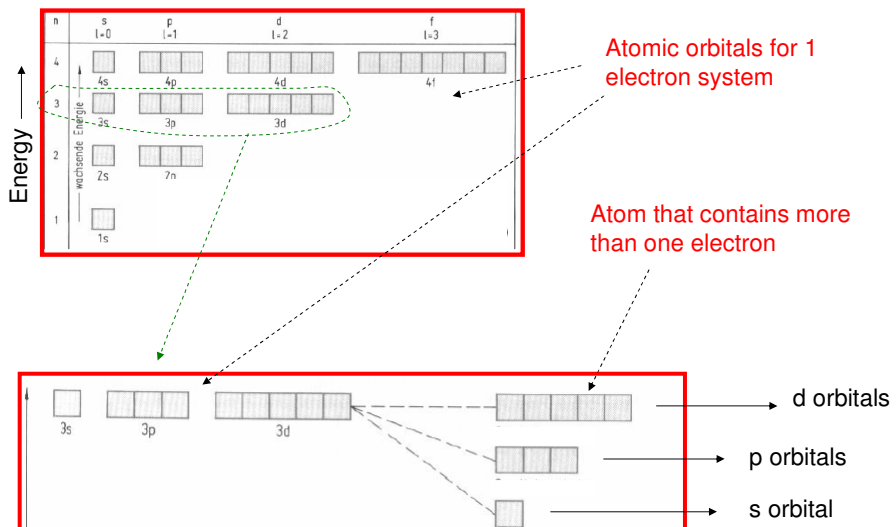
$m_s = +1/2$

$m_s = -1/2$



Spin angular moment

## Atoms: Structure of the Electron Shell



## Build-up Principle for Electron Shells

Z	Element	K 1s	L 2s 2p	M 3s 3p 3d	N 4s 4p	Symbol	Period
1	H	↑				1s <sup>1</sup>	1
2	He	↑↓				1s <sup>2</sup>	
⇒ 3	Li	↑↓	↑			[He] 2s <sup>1</sup>	2
4	Be	↑↓	↑↓			[He] 2s <sup>2</sup>	
5	B	↑↓	↑↓	↑		[He] 2s <sup>2</sup> 2p <sup>1</sup>	
6	C	↑↓	↑↓	↑↑		[He] 2s <sup>2</sup> 2p <sup>2</sup>	
7	N	↑↓	↑↓	↑↑↑		[He] 2s <sup>2</sup> 2p <sup>3</sup>	
8	O	↑↓	↑↓	↑↓↑↑		[He] 2s <sup>2</sup> 2p <sup>4</sup>	
9	F	↑↓	↑↓	↑↓↑↑↑		[He] 2s <sup>2</sup> 2p <sup>5</sup>	
⇒ 10	Ne	↑↓	↑↓	↑↓↑↓↑↓		[He] 2s <sup>2</sup> 2p <sup>6</sup>	

Li (Lithium): 1s<sup>2</sup> 2s<sup>1</sup> or [He] 2s<sup>1</sup>

Ne (Neon): 1s<sup>2</sup> 2s<sup>2</sup> 2p<sup>6</sup> or [He] 2s<sup>2</sup> 2p<sup>6</sup>

**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

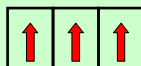
### 3 basic rules !!!!

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 *l* 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)



atom + ionisation energy (I) ➡ atom<sup>+</sup> (cation) + electron (e<sup>-</sup>)

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:



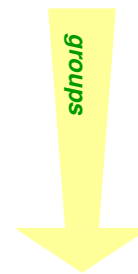
## Ionisation Energy (IE) *Tendencies within the Periodic Table*

**Increase within the periods**



**Reason:** electrostatic attraction between electrons and more positively charged nuclei increases

**Decrease within the main groups**

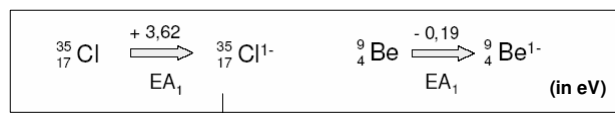


**Reason:** electrostatic attraction between positively charged nuclei and electrons in far outer shells is reduced

## Electron Affinity (EA)

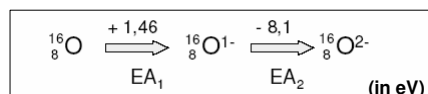


...the electron affinity is the energy that is transferred on acceptance of an electron – it can be positive or negative!



*In this case: + EA: Energy is released !*

.... in the case of oxygen:



An anion does not like to accept an electron !!!  $\longrightarrow$  2<sup>nd</sup> EA is always negative !!