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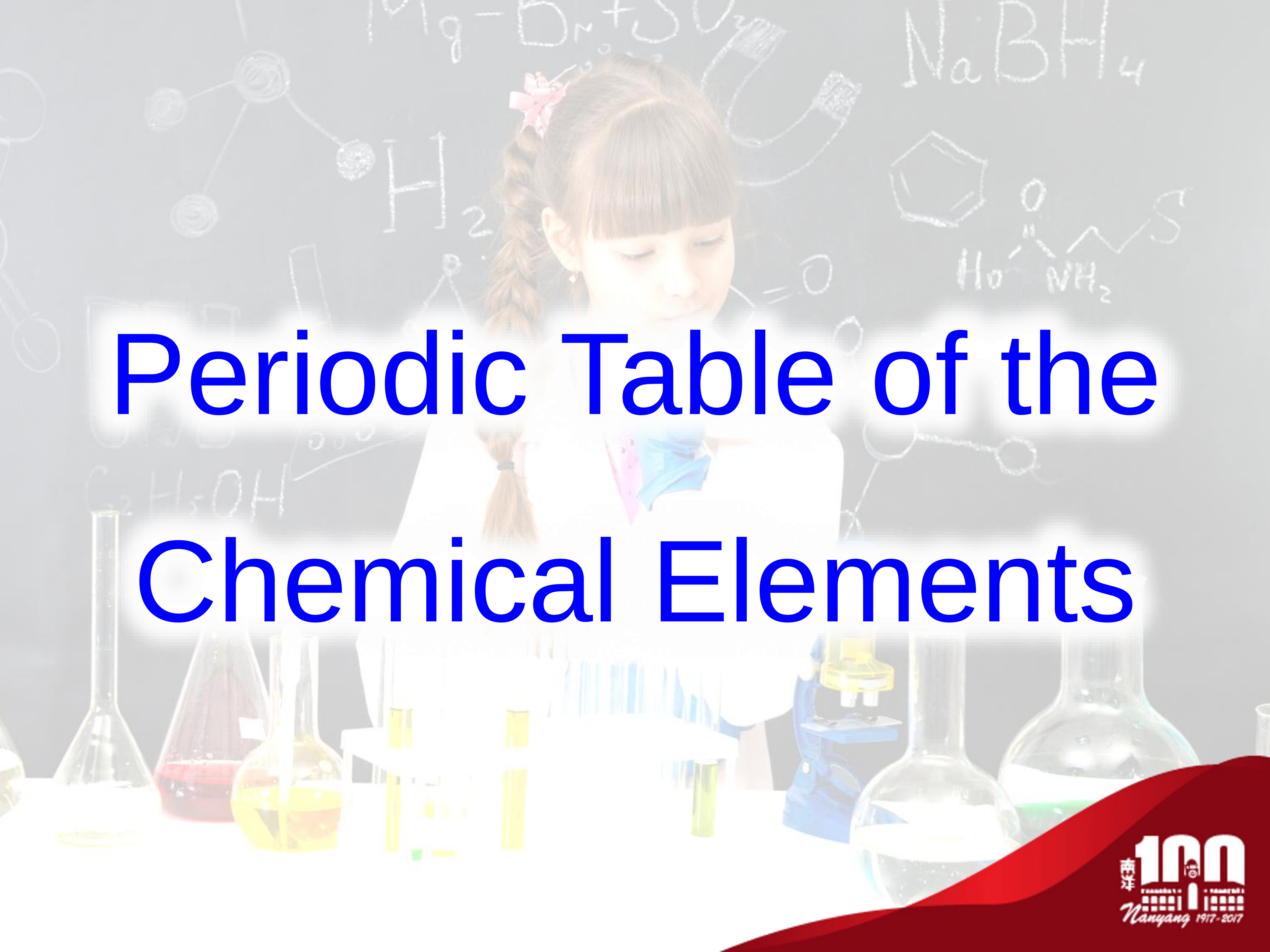
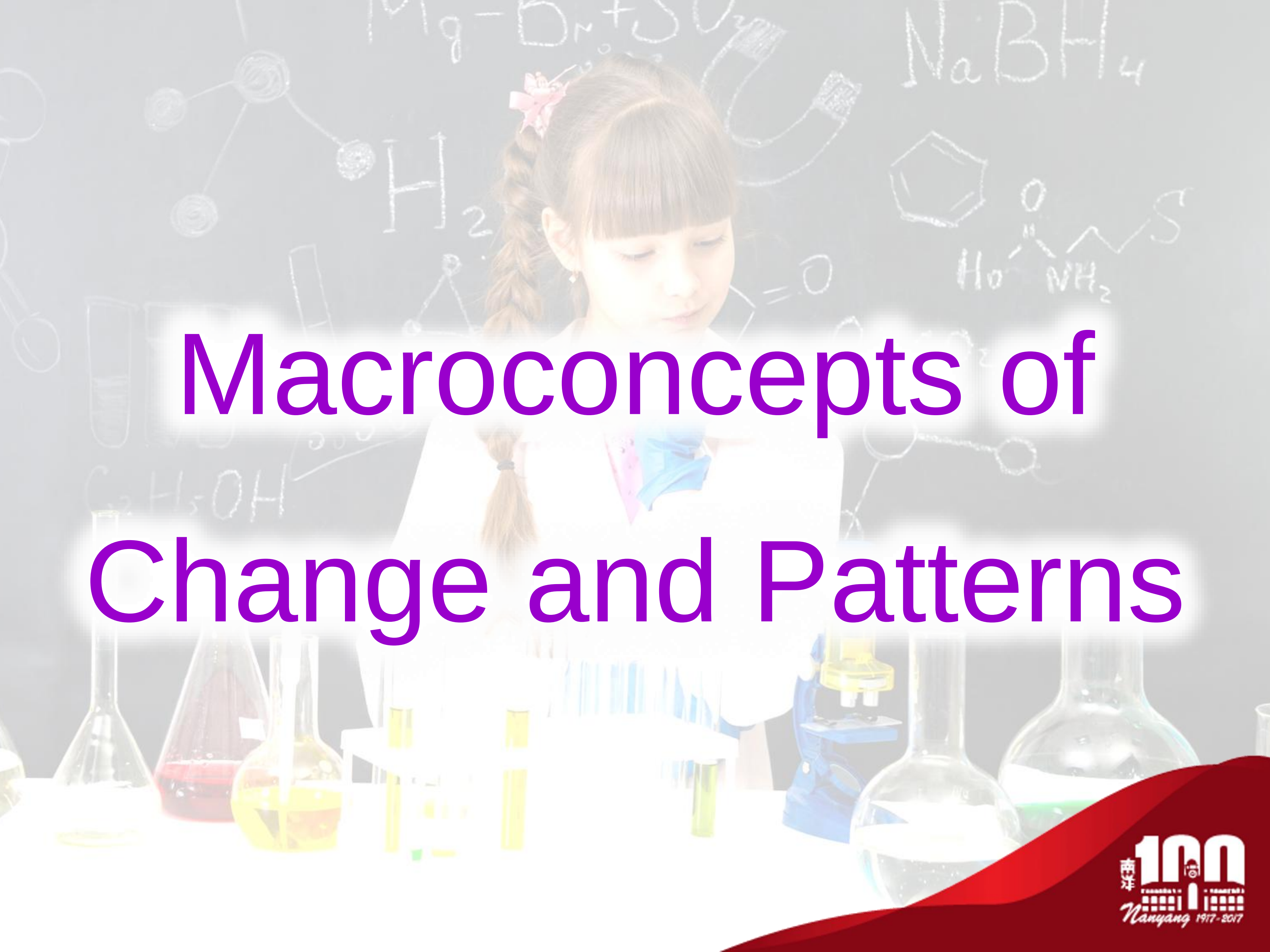
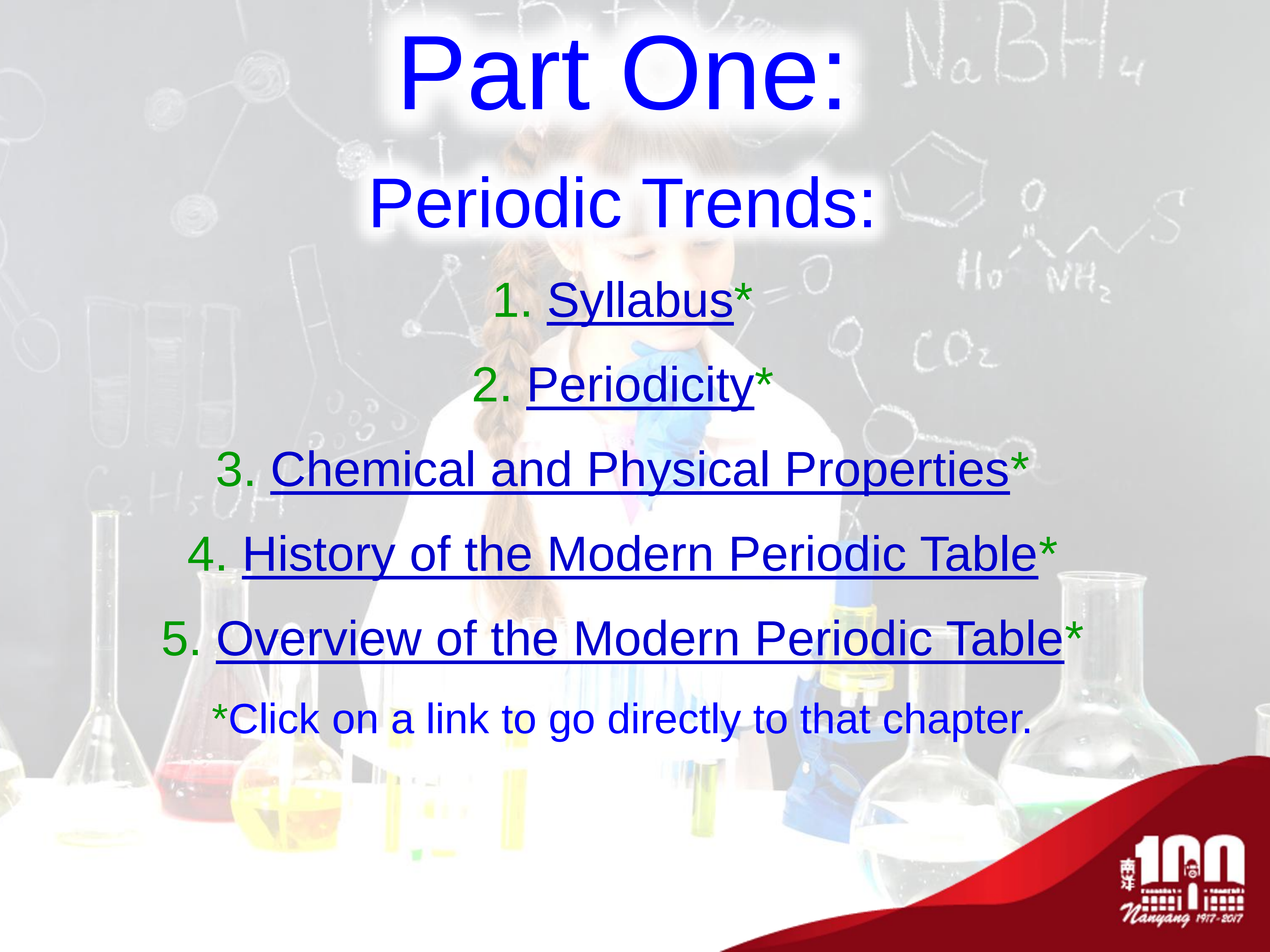
Nanyang 1917-2017



Periodic Table of the Chemical Elements



Macroconcepts of Change and Patterns



Part One:

Periodic Trends:

1. Syllabus*
2. Periodicity*
3. Chemical and Physical Properties*
4. History of the Modern Periodic Table*
5. Overview of the Modern Periodic Table*

*Click on a link to go directly to that chapter.

Part One:

Periodic Trends:

6. Essential Periodic Trends*

a) Metals, Metalloids and Non-metals*
b) Electrical Conductivity*
c) Melting Points*
d) Electrostatic Forces*
e) Atomic Radius*
f) First Ionisation Energy*
g) Electronegativity*

*Click on a link to go directly to that chapter.

The Elements

H 1 Hydrogen																	He 2 Helium
Li 3 Lithium	Be 4 Beryllium											B 5 Boron	C 6 Carbon	N 7 Nitrogen	O 8 Oxygen	F 9 Fluorine	Ne 10 Neon
Na 11 Sodium	Mg 12 Magnesium											Al 13 Aluminum	Si 14 Silicon	P 15 Phosphorus	S 16 Sulfur	Cl 17 Chlorine	Ar 18 Argon
K 19 Potassium	Ca 20 Calcium	Sc 21 Scandium	Ti 22 Titanium	V 23 Vanadium	Cr 24 Chromium	Mn 25 Manganese	Fe 26 Iron	Co 27 Cobalt	Ni 28 Nickel	Cu 29 Copper	Zn 30 Zinc	Ga 31 Gallium	Ge 32 Germanium	As 33 Arsenic	Se 34 Selenium	Br 35 Bromine	Kr 36 Krypton
Rb 37 Rubidium	Sr 38 Strontium	Y 39 Yttrium	Zr 40 Zirconium	Nb 41 Niobium	Mo 42 Molybdenum	Tc ☢ 43 Technetium	Ru 44 Ruthenium	Rh 45 Rhodium	Pd 46 Palladium	Ag 47 Silver	Cd 48 Cadmium	In 49 Indium	Sn 50 Tin	Sb 51 Antimony	Te 52 Tellurium	I 53 Iodine	Xe 54 Xenon
Cs 55 Cesium	Ba 56 Barium		Hf 72 Hafnium	Ta 73 Tantalum	W 74 Tungsten	Re 75 Rhenium	Os 76 Osmium	Ir 77 Iridium	Pt 78 Platinum	Au 79 Gold	Hg 80 Mercury	Tl 81 Thallium	Pb 82 Lead	Bi 83 Bismuth	Po ☢ 84 Polonium	At ☢ 85 Astatine	Rn ☢ 86 Radon
Fr ☢ 87 Francium	Ra ☢ 88 Radium		Rf ☢ 104 Rutherfordium	Db ☢ 105 Dubnium	Sg ☢ 106 Seaborgium	Bh ☢ 107 Bohrium	Hs ☢ 108 Hassium	Mt ☢ 109 Meitnerium	Ds ☢ 110 Darmstadtium	Rg ☢ 111 Roentgenium	Uub ☢ 112 Ununbium	Uut ☢ 113 Ununtrium	Uuq ☢ 114 Ununquadium	Uup ☢ 115 Ununpentium	Uuh ☢ 116 Ununhexium	Uus ☢ 117 Ununseptium	Uuo ☢ 118 Ununoctium
		La 57 Lanthanum	Ce 58 Cerium	Pr 59 Praseodymium	Nd 60 Neodymium	Pm ☢ 61 Promethium	Sm 62 Samarium	Eu 63 Europium	Gd 64 Gadolinium	Tb 65 Terbium	Dy 66 Dysprosium	Ho 67 Holmium	Er 68 Erbium	Tm 69 Thulium	Yb 70 Ytterbium	Lu 71 Lutetium	
		Ac ☢ 89 Actinium	Th ☢ 90 Thorium	Pa ☢ 91 Protactinium	U ☢ 92 Uranium	Np ☢ 93 Neptunium	Pu ☢ 94 Plutonium	Am ☢ 95 Americium	Cm ☢ 96 Curium	Bk ☢ 97 Berkelium	Cf ☢ 98 Californium	Es ☢ 99 Einsteinium	Fm ☢ 100 Fermium	Md ☢ 101 Mendelevium	No ☢ 102 Nobelium	Lr ☢ 103 Lawrencium	

☢ Radioactive elements

Photographs show samples of the pure or nearly pure element except as follows: At, Rn, Fr, Ac, Pa, and Np show radioactive minerals containing minute traces of the element. Po, Ra, Pm, Pu, and Am show artificial objects containing invisible amounts of the element. Technetium shows a Tc-99 bone scan. Hydrogen shows a Hubble Space Telescope image of the Eagle Nebula, which is mostly hydrogen. 96-111 show the person or place after which the element is named. 112-118 had not been named yet in 2006.

Poster and photography by Theodore W. Gray, RGB Research, Ltd.

Other sizes of this poster: periodictabletable.com
Real samples like these: element-collection.com

NANYANG GIRLS' HIGH

Periodic Table of the Chemical Elements

What do I need to know about the Periodic Table of Chemical Elements?

Syllabus

- Return to Main Menu

Periodic Table of the Chemical Elements

Syllabus

- Describe the Periodic Table as an arrangement of the elements in the order of increasing proton (atomic) number.
- Describe how the position of an element in the Periodic Table is related to proton number and electronic structure.
- Describe the relationship between group number and the ionic charge of an element.
- Explain the similarities between the elements in the same group of the Periodic Table in terms of their electronic structure.
- Describe the change from metallic to non-metallic character from left to right across a period of the Period Table.

Singapore Examinations and Assessment Board
University of Cambridge International Examinations
Ministry of Education, Singapore

Periodic Table of the Chemical Elements

Syllabus

- Describe the relationship between group number, number of valence electrons and metallic/non-metallic character.
- Predict the properties of elements in Group I and VII using the Periodic Table.
- Describe lithium, sodium and potassium in Group I (the alkali metals) as a collection of relatively soft, low density metals showing a trend in melting point and in their reaction with water.
- Describe chlorine, bromine and iodine in Group VII (the halogens) as a collection of diatomic non-metals showing a trend in colour, state and their displacement reactions with solutions of other halide ions.

Periodic Table of the Chemical Elements

Syllabus

- Describe the elements in Group 0 (the noble gases) as a collection of monatomic elements that are chemically unreactive and hence important in providing an inert atmosphere, e.g. argon and neon in light bulbs; helium in balloons; argon in the manufacture of steel.
- Describe the lack of reactivity of the noble gases in terms of their electronic structures.
- Describe the transition metals as a collection of elements with typical metallic properties, including high melting points and high densities.
- Describe the transition metals as a collection of elements that form coloured compounds, have variable oxidation states and have catalytic properties.

Periodic Table of the Chemical Elements

What is *Periodicity*? What is meant by the term *periodic trend*?

Periodicity

- Return to Main Menu

Periodic Table of the Chemical Elements

Introduction to Periodicity

- The term *periodic* refers to a property that *reoccurs* at *frequent intervals*. The frequent reoccurrence of the property often forms a *trend* or *pattern* that allows accurate *predictions* about the property to be made.

Periodic Table of the Chemical Elements

Introduction to Periodicity

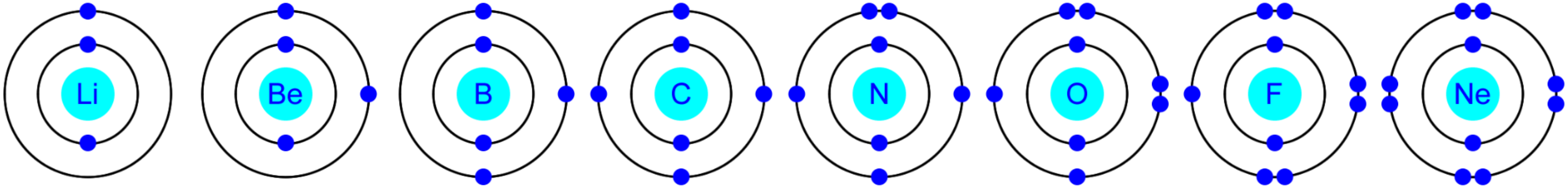
- Periodic trends are specific patterns that are present in the Periodic Table. These trends and patterns illustrate different aspects of a certain chemical element. Major periodic trends include:

→ atomic radius
→ electronegativity
→ first electron affinity
→ first ionization energy
→ melting point and boiling point
→ metallic character
→ reactivity

Periodic Table of the Chemical Elements

Introduction to Periodicity

- Periodic trends, arising from the arrangement of the chemical elements in the Periodic Table, provide chemists with an important way of predicting an element's properties. These trends exist because of the similar atomic structures and electronic configurations of the elements within their respective Groups and Periods.



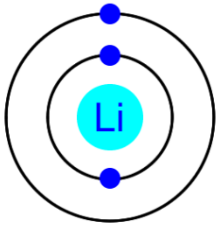
Periodic Table of the Chemical Elements

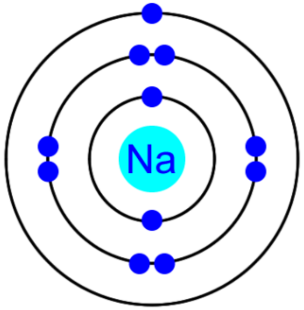
Introduction to Periodicity

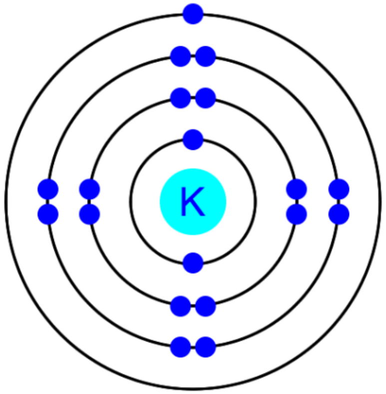
- These periodic trends are based on the *Periodic Law* which states that if the chemical elements are listed in order of increasing atomic number, many of their properties go through cyclical changes, meaning that elements with similar properties are found to occur at regular intervals.

Periodic Table of the Chemical Elements

Introduction to Periodicity







- For example, after arranging the chemical elements in order of increasing atomic number, many of the physical and chemical properties of *lithium* are found to reoccur in *sodium* (such as its vigorous reactivity with water) and then reoccur once again in *potassium*.

Periodic Table of the Chemical Elements

Introduction to Periodicity

- The reaction between *lithium* and water.

$2Li(s) + 2H_2O(l) \rightarrow 2LiOH(aq) + H_2(g)$

Periodic Table of the Chemical Elements

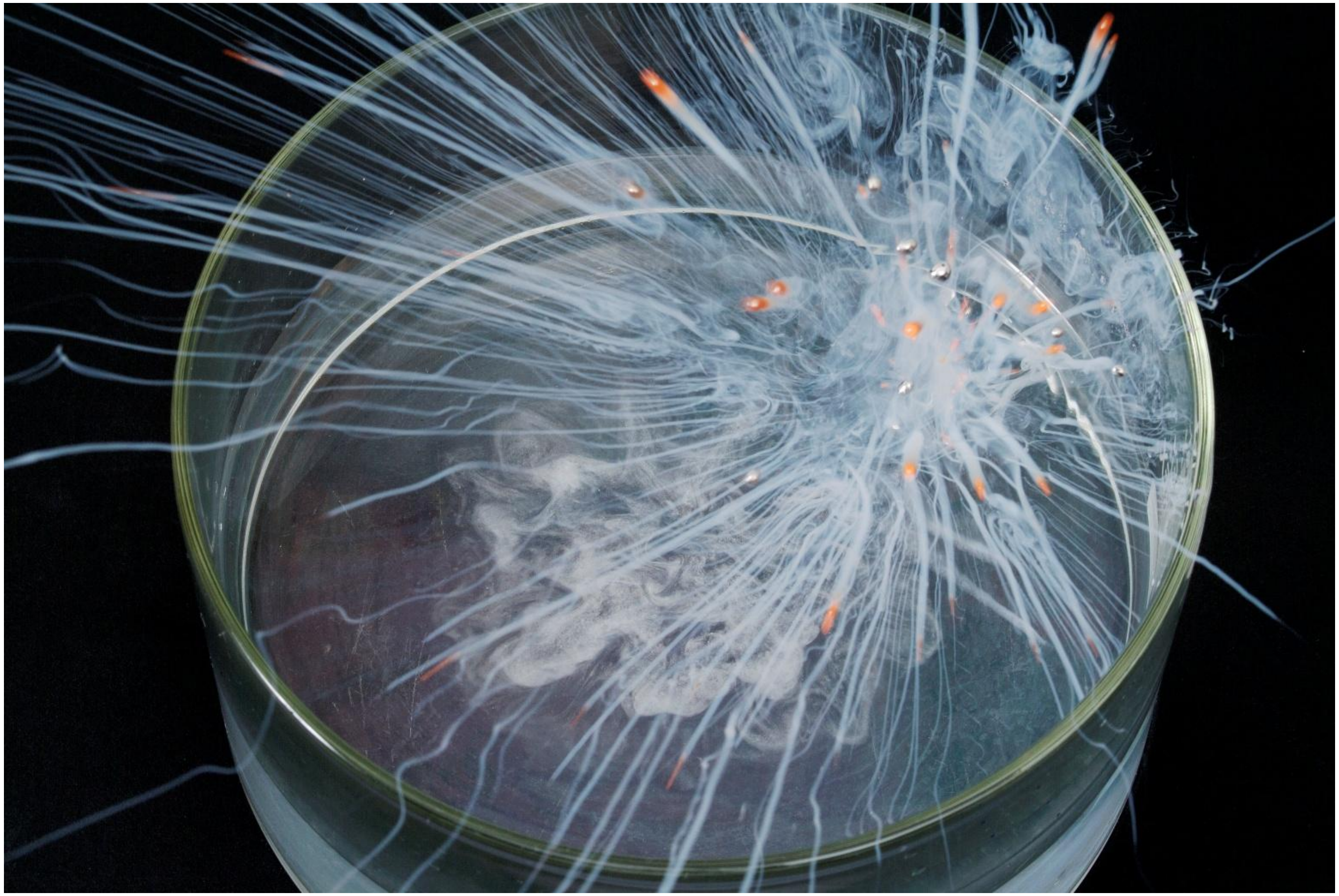
Introduction to Periodicity

- The reaction between *sodium* and water.

$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$

Periodic Table of the Chemical Elements

Introduction to Periodicity

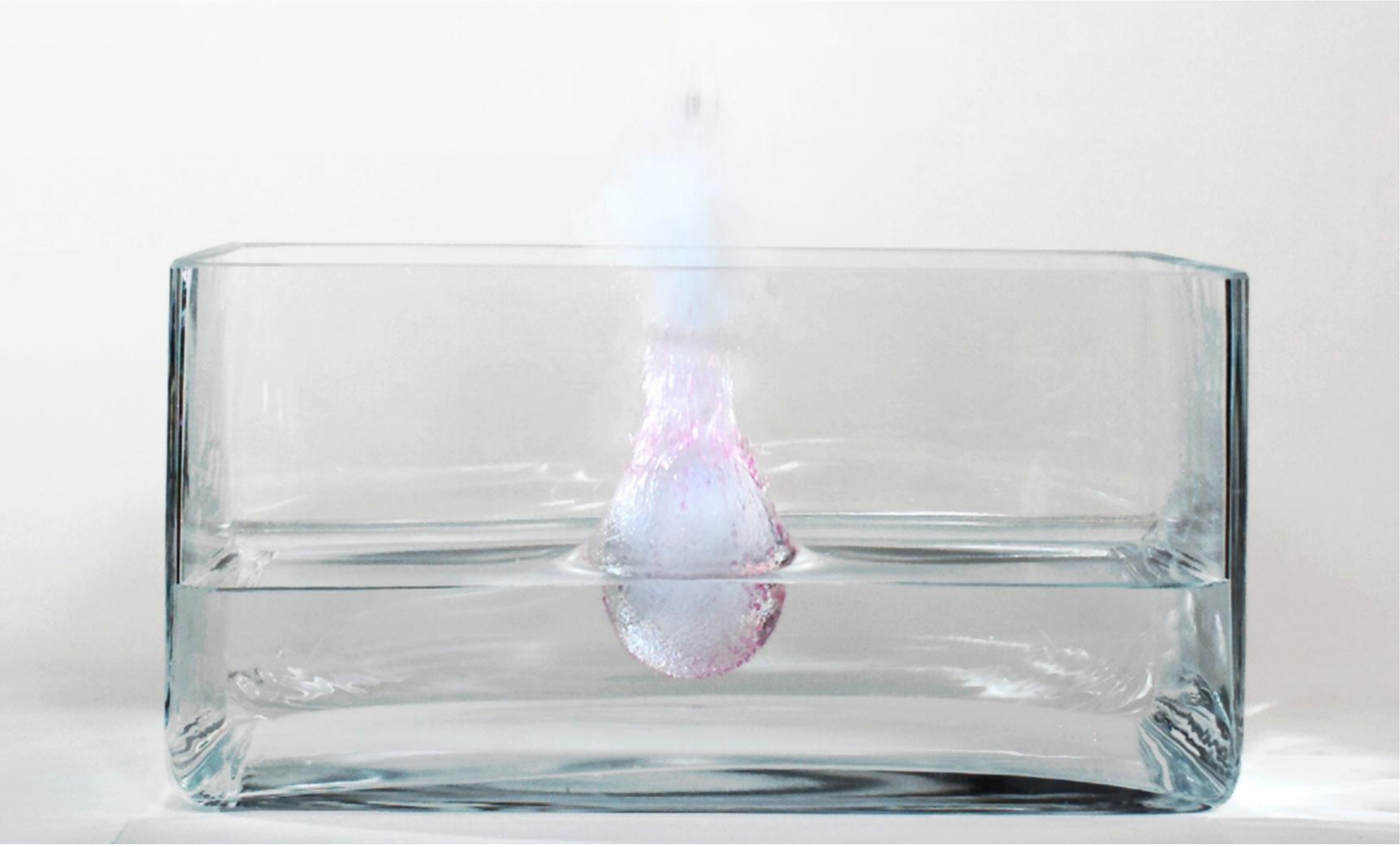


- The reaction between *potassium* and water.

$$2K(s) + 2H_2O(l) \rightarrow 2KOH(aq) + H_2(g)$$

Periodic Table of the Chemical Elements

Introduction to Periodicity



- The reaction between *rubidium* and water.

$2Rb(s) + 2H_2O(l) \rightarrow 2RbOH(aq) + H_2(g)$

Periodic Table of the Chemical Elements

What is are the differences between *chemical properties* and *physical properties*?

Chemical and Physical Properties

- Return to Main Menu

Periodic Table of the Chemical Elements

Chemical and Physical Properties

- *Chemical properties* are properties of a material that only become apparent during or after a chemical reaction. Examples of chemical properties include acid / base nature, reactivity (*e.g.* flammability) and toxicity.

- *Physical properties* are often measurable and quantifiable. Physical properties tend to be numerical in nature and (unless they are ratios) are accompanied by units. Examples of physical properties include melting point / °C and density g / cm^3.

Periodic Table of the Chemical Elements

How was the modern Periodic Table developed?

History of the Modern Periodic Table

- Return to Main Menu

Periodic Table of the Chemical Elements

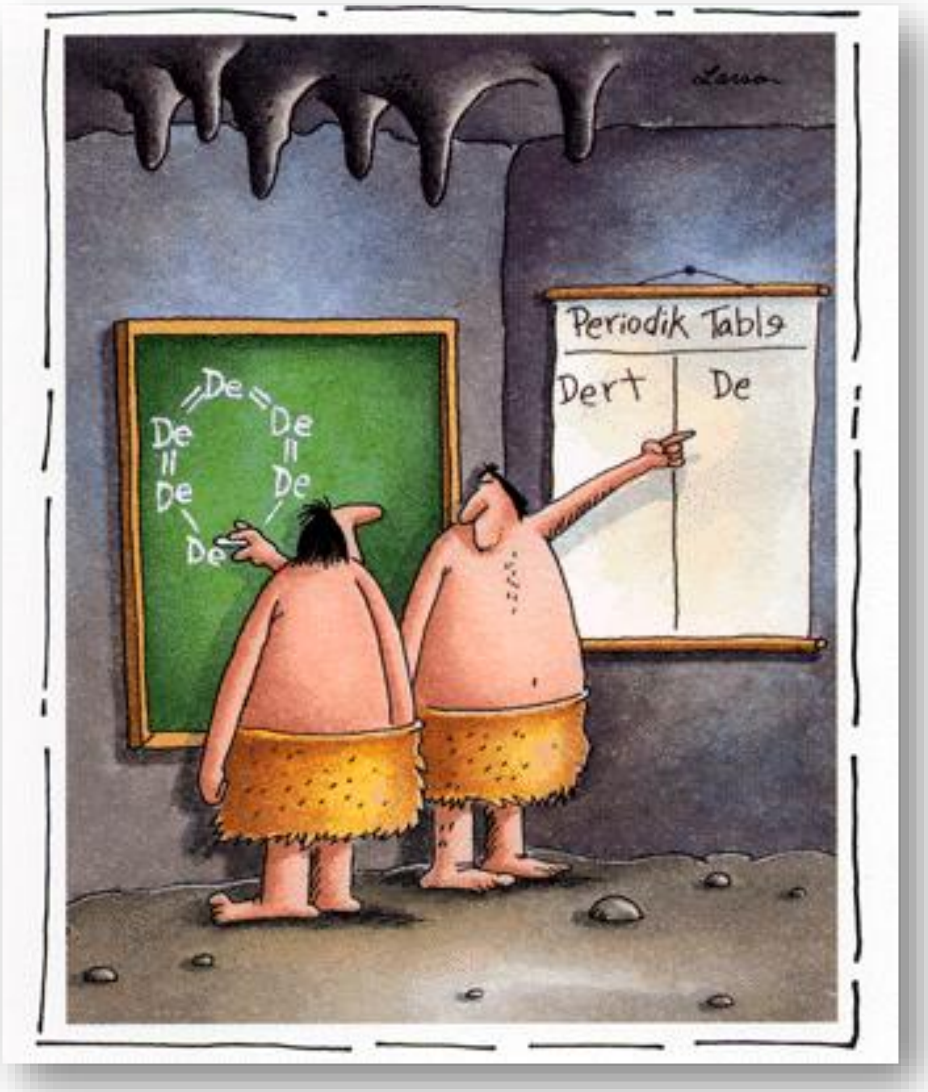
History of the Periodic Table

Some definitions:

- Element – A pure substance that cannot be converted into anything more simple by a chemical process.
- Atom – The smallest part of a chemical element that possesses all of the typical chemical properties of that element.

Periodic Table of the Chemical Elements

History of the Periodic Table



Early chemists describe the first dirt molecule.

The Far Side © Gary Larson

Periodic Table of the Chemical Elements

History of the Periodic Table

- Johann Döbereiner, 1780 – 1849

Periodic Table of the Chemical Elements

History of the Periodic Table

- In 1817, a German scientist named Johann Döbereiner realised that there was a connection between the relative atomic mass of an element and its chemical properties. In 1829 he arranged many of the chemical elements into groups of three, called *Döbereiner's Triads*, in which the relative atomic mass of the middle element is approximately the average mass of the other two.

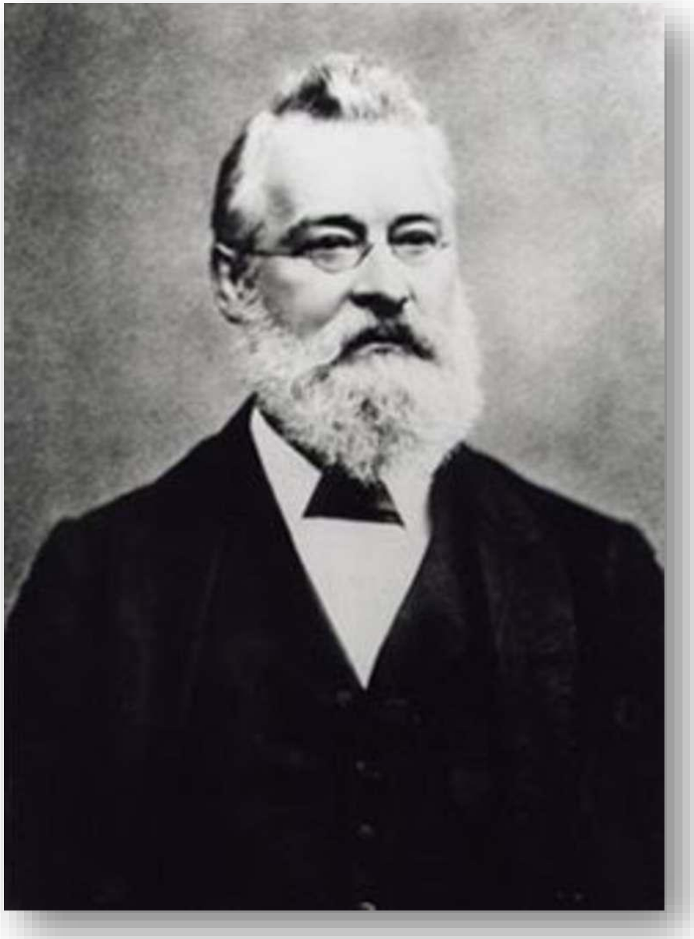
For example:

Lithium 7 Sodium 23 Potassium 39
Chlorine 35.5 Bromine 80 Iodine 127

However, only a few elements form groups of three.

Periodic Table of the Chemical Elements

History of the Periodic Table



- John Newlands, 1837 – 1898

Periodic Table of the Chemical Elements

History of the Periodic Table

- In 1864, a British chemist called John Newlands arranged the chemical elements in order of their relative atomic mass and assigned each element a number:

Hydrogen (the lightest element) = 1
(Helium was not known to exist at the time)
Lithium = 2
Beryllium = 3

… and so on …

- Newlands was the first scientist to list the chemical elements in numerical order, leave spaces for elements that were still undiscovered and even alter the position of elements when he believed that their relative atomic mass was incorrect.

Periodic Table of the Chemical Elements

History of the Periodic Table

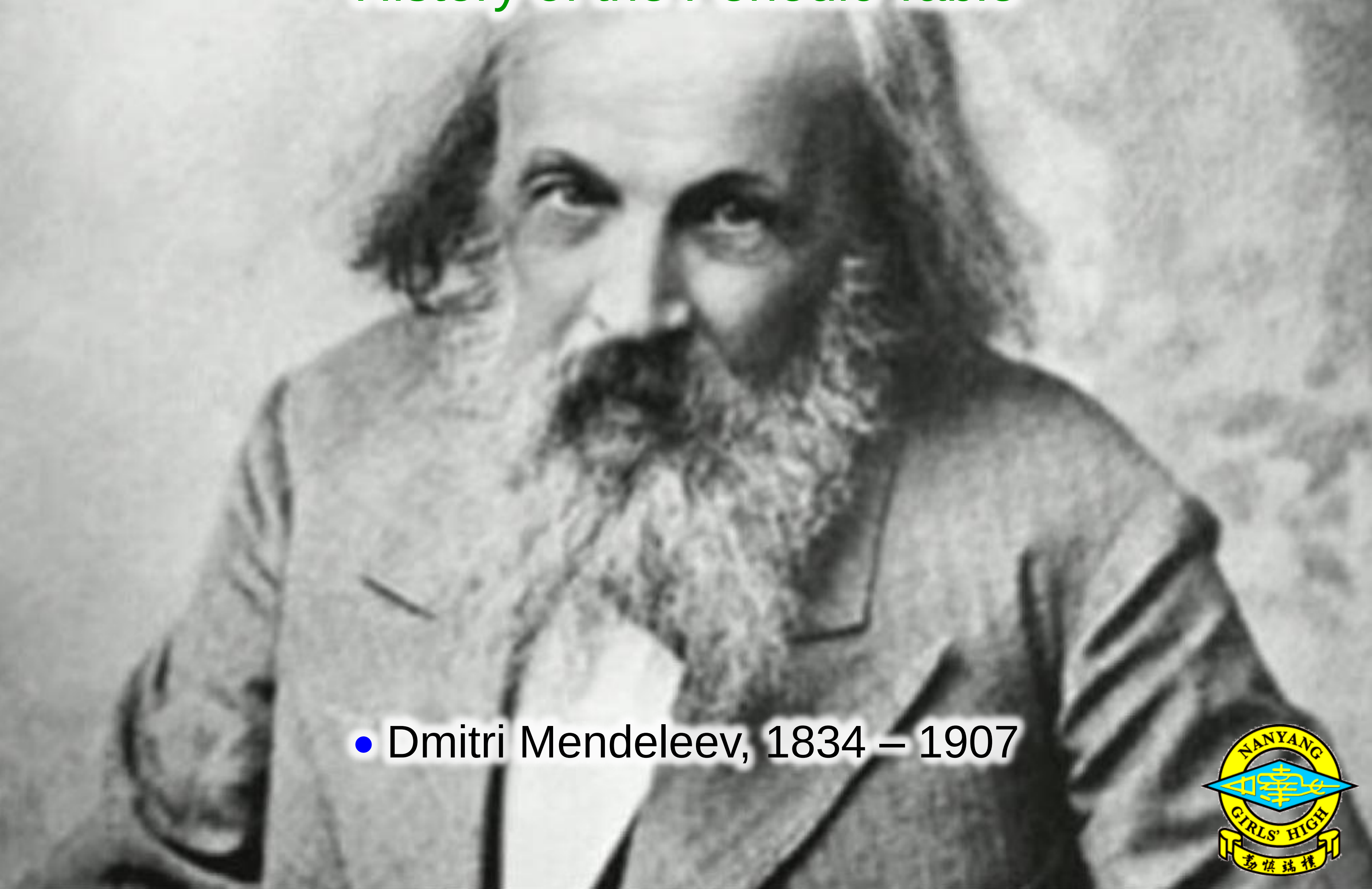
- Newland’s Law of Octaves stated that elements with similar chemical properties had numbers which differed by 7 (for example, 1, 8 and 15 were similar, and so were elements 3, 10 and 17). However, Newland’s Law did not apply after element 17, calcium.

1 H	2 Li	3 Be	4 B	5 C	6 N	7 O
8 F	9 Na	10 Mg	11 Al	12 Si	13 P	14 S
15 Cl	16 K	17 Ca				

- **Note:** Helium, neon and argon were not known to exist at the time.

Periodic Table of the Chemical Elements

History of the Periodic Table



- Dmitri Mendeleev, 1834 – 1907

Periodic Table of the Chemical Elements

History of the Periodic Table

- In 1869, a Russian chemist called Dmitri Mendeleev stated that *the properties of the elements are a periodic function of their atomic masses*. This periodic law means that if the chemical elements are arranged in order of increasing relative atomic mass, elements with similar chemical properties appear at regular intervals.

- Mendeleev’s Periodic Table was incomplete because many chemical elements (for example, the noble gases) had not been discovered at that time. In addition to this, Mendeleev’s Periodic Table contained several errors because *relative atomic mass* instead of *atomic number* had been used to arrange the elements in order.

Periodic Table of the Chemical Elements

History of the Periodic Table

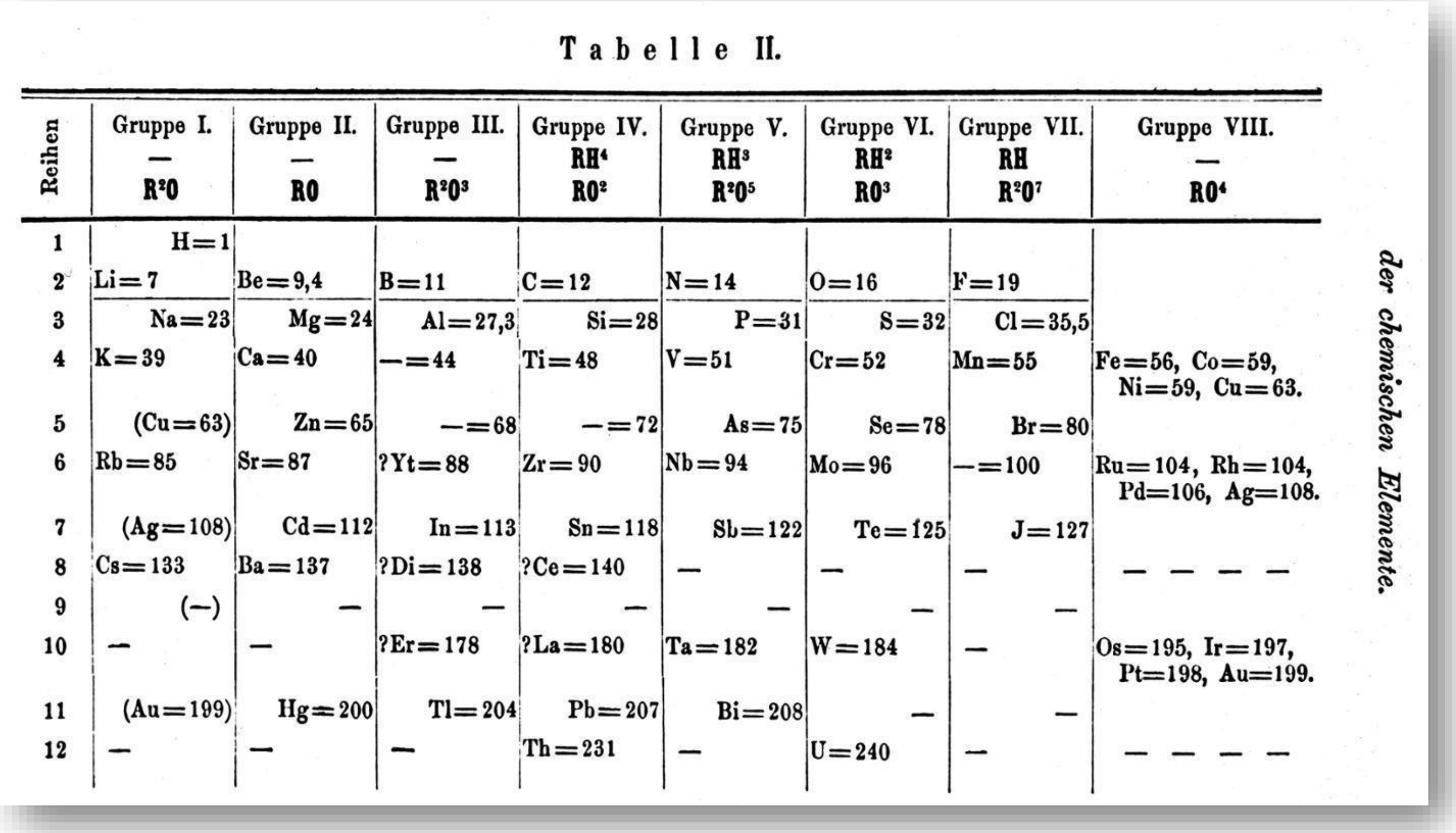


Tabelle II.

Reihen	Gruppe I. — R^2O	Gruppe II. — RO	Gruppe III. — R^2O^3	Gruppe IV. RH^4 RO^2	Gruppe V. RH^3 R^2O^5	Gruppe VI. RH^2 RO^3	Gruppe VII. RH R^2O^7	Gruppe VIII. — RO^4
1	H=1							
2	Li=7	Be=9,4	B=11	C=12	N=14	O=16	F=19	
3	Na=23	Mg=24	Al=27,3	Si=28	P=31	S=32	Cl=35,5	
4	K=39	Ca=40	—=44	Ti=48	V=51	Cr=52	Mn=55	Fe=56, Co=59, Ni=59, Cu=63.
5	(Cu=63)	Zn=65	—=68	—=72	As=75	Se=78	Br=80	
6	Rb=85	Sr=87	?Yt=88	Zr=90	Nb=94	Mo=96	—=100	Ru=104, Rh=104, Pd=106, Ag=108.
7	(Ag=108)	Cd=112	In=113	Sn=118	Sb=122	Te=125	J=127	
8	Cs=133	Ba=137	?Di=138	?Ce=140	—	—	—	— — — —
9	(—)	—	—	—	—	—	—	
10	—	—	?Er=178	?La=180	Ta=182	W=184	—	Os=195, Ir=197, Pt=198, Au=199.
11	(Au=199)	Hg=200	Tl=204	Pb=207	Bi=208	—	—	
12	—	—	—	Th=231	—	U=240	—	— — — —

der chemischen Elemente.

- Dmitri Mendeleev’s Periodic Table. Note the way that chemical formulae were written in 1869.

Periodic Table of the Chemical Elements

History of the Periodic Table

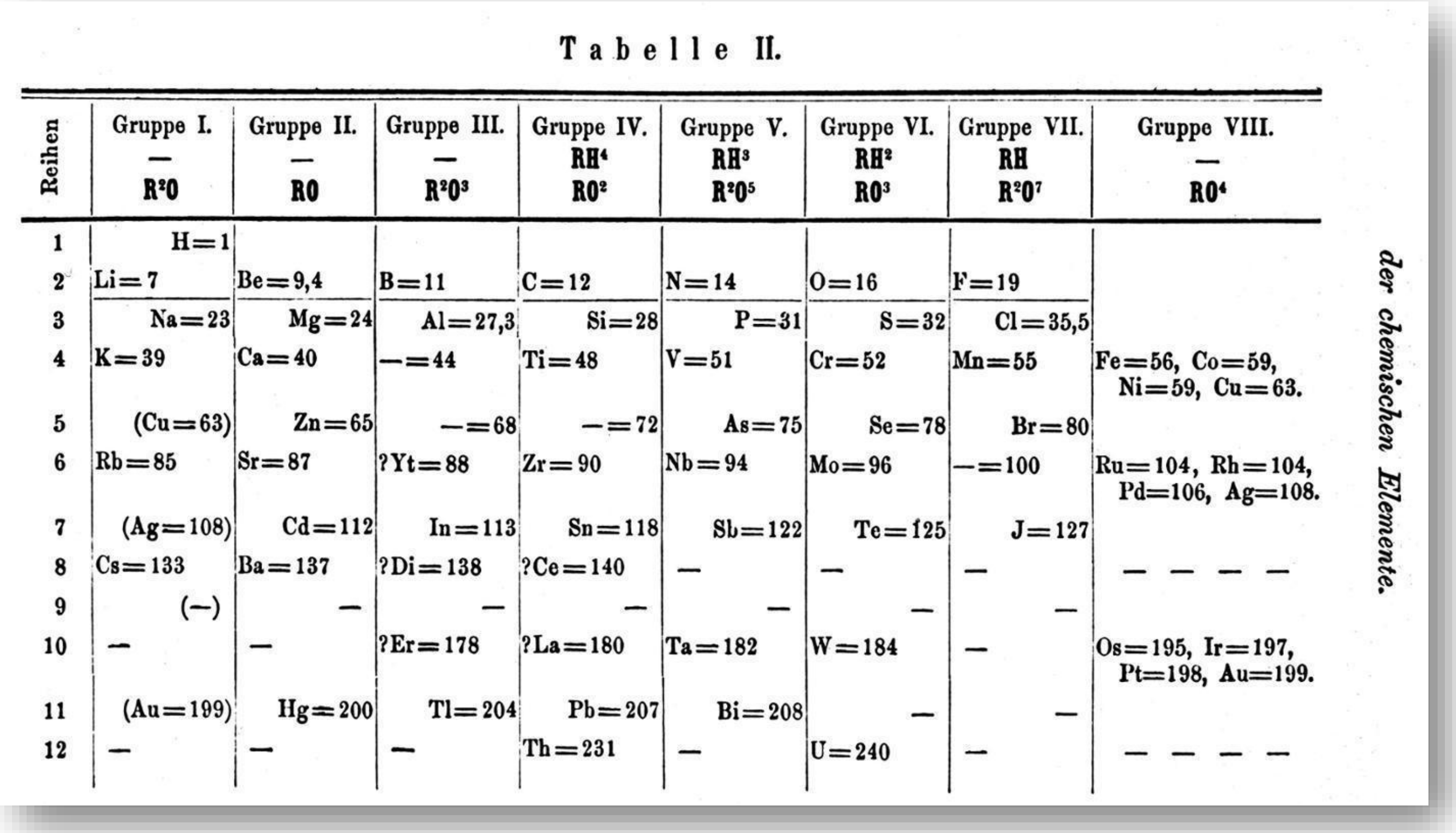


Tabelle II.

Reihen	Gruppe I. — R^2O	Gruppe II. — RO	Gruppe III. — R^2O^3	Gruppe IV. RH^4 RO^2	Gruppe V. RH^3 R^2O^5	Gruppe VI. RH^2 RO^3	Gruppe VII. RH R^2O^7	Gruppe VIII. — RO^4
1	H=1							
2	Li=7	Be=9,4	B=11	C=12	N=14	O=16	F=19	
3	Na=23	Mg=24	Al=27,3	Si=28	P=31	S=32	Cl=35,5	
4	K=39	Ca=40	—=44	Ti=48	V=51	Cr=52	Mn=55	Fe=56, Co=59, Ni=59, Cu=63.
5	(Cu=63)	Zn=65	—=68	—=72	As=75	Se=78	Br=80	
6	Rb=85	Sr=87	?Yt=88	Zr=90	Nb=94	Mo=96	—=100	Ru=104, Rh=104, Pd=106, Ag=108.
7	(Ag=108)	Cd=112	In=113	Sn=118	Sb=122	Te=125	J=127	
8	Cs=133	Ba=137	?Di=138	?Ce=140	—	—	—	— — — —
9	(—)	—	—	—	—	—	—	
10	—	—	?Er=178	?La=180	Ta=182	W=184	—	Os=195, Ir=197, Pt=198, Au=199.
11	(Au=199)	Hg=200	Tl=204	Pb=207	Bi=208	—	—	
12	—	—	—	Th=231	—	U=240	—	— — — —

der chemischen Elemente.

- Dmitri Mendeleev’s Periodic Table. Also note the spaces that Mendeleev left for elements that had not been discovered at the time.

Periodic Table of the Chemical Elements

History of the Periodic Table

- Henry Moseley, 1887 – 1915

Periodic Table of the Chemical Elements

History of the Periodic Table

RSC | Advancing the Chemical Sciences

National Chemical Landmark

Clarendon Laboratory

where H G J Moseley (1887-1915) completed his pioneering studies on the frequencies of X-rays emitted from the elements. His work established the concept of atomic number and helped reveal the structure of the atom. He predicted several new elements and laid the ground for a major tool in chemical analysis.

24 September 2007

- Henry Moseley, 1887 – 1915

Periodic Table of the Chemical Elements

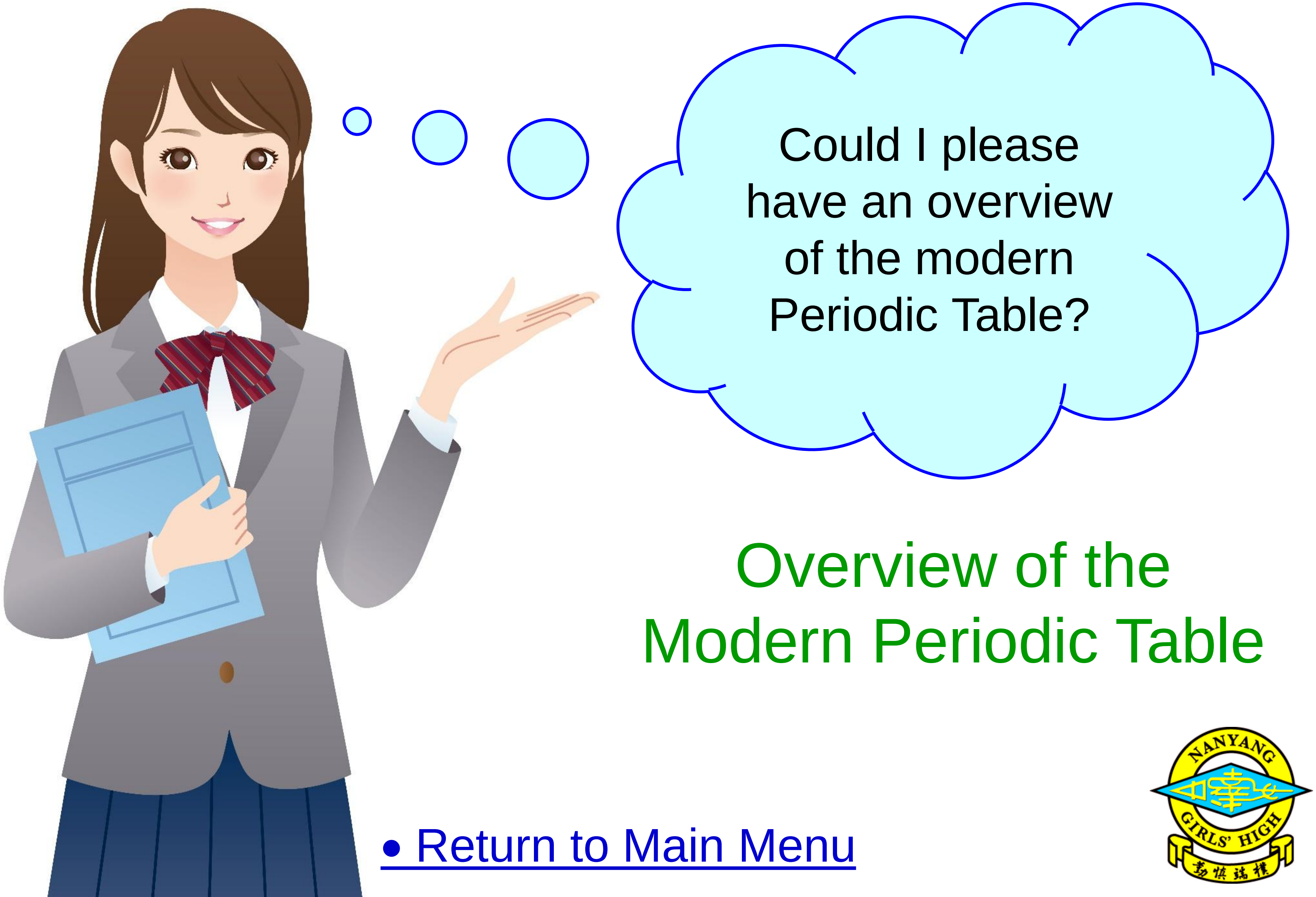
History of the Periodic Table

- In 1913, An English research student called Henry Moseley investigated the X-ray spectra of the chemical elements. He discovered that *atomic number* (proton number) is more important than relative atomic mass when determining the position of an element in the Periodic Table. Two pairs of elements that are placed in the wrong order using relative atomic mass are:

Potassium (39.1) and Argon (39.95)
Iodine (126.9) and Tellurium (127.6)

Moseley's discovery that atomic number (proton number) is more significant than relative atomic mass removed this anomaly from Mendeleev's Periodic Table.

Periodic Table of the Chemical Elements



Overview of the Modern Periodic Table

- Return to Main Menu

Periodic Table of the Chemical Elements

The Modern Periodic Table

Group

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	H																	He
2	Li	Be											B	C	N	O	F	Ne
3	Na	Mg											A*l*	Si	P	S	C*l*	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	T*l*	Pb	Bi	Po	At	Rn
7	Fr	Ra	Ac															

Periodic Table of the Chemical Elements

The Modern Periodic Table

Group

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1																	2
2	3	4											5	6	7	8	9	10
3	11	12											13	14	15	16	17	18
4	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
5	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
6	55	56	57	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
7	87	88	89															

- Elements are arranged in order of their atomic (proton) numbers.

Periodic Table of the Chemical Elements

The Modern Periodic Table

Group

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	H																	He
2	Li	Be											B	C	N	O	F	Ne
3	Na	Mg											A*l*	Si	P	S	C*l*	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	T*l*	Pb	Bi	Po	At	Rn
7	Fr	Ra	Ac															

Periodic Table of the Chemical Elements

The Modern Periodic Table

Group

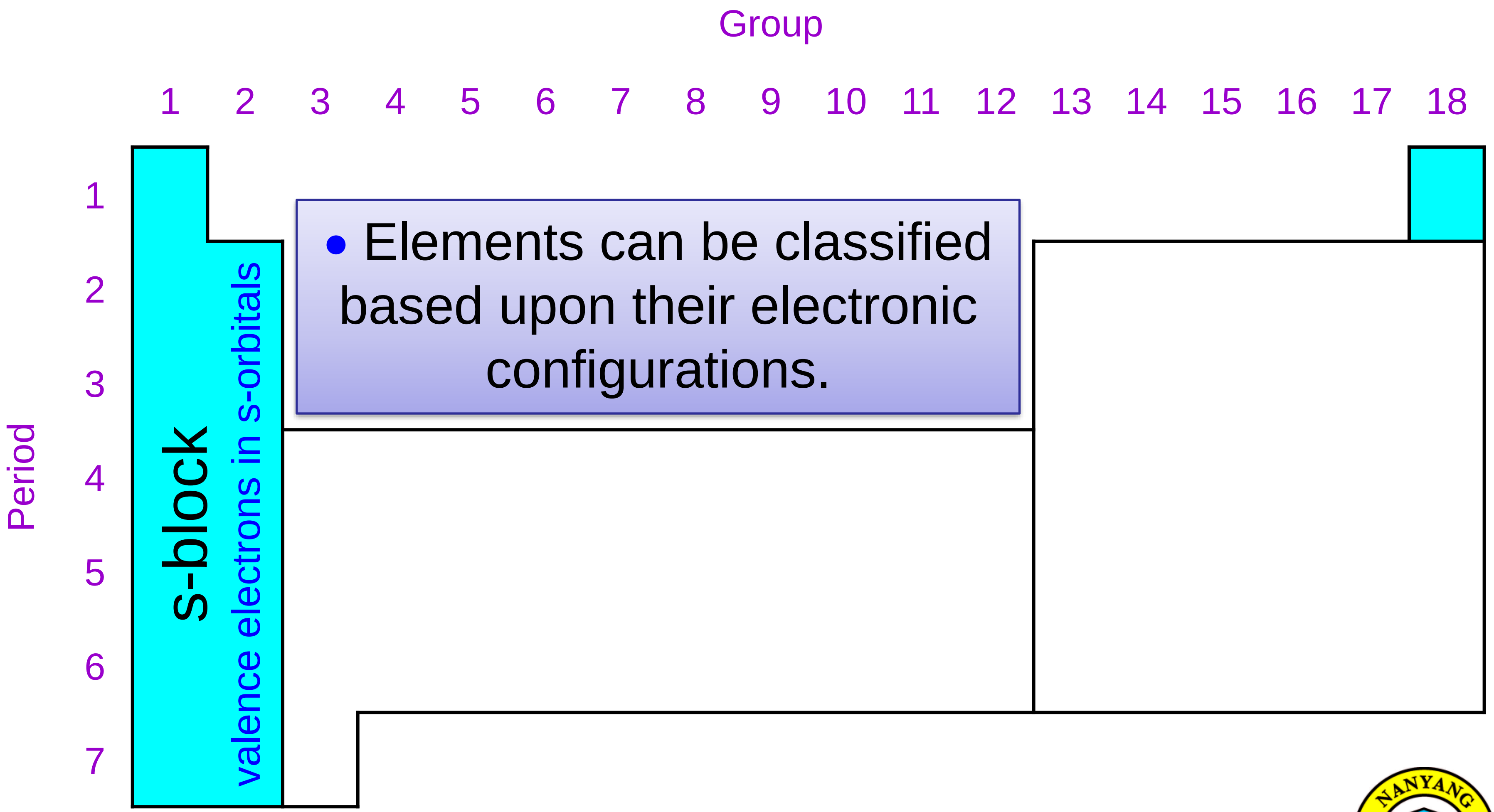
Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1s																	1s
2	2s	2s											2p	2p	2p	2p	2p	2p
3	3s	3s											3p	3p	3p	3p	3p	3p
4	4s	4s	3d	3d	3d	3d	3d	3d	3d	3d	3d	3d	4p	4p	4p	4p	4p	4p
5	5s	5s	4d	4d	4d	4d	4d	4d	4d	4d	4d	4d	5p	5p	5p	5p	5p	5p
6	6s	6s	5d	5d	5d	5d	5d	5d	5d	5d	5d	5d	6p	6p	6p	6p	6p	6p
7	7s	7s	6d															

- Elements can be classified based upon their electronic configurations.

Periodic Table of the Chemical Elements

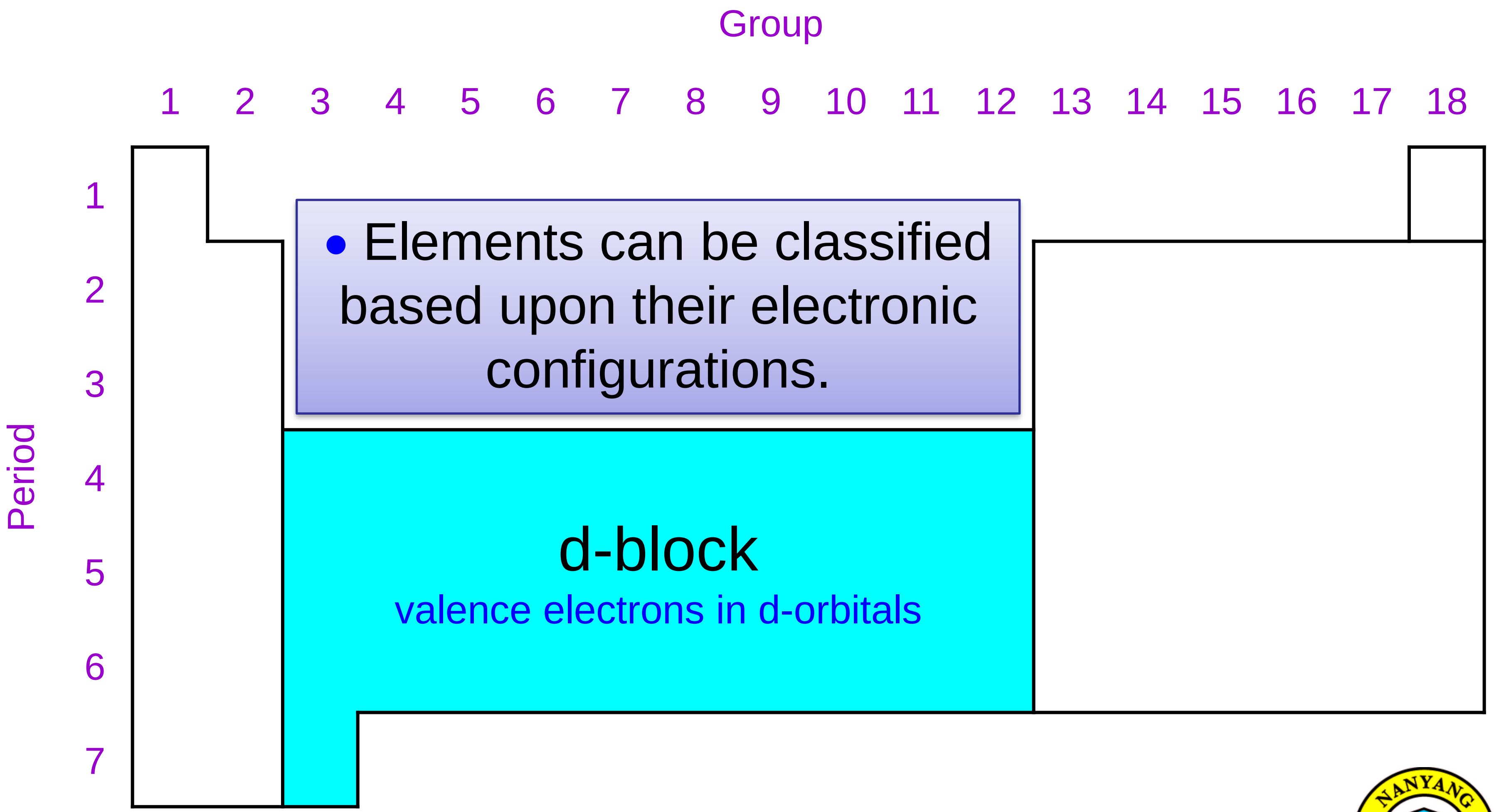
The Modern Periodic Table

- Elements can be classified based upon their electronic configurations.



Periodic Table of the Chemical Elements

The Modern Periodic Table



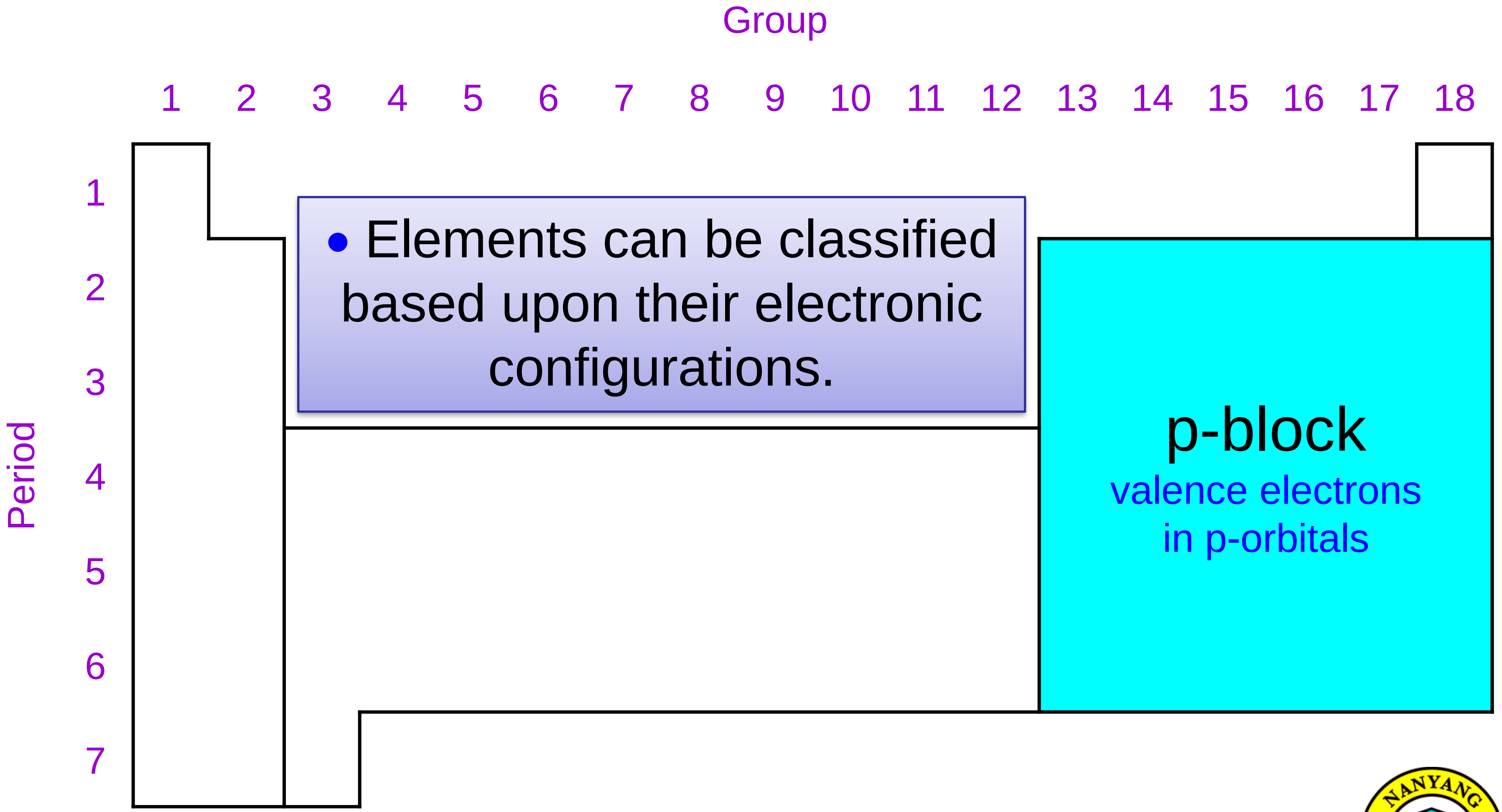
- Elements can be classified based upon their electronic configurations.

d-block

valence electrons in d-orbitals

Periodic Table of the Chemical Elements

The Modern Periodic Table



- Elements can be classified based upon their electronic configurations.

Periodic Table of the Chemical Elements

The Modern Periodic Table

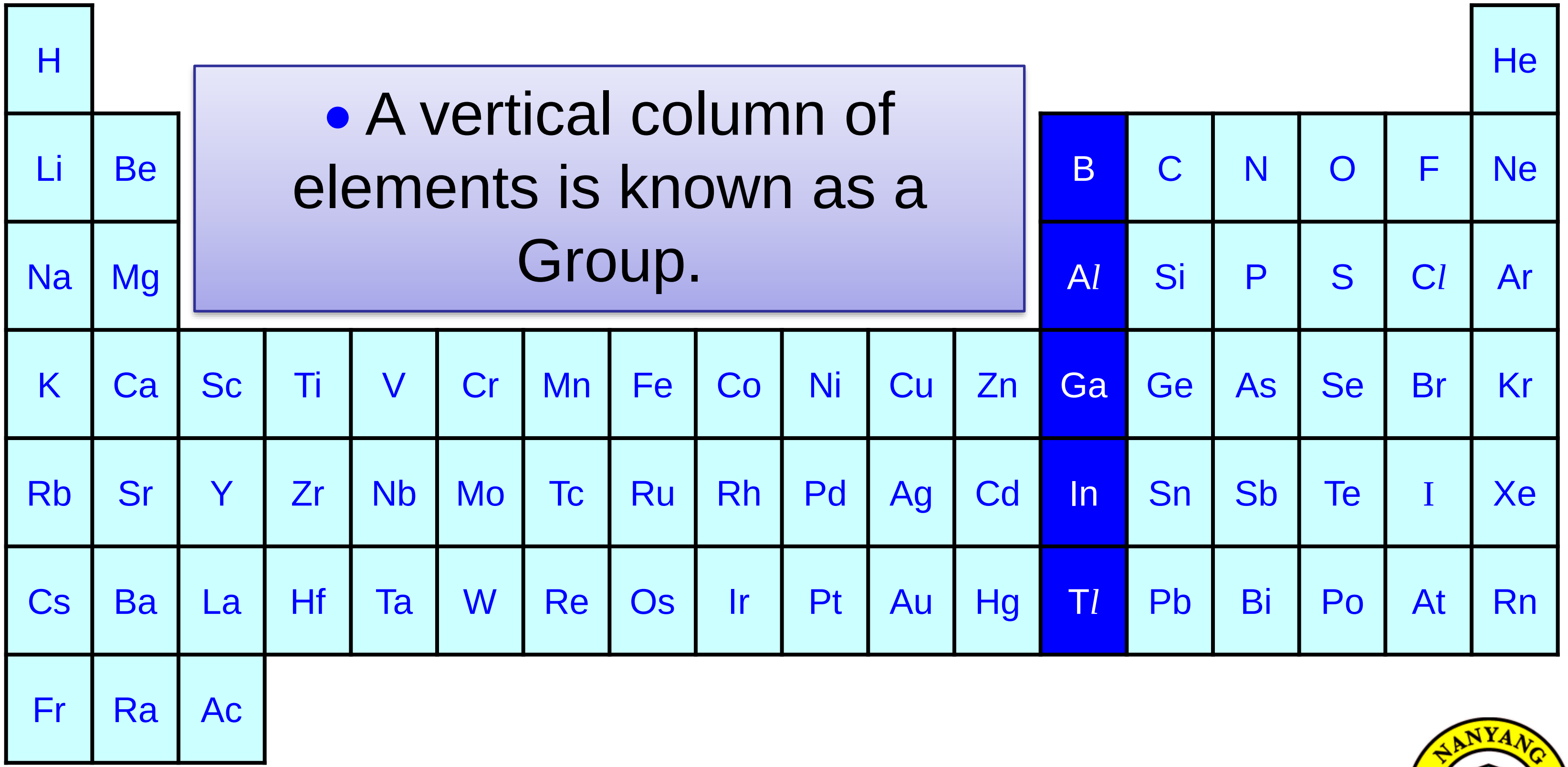
Group

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	H																	He
2	Li	Be											B	C	N	O	F	Ne
3	Na	Mg											A*l*	Si	P	S	C*l*	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	T*l*	Pb	Bi	Po	At	Rn
7	Fr	Ra	Ac															

Periodic Table of the Chemical Elements

The Modern Periodic Table

- A vertical column of elements is known as a Group.



	Group																	
Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	H																	He
2	Li	Be											B	C	N	O	F	Ne
3	Na	Mg											A*l*	Si	P	S	C*l*	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	T*l*	Pb	Bi	Po	At	Rn
7	Fr	Ra	Ac															

Periodic Table of the Chemical Elements

The Modern Periodic Table

Group

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	H																	He
2	Li	Be											B	C	N	O	F	Ne
3	Na	Mg											A*l*	Si	P	S	C*l*	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	T*l*	Pb	Bi	Po	At	Rn
7	Fr	Ra	Ac															

Periodic Table of the Chemical Elements

The Modern Periodic Table

Group

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	H																	He
2	Li	Be											B	C	N	O	F	Ne
3	Na	Mg											Al	Si	P	S	Cl	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	Ac															

- A horizontal row of elements is known as a Period.

Periodic Table of the Chemical Elements

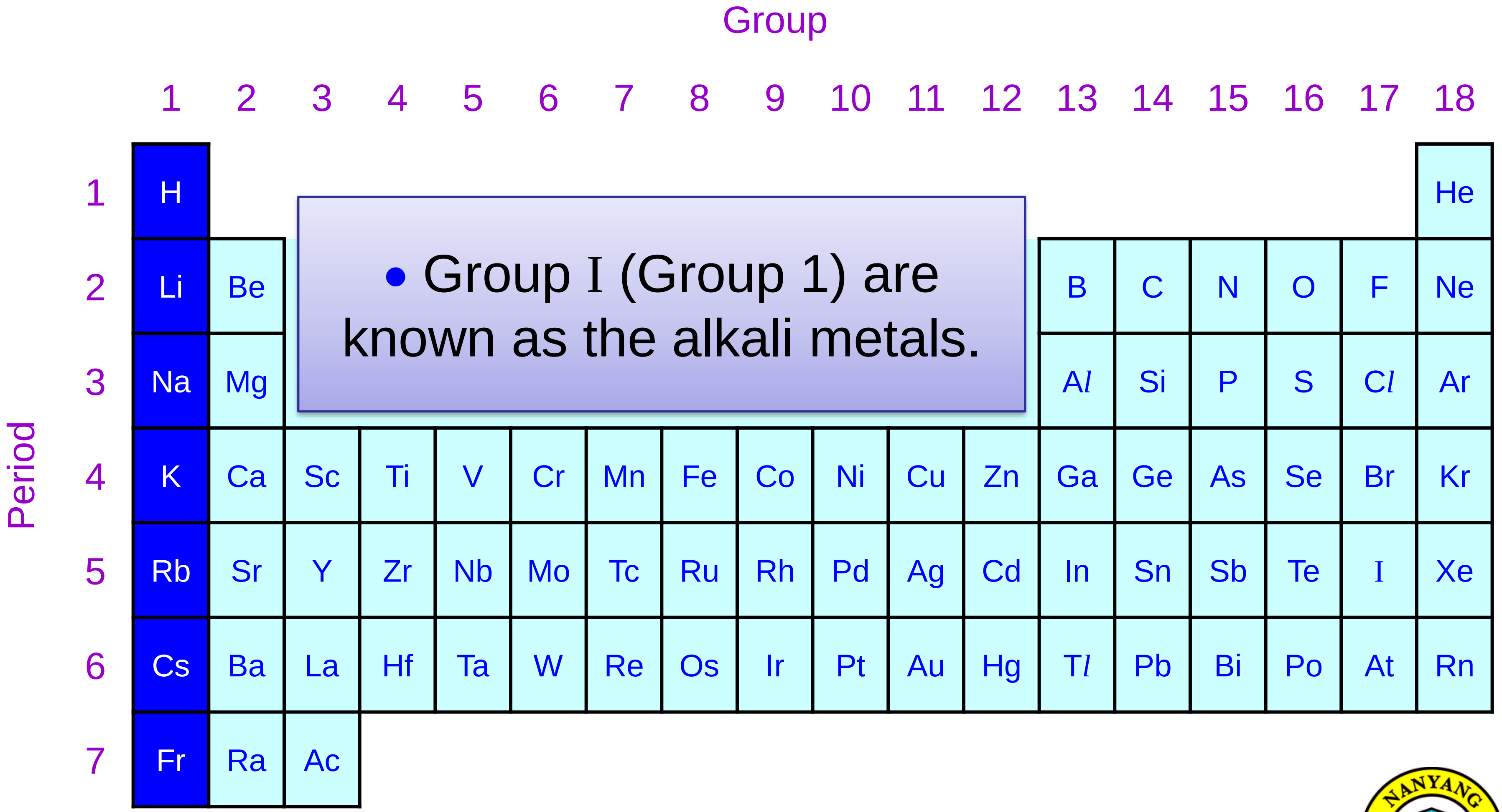
The Modern Periodic Table

Group

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	H																	He
2	Li	Be											B	C	N	O	F	Ne
3	Na	Mg											A*l*	Si	P	S	C*l*	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	T*l*	Pb	Bi	Po	At	Rn
7	Fr	Ra	Ac															

Periodic Table of the Chemical Elements

The Modern Periodic Table



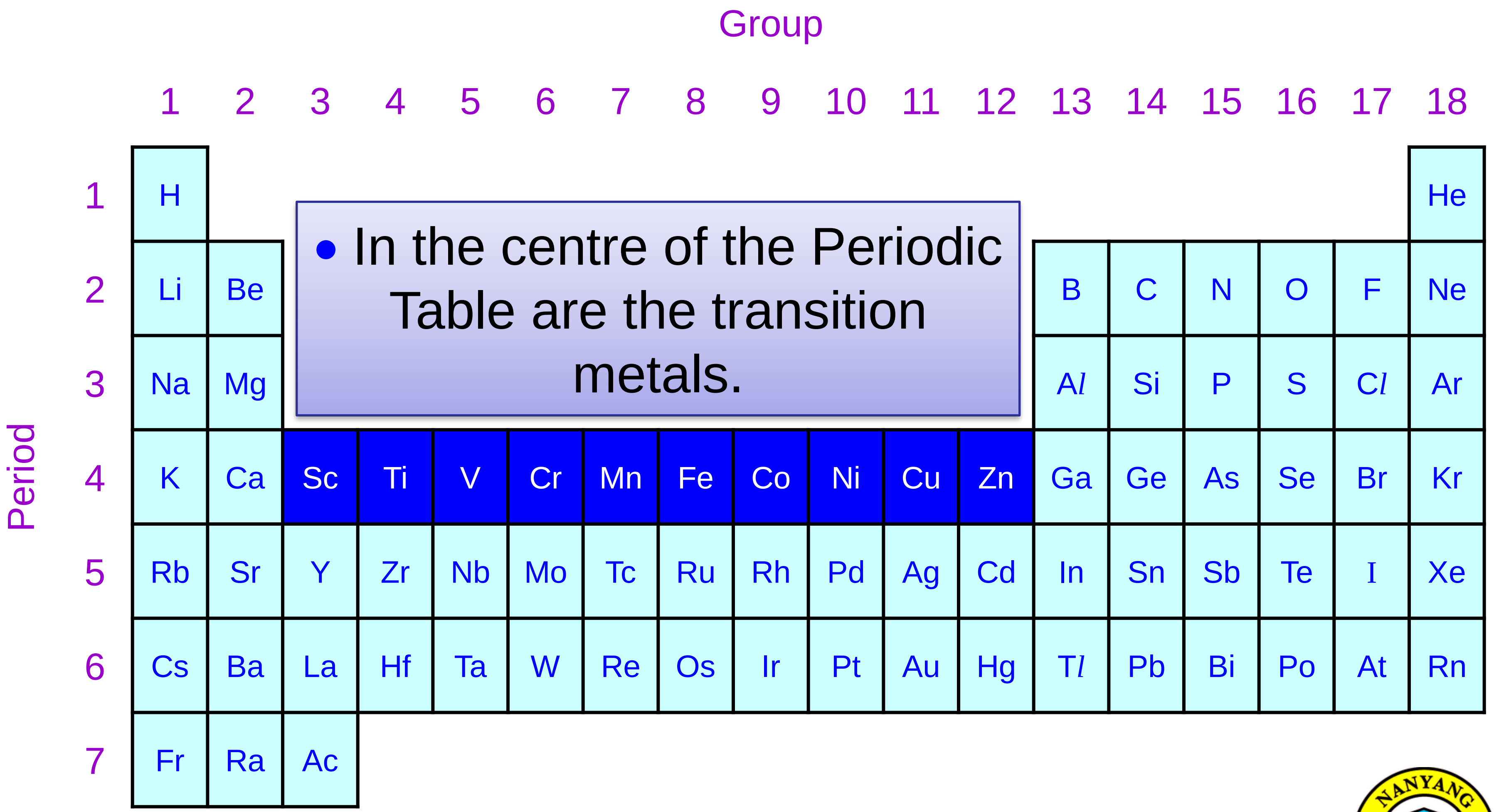
Group

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	H																	He
2	Li	Be											B	C	N	O	F	Ne
3	Na	Mg											Al	Si	P	S	Cl	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	Ac															

- Group I (Group 1) are known as the alkali metals.

Periodic Table of the Chemical Elements

The Modern Periodic Table



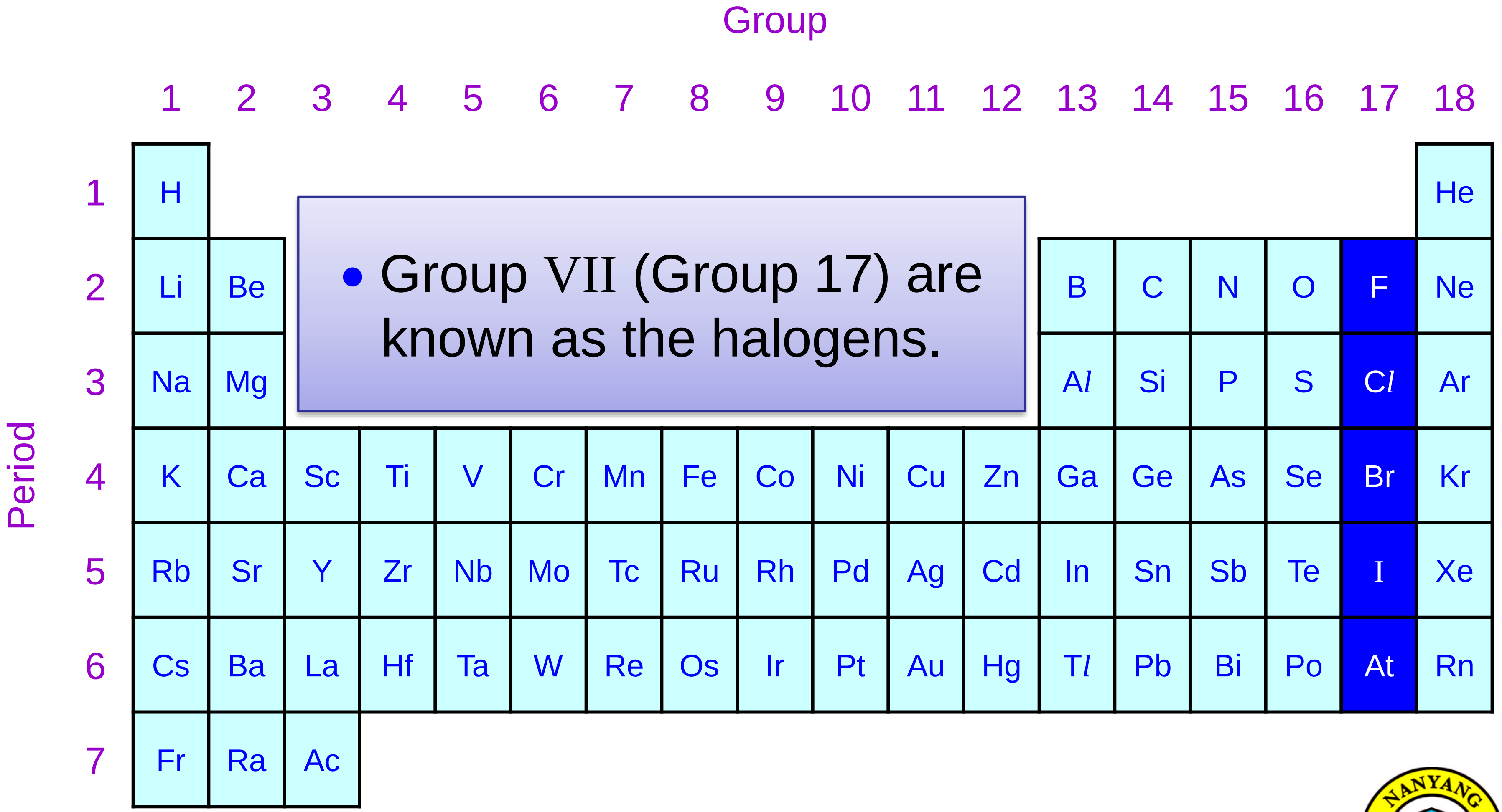
Group

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	H																	He
2	Li	Be											B	C	N	O	F	Ne
3	Na	Mg											A*l*	Si	P	S	C*l*	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	T*l*	Pb	Bi	Po	At	Rn
7	Fr	Ra	Ac															

- In the centre of the Periodic Table are the transition metals.

Periodic Table of the Chemical Elements

The Modern Periodic Table



- Group VII (Group 17) are known as the halogens.

Period \ Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	H																	He
2	Li	Be											B	C	N	O	F	Ne
3	Na	Mg											Al	Si	P	S	Cl	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	Ac															

Periodic Table of the Chemical Elements

The Modern Periodic Table

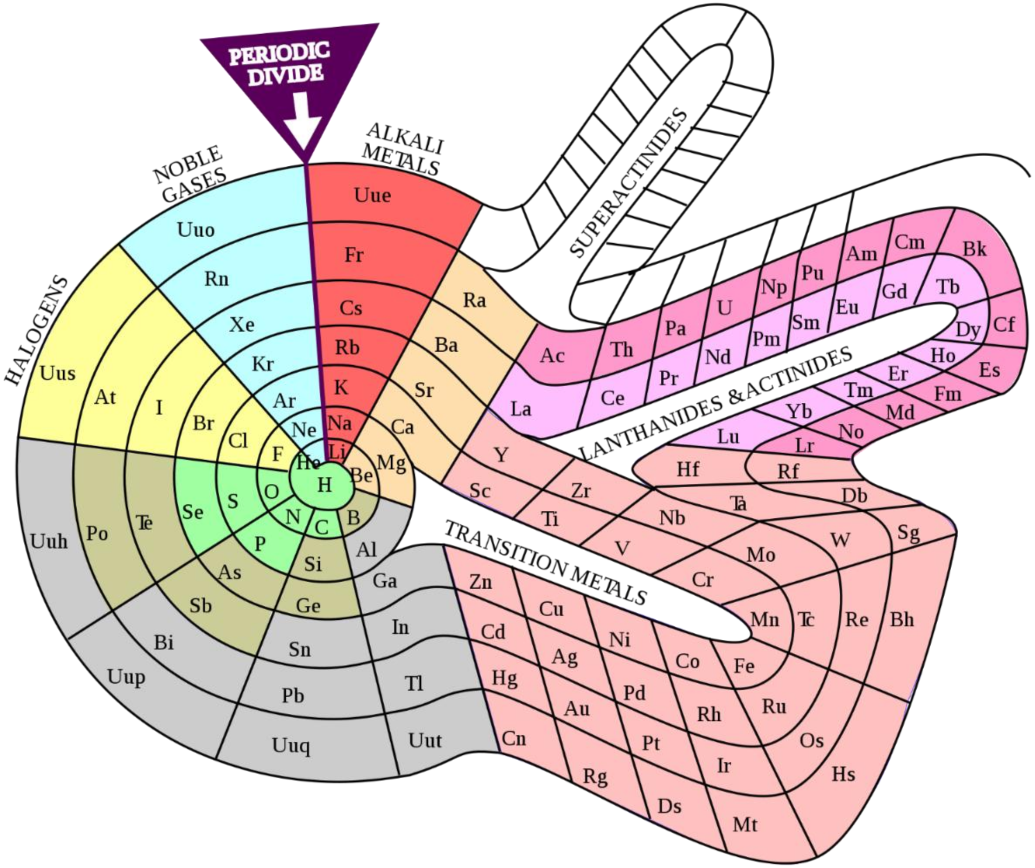
Group

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	H																	He
2	Li	Be											B	C	N	O	F	Ne
3	Na	Mg											Al	Si	P	S	Cl	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	Ac															

- Group 0 (Group 18) are known as the noble gases.

Periodic Table of the Chemical Elements

The Modern Periodic Table



- Professor Theodor Benfey's Spiral Periodic Table (1964).

Periodic Table of the Chemical Elements

What are some general periodic trends of the chemical elements?

Essential Periodic Trends

• Return to Main Menu

Periodic Table of the Chemical Elements

Metals, Metalloids and Non-metals

- Moving from the left-hand-side of the Periodic Table to the right-hand-side of the Periodic Table, there is a change in the element's chemical and physical properties from *metallic*, through *metalloid* (semimetal) to *non-metallic*.

- Magnesium
Group 2 (II)
Metallic

- Silicon
Group 14 (IV)
Metalloid

- Sulfur
Group 16 (VI)
Non-metallic

- Return to Main Menu

Periodic Table of the Chemical Elements

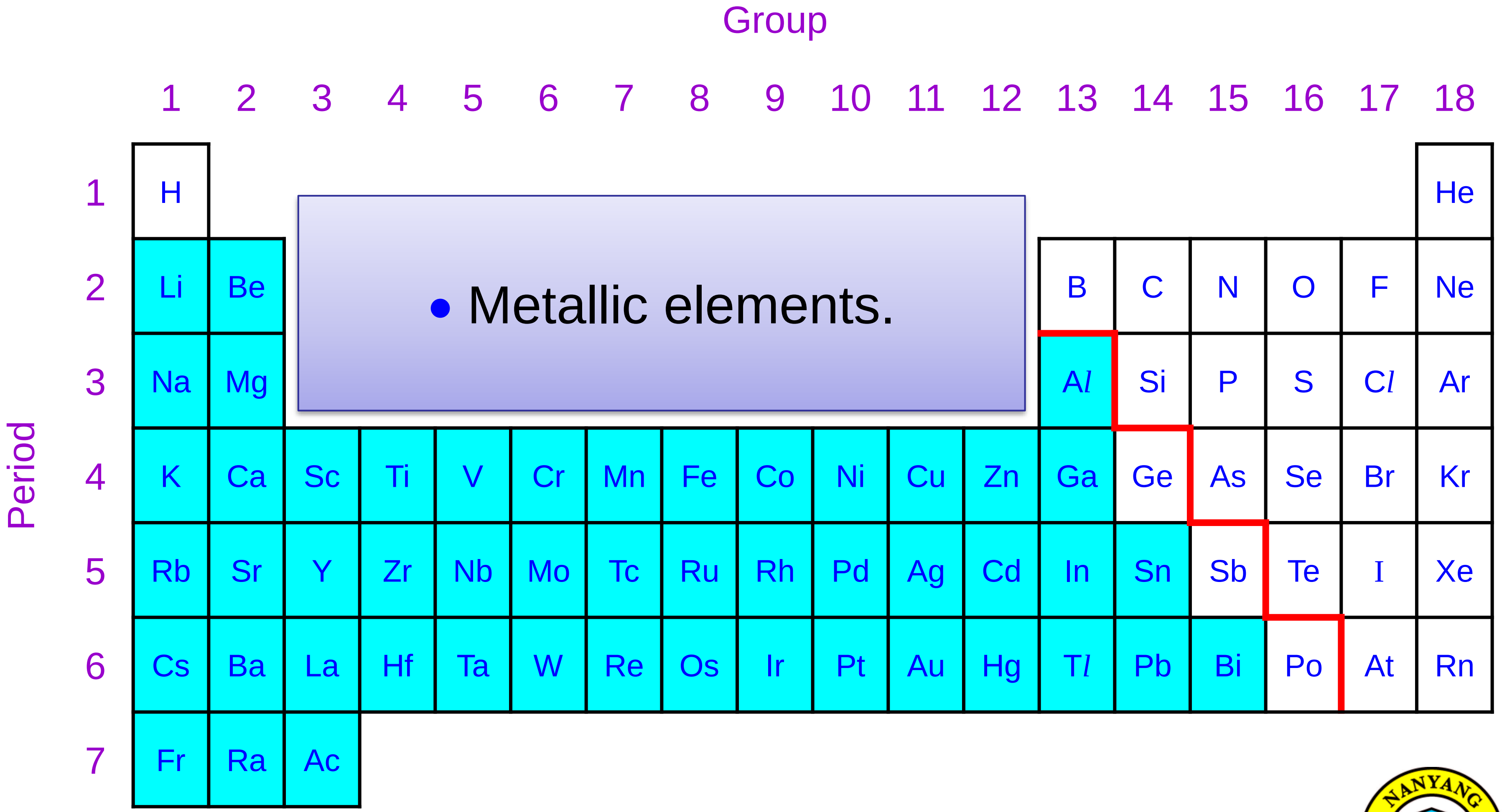
Metals, Metalloids and Non-metals

Group

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	H																	He
2	Li	Be											B	C	N	O	F	Ne
3	Na	Mg											A*l*	Si	P	S	C*l*	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	T*l*	Pb	Bi	Po	At	Rn
7	Fr	Ra	Ac															

Periodic Table of the Chemical Elements

Metals, Metalloids and Non-metals



Group

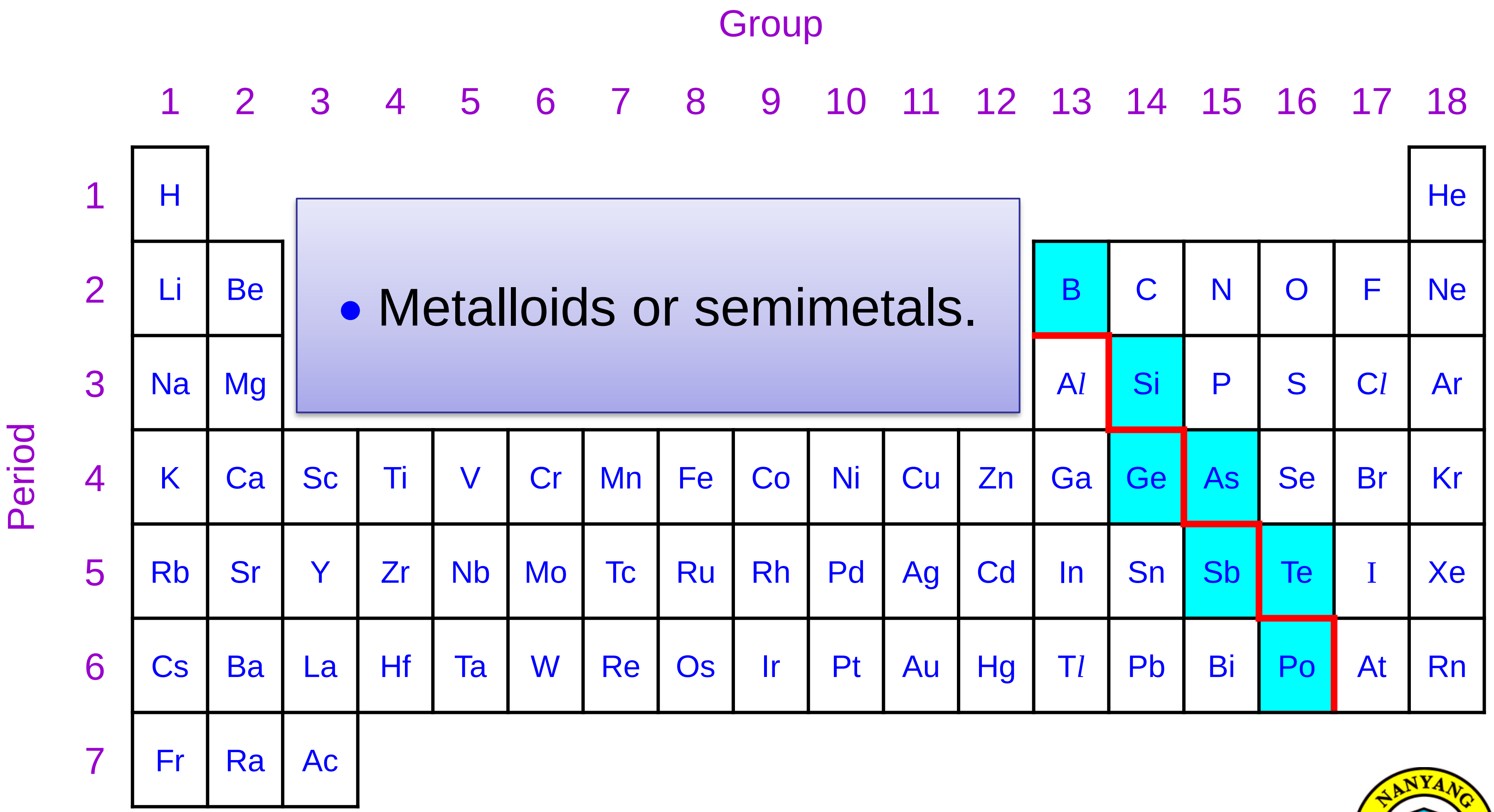
Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	H																	He
2	Li	Be											B	C	N	O	F	Ne
3	Na	Mg											Al	Si	P	S	Cl	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	Ac															

- Metallic elements.

Periodic Table of the Chemical Elements

Metals, Metalloids and Non-metals

- Metalloids or semimetals.

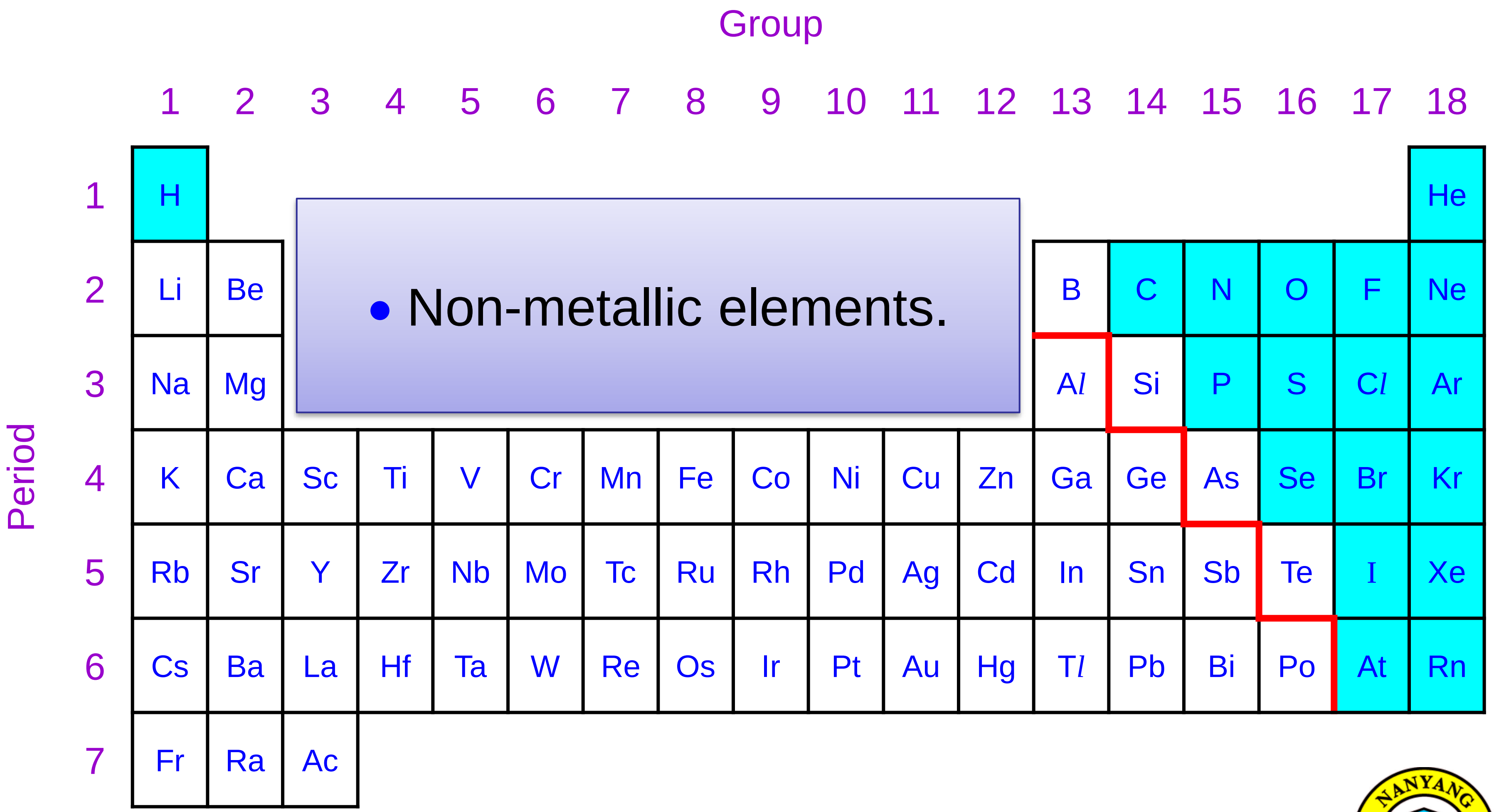


Group

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	H																	He
2	Li	Be											B	C	N	O	F	Ne
3	Na	Mg											Al	Si	P	S	Cl	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	Ac															

Periodic Table of the Chemical Elements

Metals, Metalloids and Non-metals



- Non-metallic elements.

Group

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	H																	He
2	Li	Be											B	C	N	O	F	Ne
3	Na	Mg											Al	Si	P	S	Cl	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	Ac															

Periodic Table of the Chemical Elements

Metals, Metalloids and Non-metals

- What are the typical properties of metallic elements?

→ *Good conductors* of heat and electricity.

→ Generally have *high melting points* and *high boiling points*.

→ Clean surface of a metal has a *metallic lustre* (shiny).

→ *Malleable* and *ductile* (shape changed without breaking).

→ Generally have *high densities*.

→ Generally *hard* and *strong*.

→ *Sonorous* (ring when struck).

→ React by *losing their valence* electron(s) to obtain a noble gas electronic configuration.

→ Oxides are *basic* in nature.

Periodic Table of the Chemical Elements

Metals, Metalloids and Non-metals

- What are the typical properties of non-metallic elements?

→ *Poor conductors* of heat and electricity (insulators).

→ Generally have *low melting points* and *low boiling points*.

→ Surface is generally *dull* (unless crystalline).

→ Generally *brittle*.

→ Generally have *low densities*.

→ Generally *soft*.

→ *Not sonorous*.

→ React by *accepting electrons* into their valence shell to obtain a noble gas electronic configuration.

→ Oxides are *acidic* in nature.

Periodic Table of the Chemical Elements

Metals, Metalloids and Non-metals

- Note: Many of these properties are *relative*, *i.e.* the properties are only meaningful when a *comparison* is made.

- For example, the melting points of metallic elements are *relatively high* when *compared* to the melting points of non-metallic elements.

- For example, the densities of non-metallic elements are *relatively low* when *compared* to the densities of metallic elements.

Periodic Table of the Chemical Elements

Metals, Metalloids and Non-metals

- What are the typical properties of metalloids?

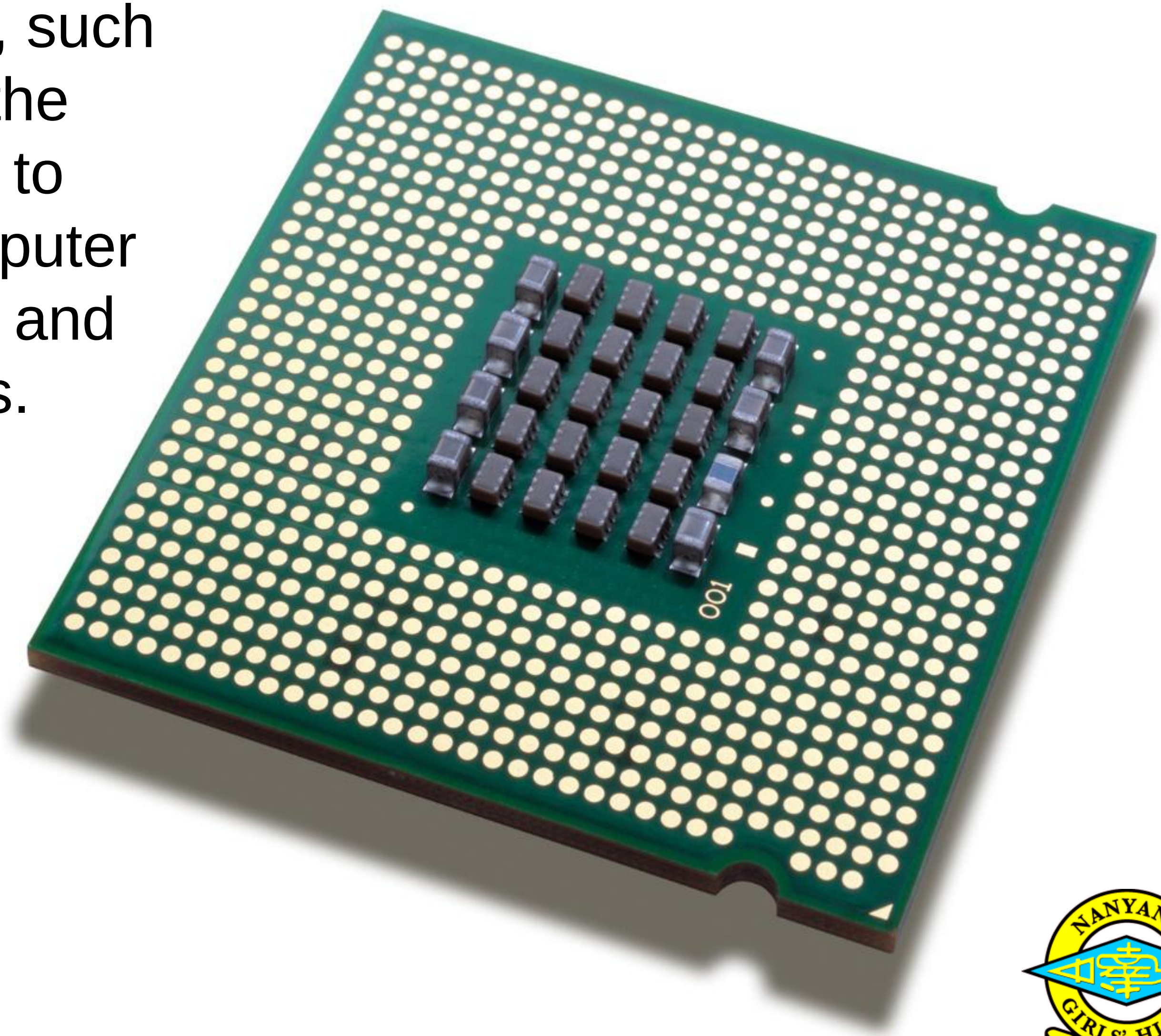
→ Metalloids are *semiconductors*. A semiconductor is a substance that conducts electricity under some conditions, but behaves as an electrical insulator under other conditions.

→ The oxides of metalloids are *amphoteric*. Under some conditions they are acidic in nature while under other conditions they are basic in nature.

Periodic Table of the Chemical Elements

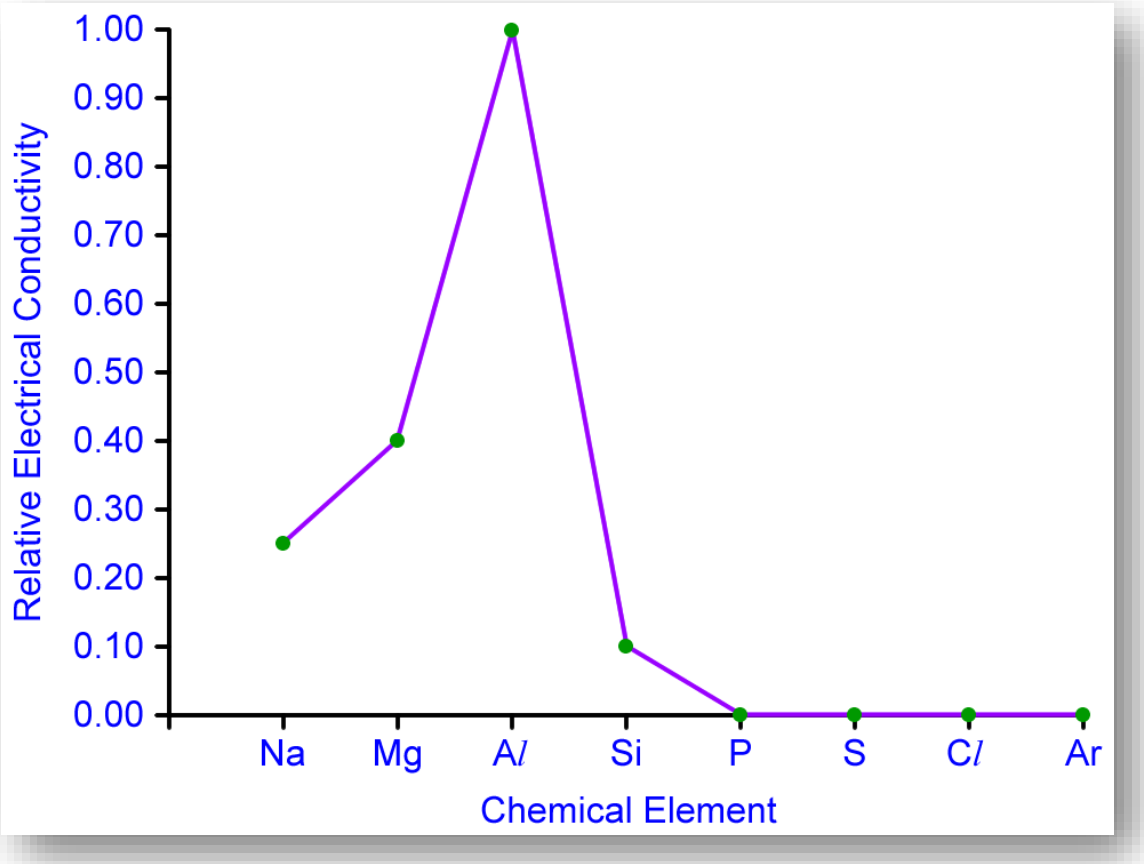
Metals, Metalloids and Non-metals

- Semiconductors, such as *silicon*, are the materials used to manufacture computer microprocessors and memory chips.



Periodic Table of the Chemical Elements

Periodic Trends – Electrical Conductivity



- Electrical conductivity increases from sodium to aluminium, decreases sharply from aluminium to silicon, falls to zero from silicon to phosphorus and remains at zero from phosphorus through to argon.

- Electrical conductivity across Period 3.

- Return to Main Menu

Periodic Table of the Chemical Elements

Periodic Trends – Electrical Conductivity

- For a chemical element to conduct electricity, it must contain *delocalised electrons*.

- When delocalised electrons flow in the same direction, they function as *mobile charge carrying particles* that enable an electric current to flow through the element.

- In general, *metallic elements* contain delocalised electrons and are *good conductors* of electricity while *non-metallic elements* do not contain delocalised electrons and are *poor conductors* of electricity*.

*One notable exception is *graphite* – an allotrope of the non-metallic element carbon. Graphite contains electrons that are delocalised between the hexagonal layers of carbon atoms. As a consequence, graphite is a good conductor of electricity.

Periodic Table of the Chemical Elements

Periodic Trends – Electrical Conductivity

Sodium, Magnesium and Aluminium

- Sodium, magnesium and aluminium are all *metallic elements*. They are composed of positively charged ions (cations) arranged in a crystal lattice, surrounded by a sea of *delocalised electrons*.

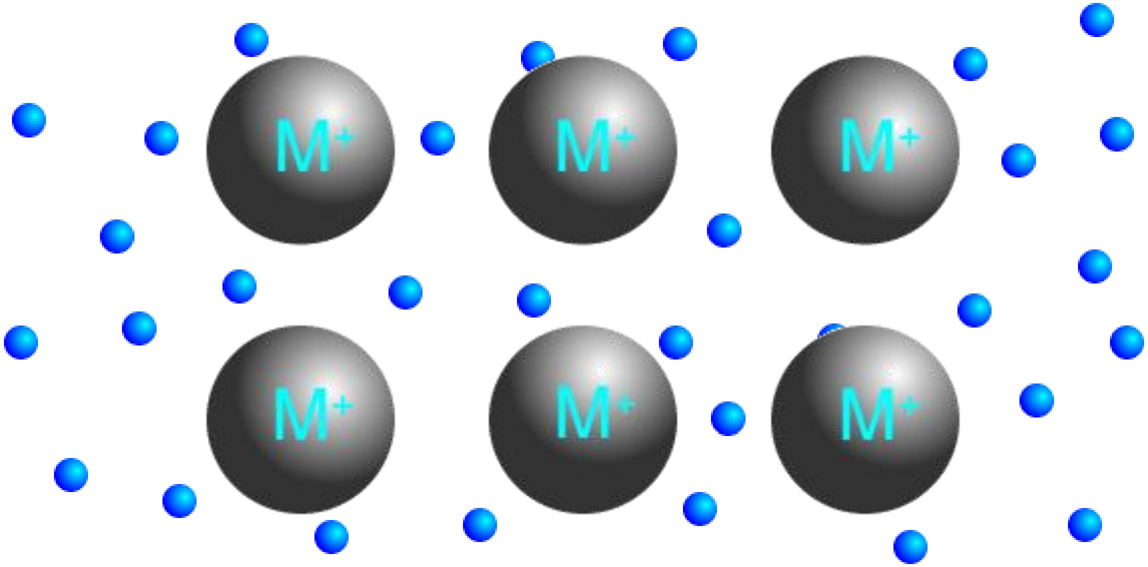
- The delocalised electrons are free to move, and function as charge carrying particles.

- Moving from sodium to magnesium to aluminium, the number of electrons in the valence shell of an atom of each element increases from *one* to *two* to *three* respectively.

Periodic Table of the Chemical Elements

Periodic Trends – Electrical Conductivity

Sodium, Magnesium and Aluminium

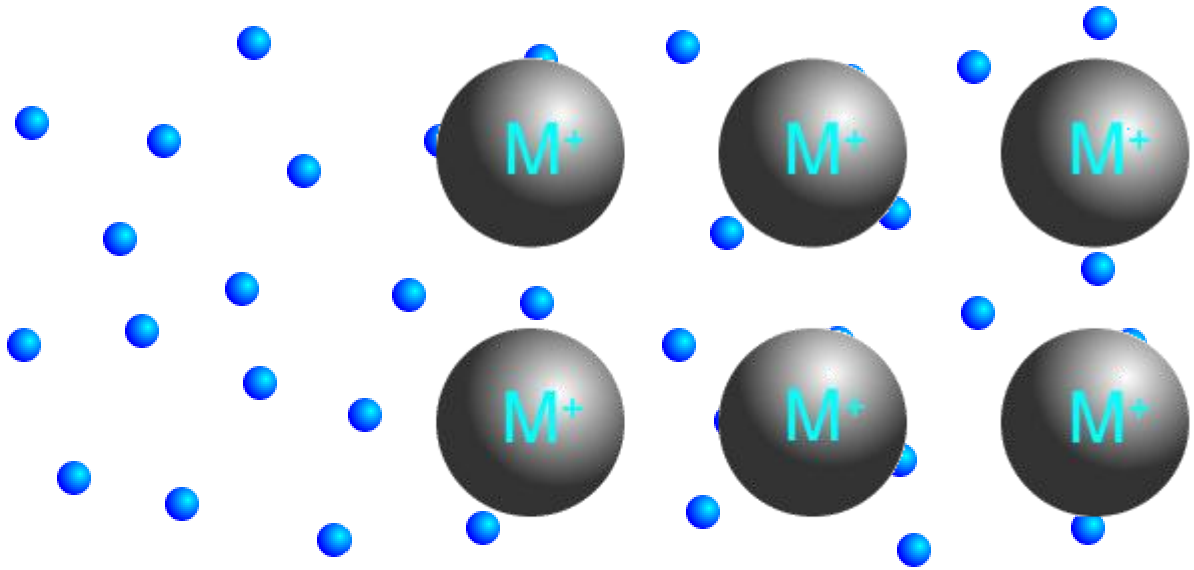


- A metallic element is composed of cations surrounded by a sea of delocalised electrons. The sea of delocalised electrons is formed when the metal atoms lose their valence electron(s) in order to obtain a noble gas electronic configuration.

Periodic Table of the Chemical Elements

Periodic Trends – Electrical Conductivity

Sodium, Magnesium and Aluminium



- A metallic element is composed of cations surrounded by a sea of delocalised electrons. The sea of delocalised electrons is formed when the metal atoms lose their valence electron(s) in order to obtain a noble gas electronic configuration.

Periodic Table of the Chemical Elements

Periodic Trends – Electrical Conductivity

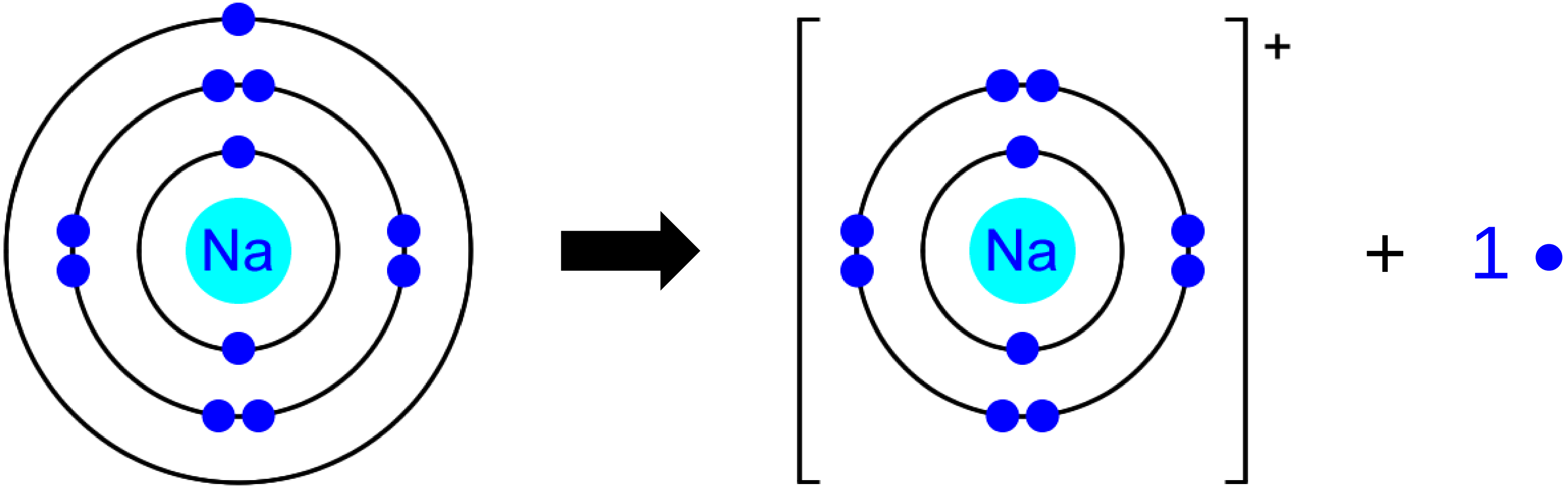
Sodium, Magnesium and Aluminium

- In metallic bonding, atoms of metallic elements lose their valence electron(s) to form the delocalised sea of electrons, hence an atom of *sodium* will lose *one* electron, an atom of *magnesium* will lose *two* electrons and an atom of *aluminium* will lose *three* electrons.
- As the number of electrons that constitutes the delocalised sea of electrons increases, so electrical conductivity also increases because there are more electrons to serve as mobile charge carrying particles.
- Hence, electrical conductivity *increases* moving across the Period 3 from sodium to aluminium.

Periodic Table of the Chemical Elements

Periodic Trends – Electrical Conductivity

Sodium, Magnesium and Aluminium

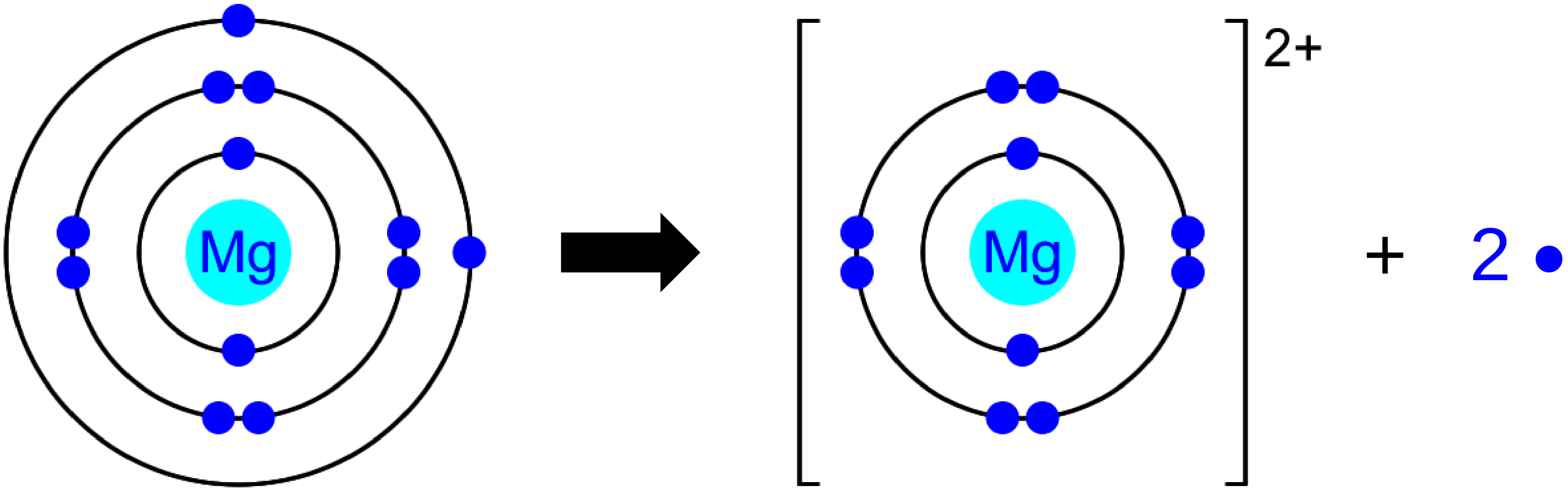


- Each sodium atom loses *one* electron to form the delocalised sea of electrons.

Periodic Table of the Chemical Elements

Periodic Trends – Electrical Conductivity

Sodium, Magnesium and Aluminium

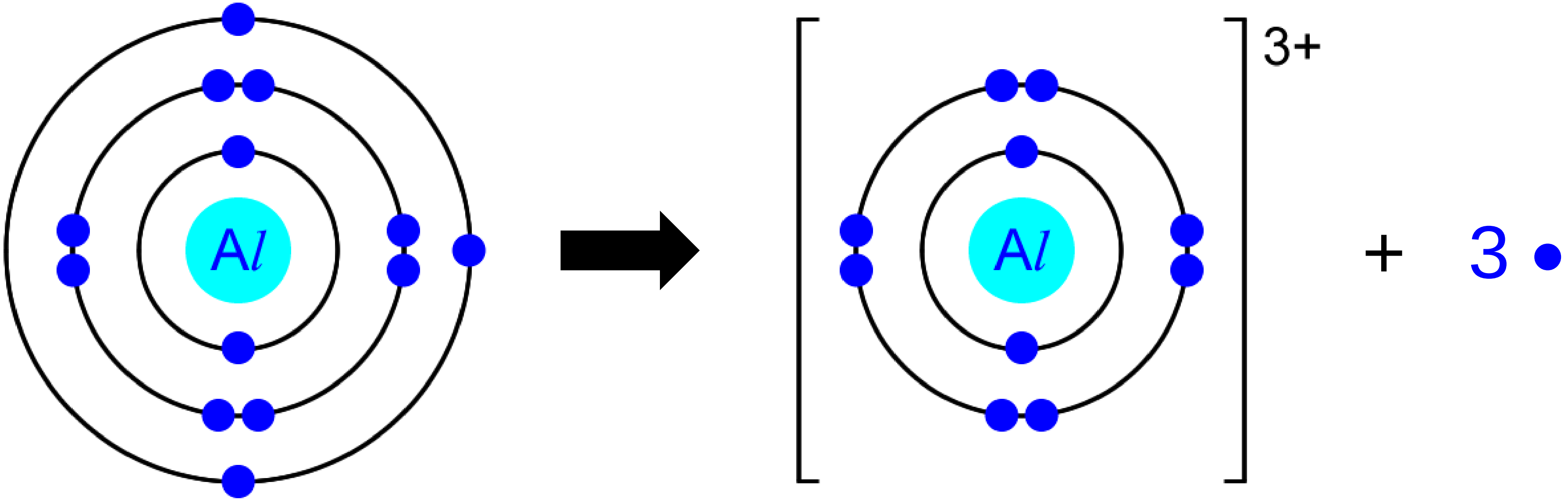


- Each magnesium atom loses *two* electrons to form the delocalised sea of electrons. Magnesium is a better conductor of electricity than sodium.

Periodic Table of the Chemical Elements

Periodic Trends – Electrical Conductivity

Sodium, Magnesium and Aluminium



- Each aluminium atom loses *three* electrons to form the delocalised sea of electrons. Aluminium is a better conductor of electricity than magnesium.

Periodic Table of the Chemical Elements

Periodic Trends – Electrical Conductivity

Silicon

- Silicon is a *metalloid* (an element that has some properties of a metallic element and some properties of a non-metallic element).

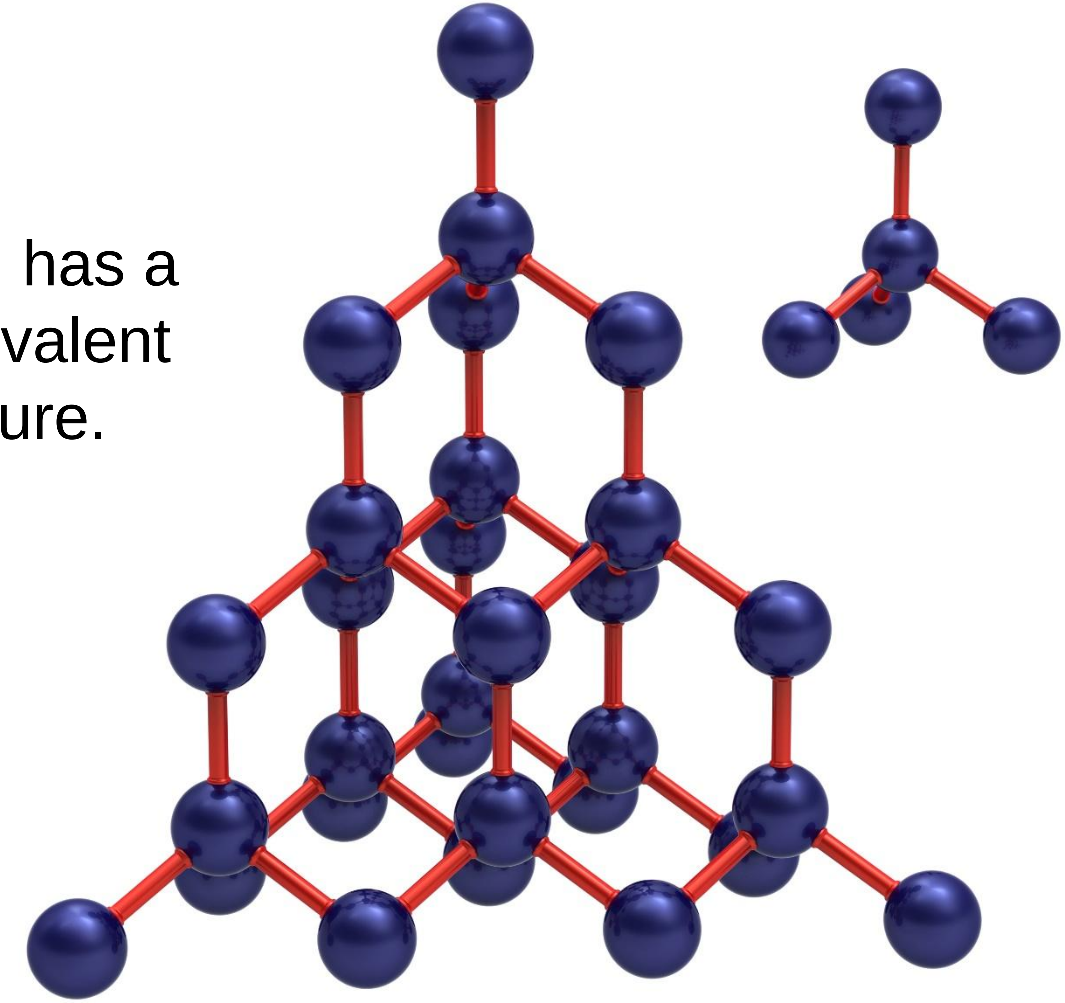
- Silicon has a giant covalent or macromolecular structure in which each atom of silicon is covalently bonded to four other atoms of silicon in a tetrahedral arrangement, similar to diamond.

Periodic Table of the Chemical Elements

Periodic Trends – Electrical Conductivity

Silicon

- Silicon has a giant covalent structure.



Periodic Table of the Chemical Elements

Periodic Trends – Electrical Conductivity

Silicon

- Silicon is a *semiconductor* because, at room temperature, the four valence electrons of each silicon atom are contained in covalent bonds and are therefore unable to delocalise and function as mobile charge carrying particles.

- At higher temperatures, some of the electrons in the valence shell of a silicon atom are promoted to higher energy levels where they become delocalised throughout the entire structure of the silicon. This gives silicon the ability to conduct electricity, albeit to a small extent.

Periodic Table of the Chemical Elements

Periodic Trends – Electrical Conductivity

Phosphorus, Sulfur, Chlorine and Argon

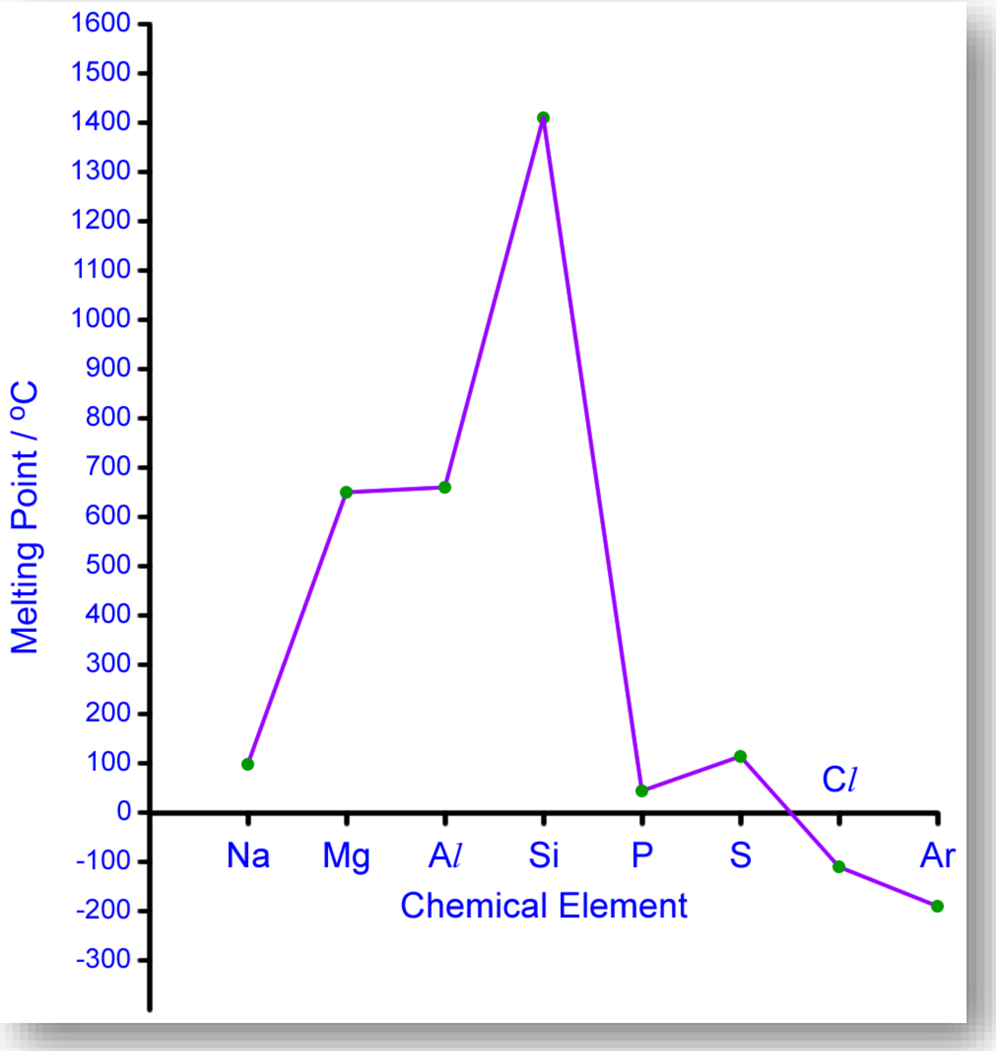
- Phosphorus, sulfur, chlorine an argon in Period 3 are *non-metallic elements* that do not conduct electricity, *i.e.* they are *electrical insulators*.

- Phosphorus, sulfur and chlorine (which exist as simple covalent molecules) are unable to conduct electricity because they do not contain any delocalise electrons. The valence electrons are contained in covalent bonds and stable electron shells.

- In argon (which is monatomic) the valence electrons are arranged in stable electron shells and are not delocalised.

Periodic Table of the Chemical Elements

Periodic Trends – Melting Points



- Melting points generally *increase* from sodium to silicon, and then *decrease sharply* from silicon to phosphorus. Melting points generally *decrease* from phosphorus to argon, albeit with a small increase from phosphorus to sulfur.

- Return to Main Menu

- Melting points across Period 3.

Periodic Table of the Chemical Elements

Periodic Trends – Melting Points

- In a solid, forces of attraction between the particles hold the particles closely packed together. The particles vibrate about fixed positions in a regular / ordered arrangement.

- When a substance melts, thermal energy is used to weaken the forces of attraction that hold the particles together, thus allowing the particles to travel short distances by sliding over each other.

- The *stronger the force of attraction* that holds the particles together, the *greater the amount of thermal energy* that is required to weaken that force of attraction, and the *higher the melting point* of that substance.

Periodic Table of the Chemical Elements

Periodic Trends – Melting Points

Sodium, Magnesium and Aluminium

- Sodium, magnesium and aluminium are all *metallic elements*. They are all composed of positively charged ions (cations) arranged in a crystal lattice, surrounded by a sea of delocalised electrons.

- The sodium cation has a charge of *1*+, the magnesium cation has a charge of *2*+ and the aluminium cation has a charge of *3*+.

- The number of electrons in the delocalised sea of electrons also increases from sodium to aluminium as a sodium atom loses *one* valence electron, a magnesium atom loses *two* valence electrons and an aluminium atom loses *three* valence electrons.

Periodic Table of the Chemical Elements

Periodic Trends – Melting Points

Sodium, Magnesium and Aluminium

- The *electrostatic force of attraction* between the metal cation and delocalised sea of electrons *increases* from sodium to aluminium.

- This is because the charge on the cation is increasing (Na^{+}, Mg^{2+}, Al^{3+}) and the number of electrons present in the delocalised sea of electrons is also increasing from sodium to aluminium.

- An *increasing amount of thermal energy* is required to weaken this electrostatic force of attraction between the cation and delocalised sea of electrons, hence *melting points increases* from sodium to aluminium.

Periodic Table of the Chemical Elements

Periodic Trends – Melting Points

Silicon

- Silicon is a *metalloid* (an element that has some properties of a metallic element and some properties of a non-metallic element).

- Silicon has a *giant covalent* or *macromolecular* structure in which each atom of silicon is covalently bonded to four other atoms of silicon in a tetrahedral arrangement, similar to diamond.

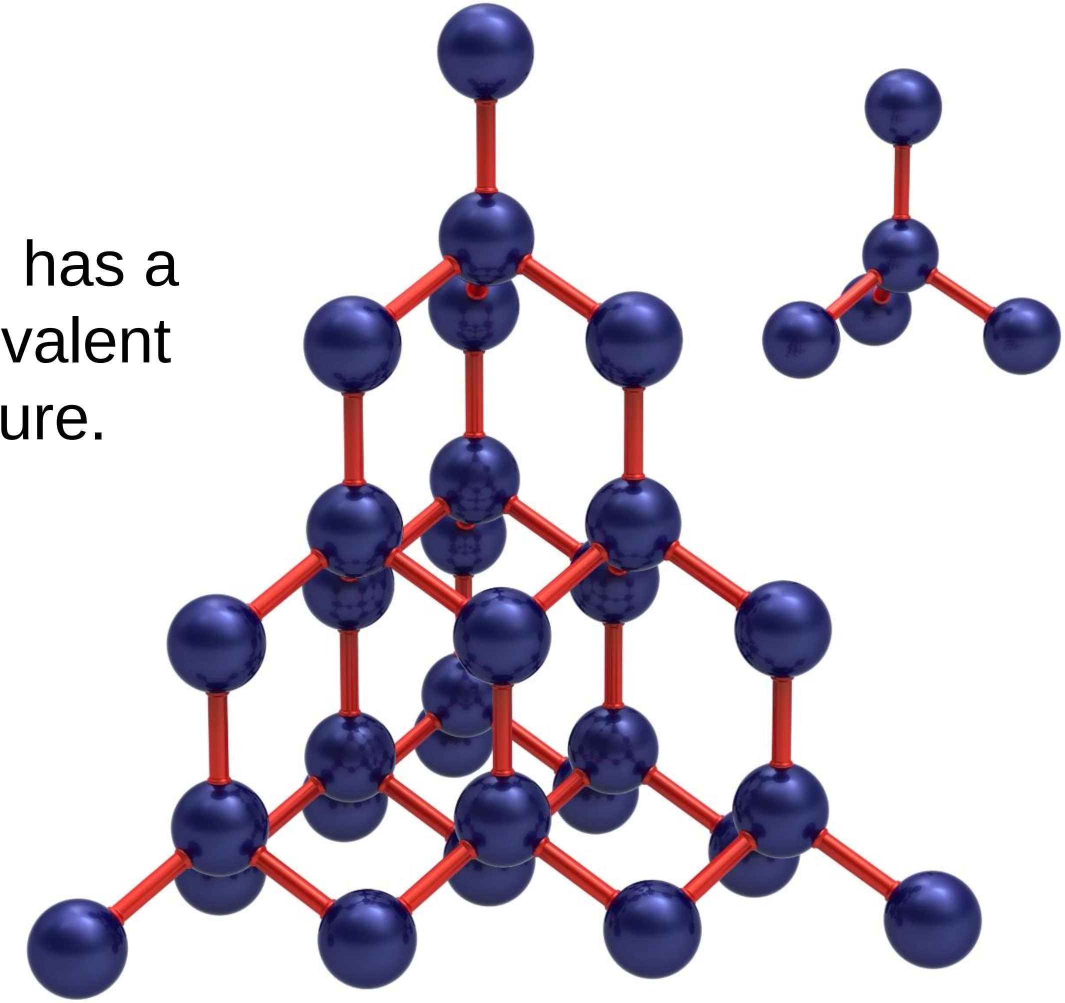
- Silicon has a *high melting point* because all of the atoms are held together by *strong covalent bonds* which require a *large amount of thermal energy* to weaken.

Periodic Table of the Chemical Elements

Periodic Trends – Melting Points

Silicon

- Silicon has a giant covalent structure.



Periodic Table of the Chemical Elements

Periodic Trends – Melting Points

Phosphorus, Sulfur, Chlorine and Argon

- Phosphorus, sulfur, chlorine and argon are all *non-metallic elements*. Phosphorus (P_4), sulfur (S_8) and chlorine (Cl_2) exist as simple covalent molecules while argon (Ar) is monatomic.

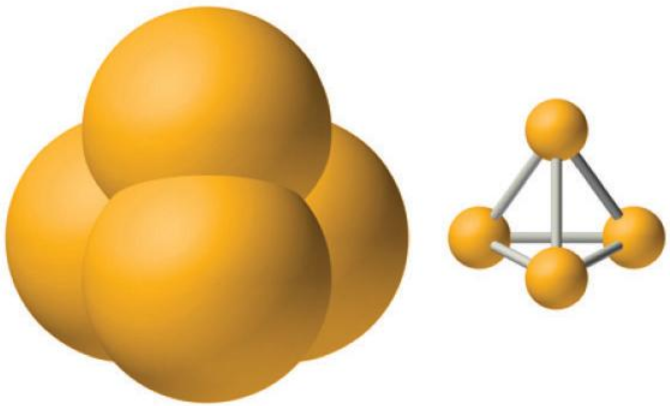
- Weak *instantaneous dipole-induced dipole forces of attraction* (London dispersion forces) exist between the P_4 molecules, S_8 molecules, Cl_2 molecules and Ar atoms.

- Weak London dispersion forces only require a *small amount of thermal energy* to weaken and hence these non-metallic elements have *low melting points*.

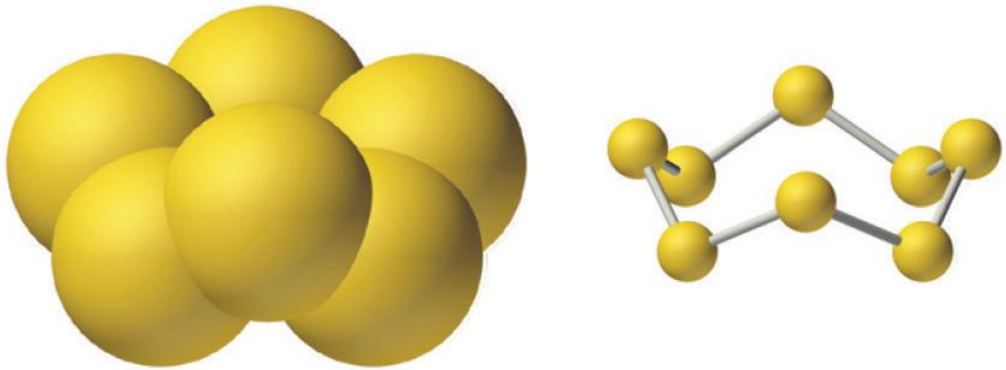
Periodic Table of the Chemical Elements

Periodic Trends – Melting Points

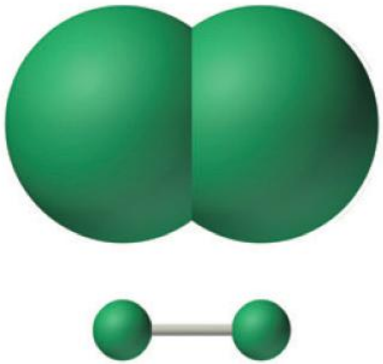
Phosphorus, Sulfur, Chlorine and Argon



- Phosphorus, P_4



- Sulfur, S_8

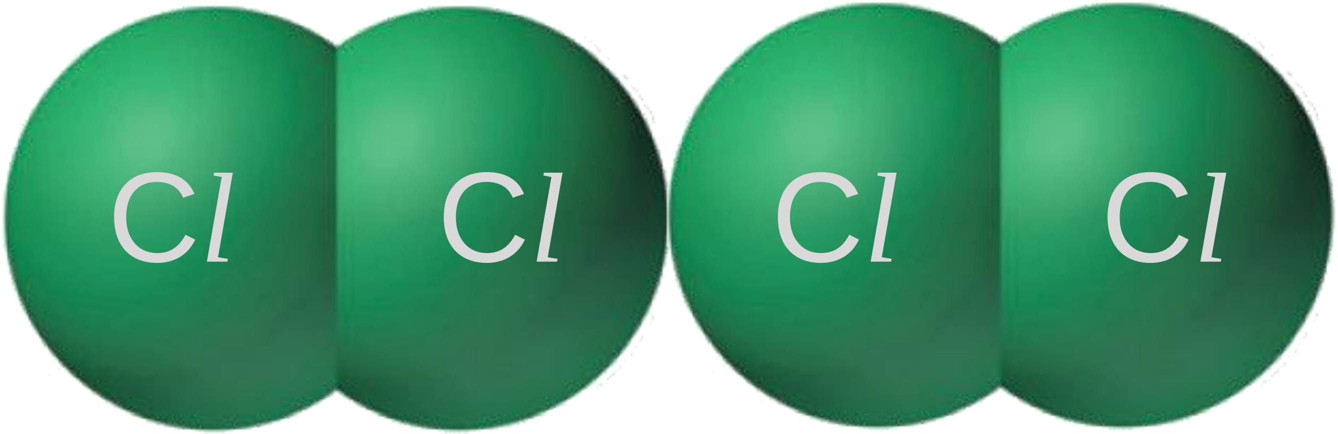


- Chlorine, Cl_2

Periodic Table of the Chemical Elements

Periodic Trends – Melting Points

Phosphorus, Sulfur, Chlorine and Argon

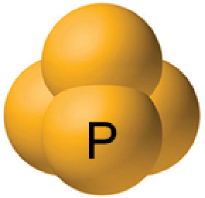
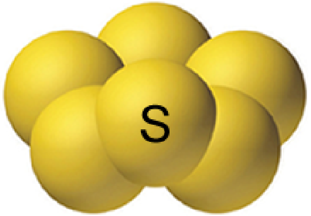
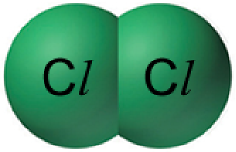
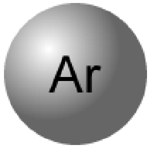


- Weak London dispersion forces only require a small amount of thermal energy to weaken and hence these non-metallic elements have low melting points.

Periodic Table of the Chemical Elements

Periodic Trends – Melting Points

Phosphorus, Sulfur, Chlorine and Argon

Element	melting point /°C	boiling point /°C	total number of electrons	relative molecular mass
	44.1	280	4 × 15 = 60	124.0
	115	445	8 × 16 = 128	256.8
	-101	-35.0	2 × 17 = 34	71.0
	-189	-186	1 × 18 = 18	39.9

Periodic Table of the Chemical Elements

Periodic Trends – Melting Points

Phosphorus, Sulfur, Chlorine and Argon

- As the *number of electrons* within a single molecule of the element increases, so the *polarisability* of the molecule increases. This increases the strength of the *instantaneous dipole-induced dipole forces of attraction* (London dispersion forces), meaning that a greater amount of thermal energy is required to weaken them, hence *increasing* the melting points and boiling points.

Periodic Table of the Chemical Elements

Periodic Trends – Melting Points

Phosphorus, Sulfur, Chlorine and Argon

- As the covalent radii of the atoms increases, so the *surface area* of the molecules also *increases*. The larger the surface area available for London dispersion forces to operate over, the stronger they become, and the greater the amount of thermal energy required to weaken them, hence leading to *higher* melting points and boiling points.

Periodic Table of the Chemical Elements

Periodic Trends – Melting Points

Phosphorus, Sulfur, Chlorine and Argon

- As the *relative molecular mass* of the molecules *increases*, so the melting points and boiling points also *increase*. More energy is required to overcome the *inertia** of the molecules with the greater relative molecular mass.

***Note:** *Inertia* is the natural tendency of an object to stay at rest, or remain in motion.

Periodic Table of the Chemical Elements

Periodic Trends – Melting Points

Phosphorus, Sulfur, Chlorine and Argon

- Sulfur has a slightly higher melting point that phosphorus, chlorine and argon due to a difference in the size and relative molecular masses of the molecules.

- The strength of the London dispersion forces *decrease* – and hence the melting points *decrease* – as the size and relative molecular masses of the molecules *decrease*:

- Higher Melting Point
- Lower Melting Point

S_8 (M_r = 256) > P_4 (M_r = 124) > Cl_2 (M_r = 71) > Ar (A_r = 40)

Periodic Table of the Chemical Elements

Periodic Trends – Electrostatic Forces

- The force of attraction between oppositely charged particles is given by Coulomb's Law:

$$F = \frac{1}{4 \times \pi \times \varepsilon_0} \times \frac{q_1 \times q_2}{r^2}$$

F = force of attraction between oppositely charged particles, N

ε_0 = permittivity of free space, $C^2\ m^{-2}\ N^{-1}$

q_1 = charge on particle one, C

q_2 = charge on particle two, C

r = distance between particle one and particle two, m

• Return to Main Menu

Periodic Table of the Chemical Elements

Periodic Trends – Electrostatic Forces

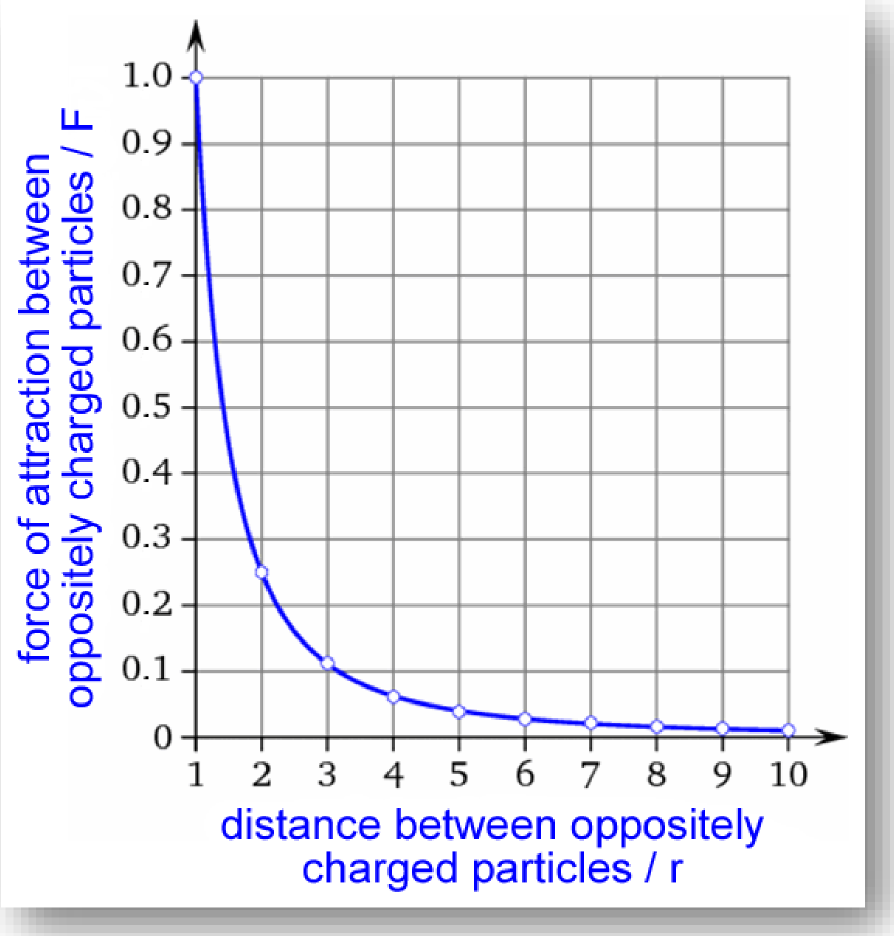
- The force of attraction between oppositely charged particles is given by Coulomb's Law:

$$F \propto \frac{q_1 \times q_2}{r^2}$$

- The *force of attraction* (F) between a proton and an electron in an atom is related to their *charge* (q_1 and q_2), and it *decreases rapidly* as the *distance* between the particles (r) *increases* (inverse square law).

Periodic Table of the Chemical Elements

Periodic Trends – Electrostatic Forces



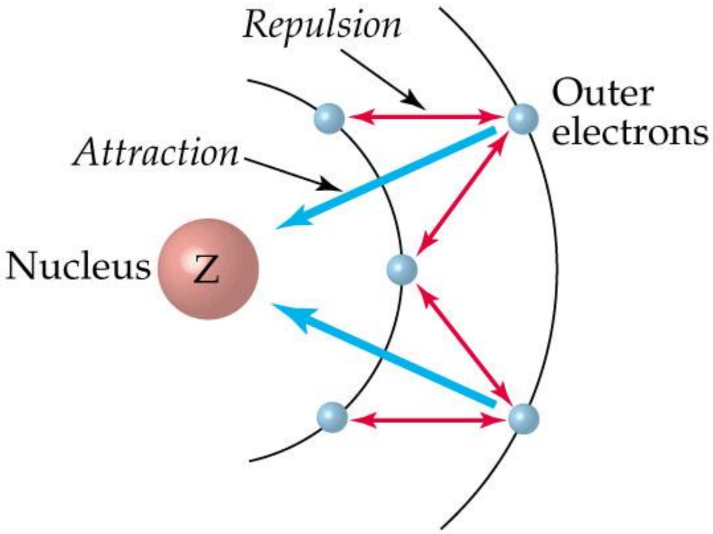
- The force of attraction (F) between two oppositely charged particles decreases rapidly as the distance between the particles (r) increases – inverse square law.

Periodic Table of the Chemical Elements

Periodic Trends – Electrostatic Forces

- A note about *effective nuclear charge*.

- In an atom with many electrons, the negatively charged electron(s) in the *valence shell* is simultaneously *attracted* towards the positively charged nucleus and *repelled* by the negatively charged electrons of the inner electron shells.



Periodic Table of the Chemical Elements

Periodic Trends – Electrostatic Forces

- A note about *effective nuclear charge*.
- The *effective nuclear charge* is the overall charge that an electron(s) in the valence shell of an atom experiences. This takes into account:

→ The number of positively charged protons in the nucleus of the atom (atomic number) that are *attracting* the negatively charged valence electron(s).

→ The number of negatively charged electrons occupying the inner electron shells that are *repelling* the negatively charged valence electron(s). This is often referred to as the *shielding effect*, as these electrons *shield* the valence electron(s) from attractive force of the positively charged nucleus.

Periodic Table of the Chemical Elements

Periodic Trends – Electrostatic Forces

- A note about *effective nuclear charge*.

$$Z_{\text{eff}} = Z - S$$

Where:

Z_{eff} = the effective nuclear charge.

Z = the number of positively charged protons in the nucleus of the atom (atomic number).

S = the number of electrons in-between the positively charged nucleus and negatively charged valence electron(s), *i.e.* the number of non-valence electrons, which give rise to the *shielding effect*.

Periodic Table of the Chemical Elements

Periodic Trends – Electrostatic Forces

Periodic Table of the Chemical Elements

Periodic Trends – Electrostatic Forces

- At analogy of effective nuclear charge:

At a concert, if the group that are performing are not very good (weak nuclear charge) and the audience is large (large shielding effect) then a member of the audience seated at the back (valence electron) is likely to leave (weak electrostatic force of attraction).

Periodic Table of the Chemical Elements

Periodic Trends – Electrostatic Forces

Small nuclear charge.

Large amount of shielding. Large distance from the nucleus.

Weak electrostatic force of attraction.

I don’t like this type of music, the band sound out of tune!

I can’t see the stage, there are too many people in the way!

I’m not staying here any longer, I’m leaving!

Periodic Table of the Chemical Elements

Periodic Trends – Electrostatic Forces

- At analogy of effective nuclear charge:

At a concert, if the group that are performing are very good (strong nuclear charge) and the audience is small (small shielding effect) then a member of the audience seated at the back (valence electron) is unlikely to leave (strong electrostatic force of attraction).

Periodic Table of the Chemical Elements

Periodic Trends – Electrostatic Forces

Large nuclear charge.

This band is great, I really enjoy this type of music!

Small amount of shielding. Small distance from the nucleus.

I'm glad that I've got such a good view of the stage.

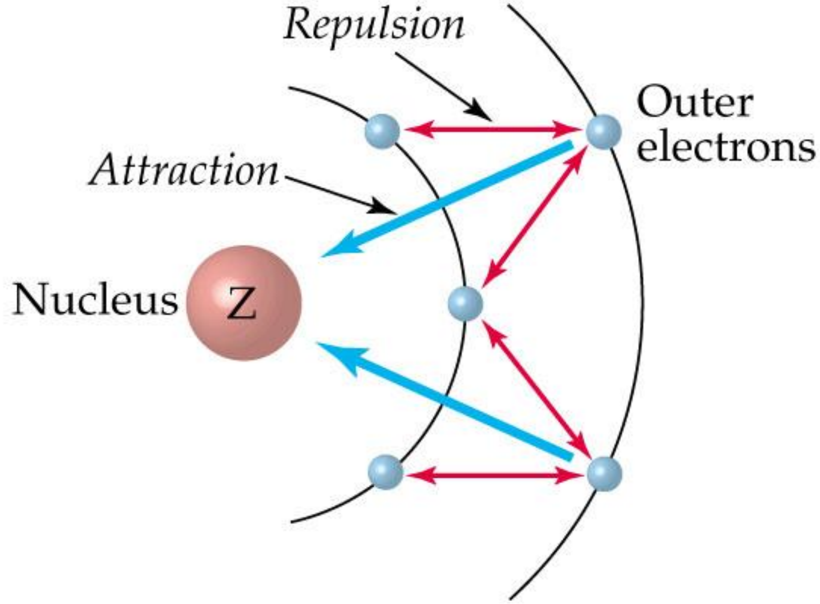
Strong electrostatic force of attraction.

The atmosphere in here is great, I could stay all night.

Periodic Table of the Chemical Elements

Periodic Trends – Electrostatic Forces

- A note about *shielding effect*.

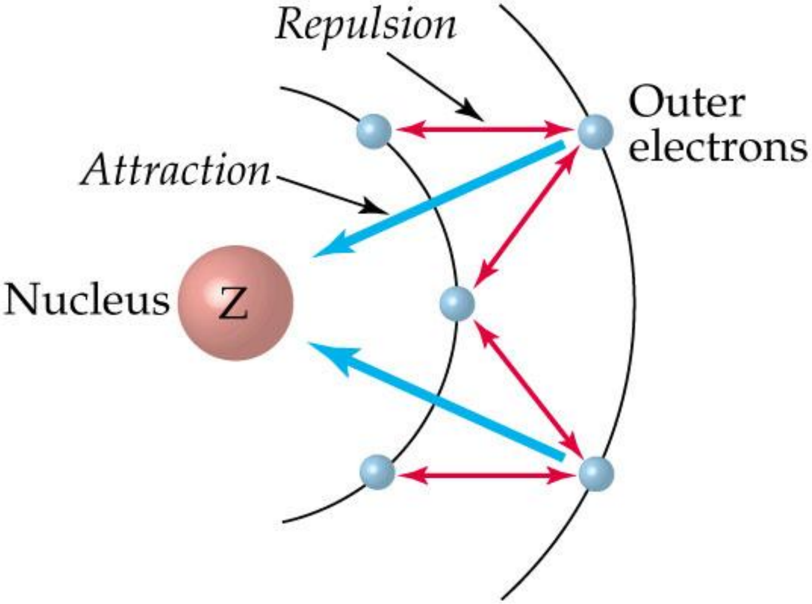


- Electrons in the valence shell of the atom are *shielded* from the positively charged nucleus by negatively charged electrons of the inner electron shells. *Shielding* results in the valence electrons experiencing a *weaker effective nuclear charge*.

Periodic Table of the Chemical Elements

Periodic Trends – Electrostatic Forces

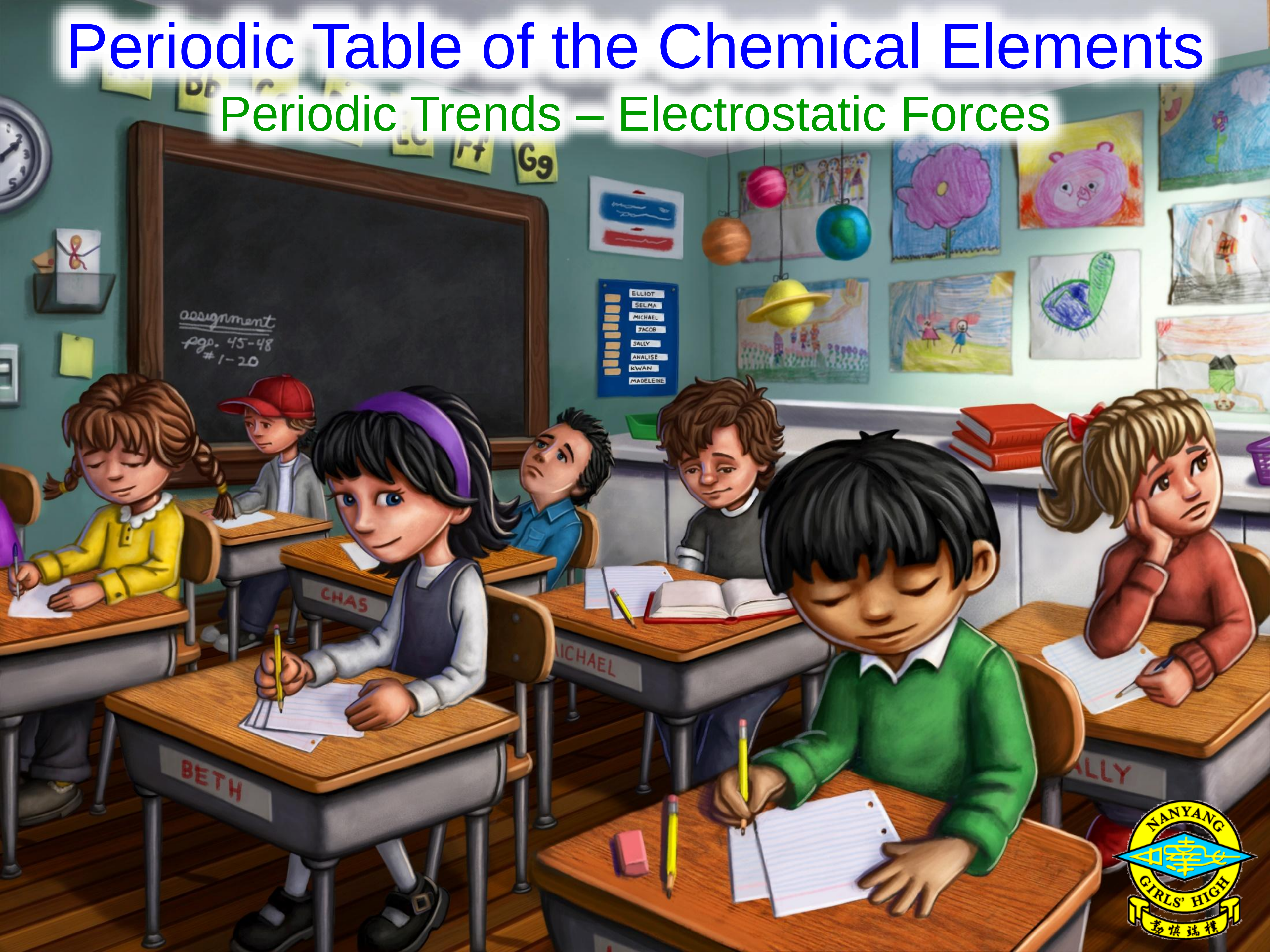
- A note about *shielding effect*.



- Due to the *shielding effect*, the *electrostatic force of attraction* between the positively charged protons in the nucleus and negatively charged electron(s) in the valence shell of the atom is *reduced*.

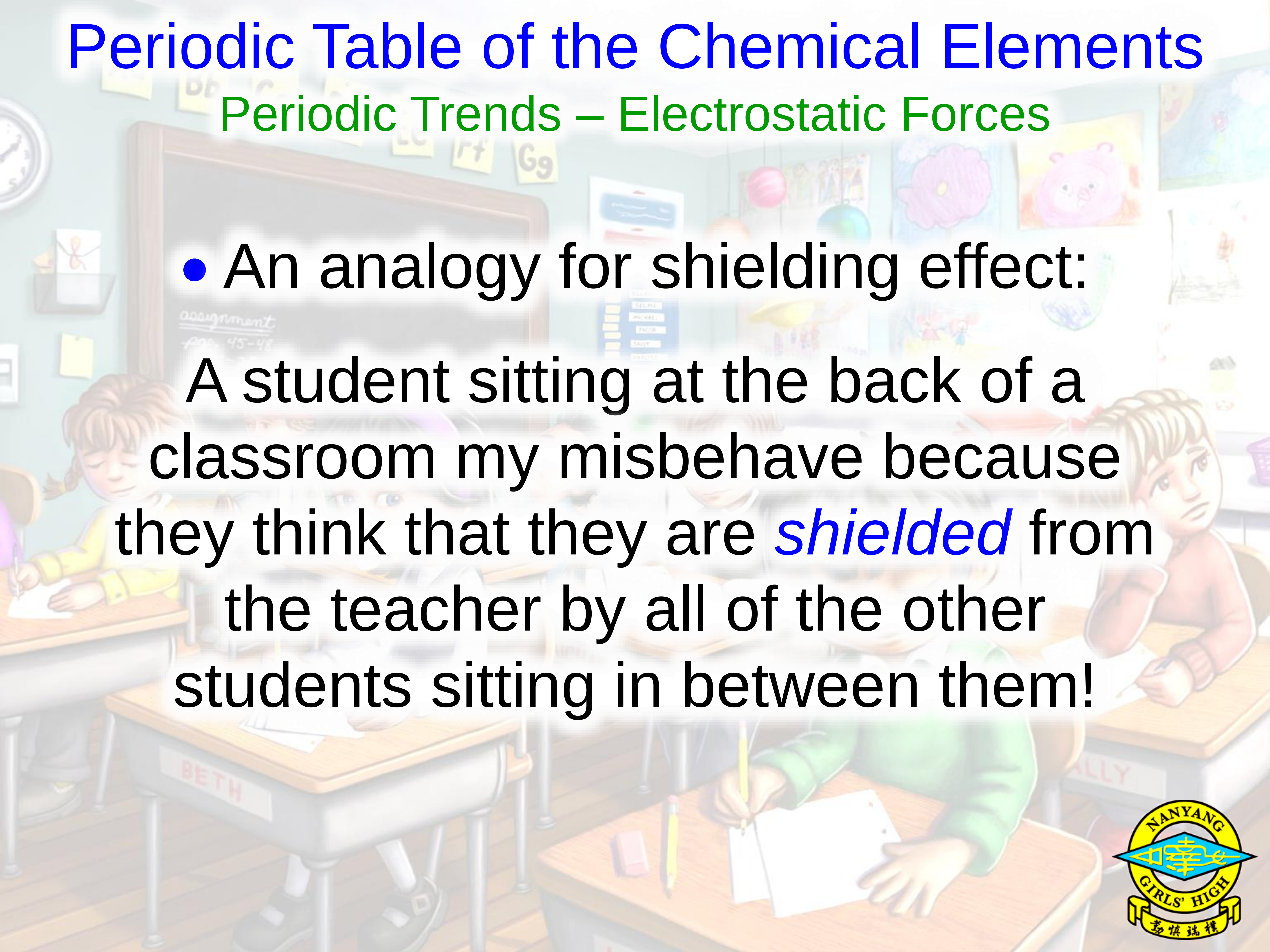
Periodic Table of the Chemical Elements

Periodic Trends – Electrostatic Forces



Periodic Table of the Chemical Elements

Periodic Trends – Electrostatic Forces

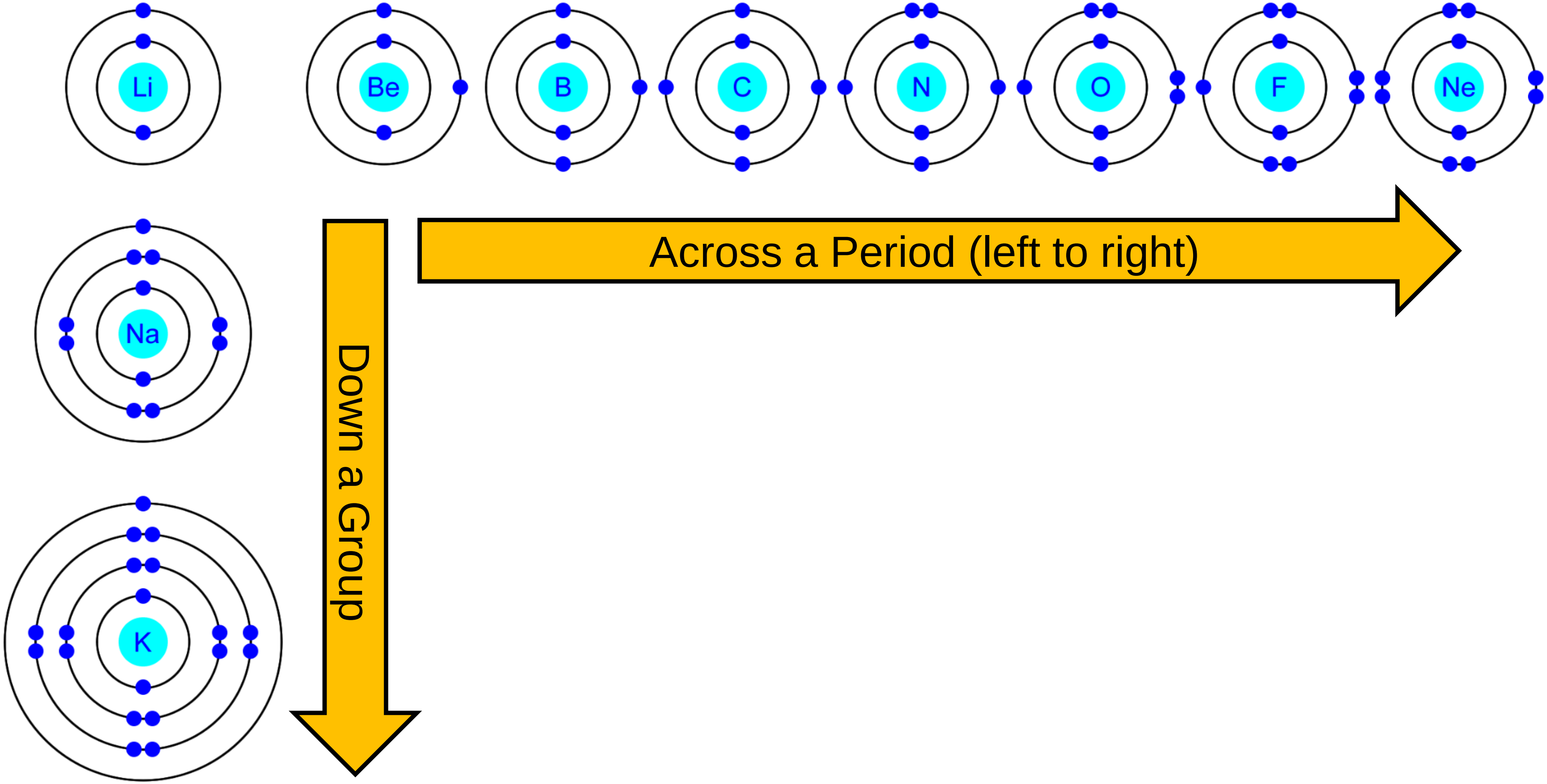


- An analogy for shielding effect:

A student sitting at the back of a classroom my misbehave because they think that they are *shielded* from the teacher by all of the other students sitting in between them!

Periodic Table of the Chemical Elements

Periodic Trends – Electrostatic Forces

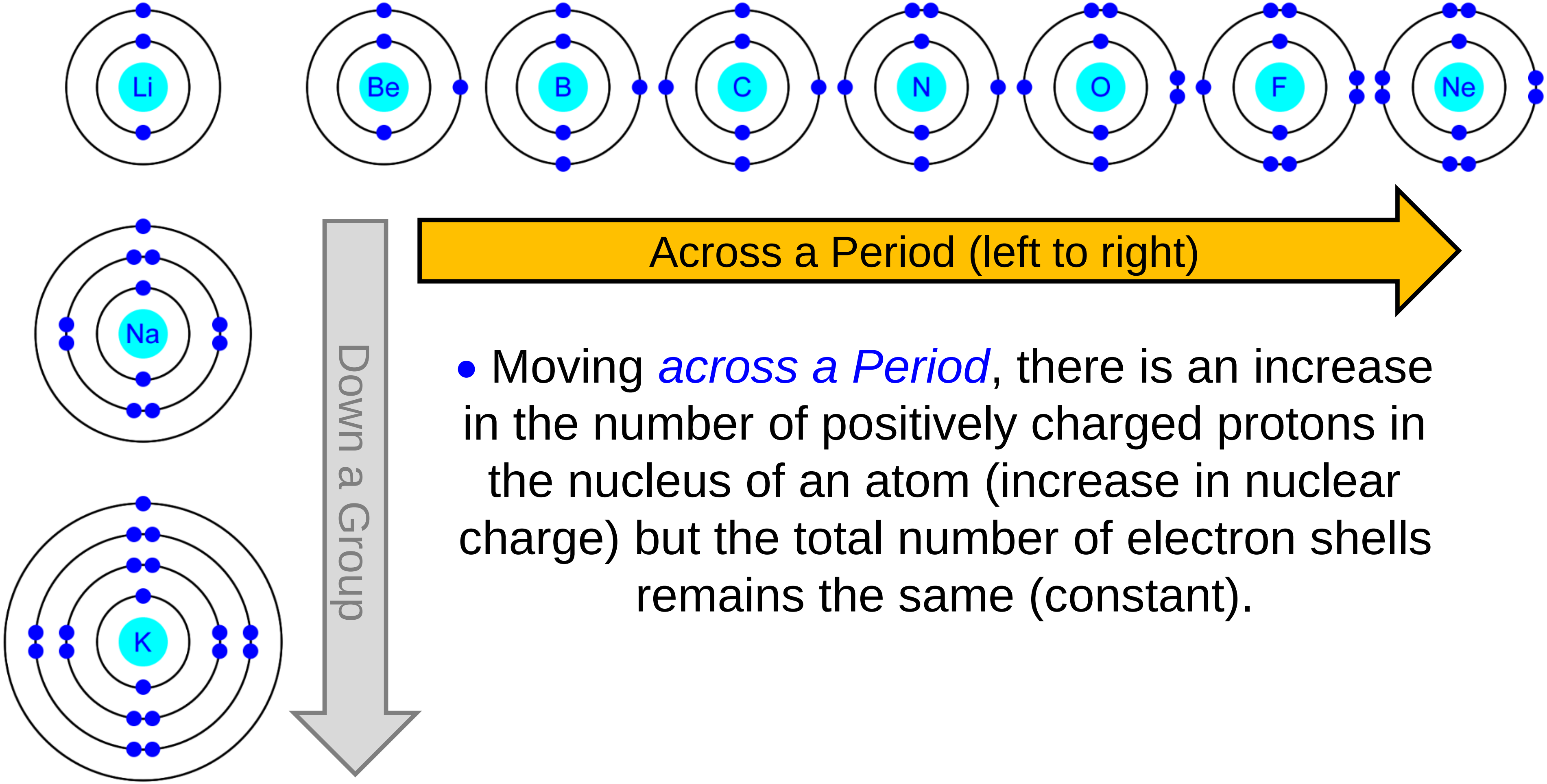


Across a Period (left to right)

Down a Group

Periodic Table of the Chemical Elements

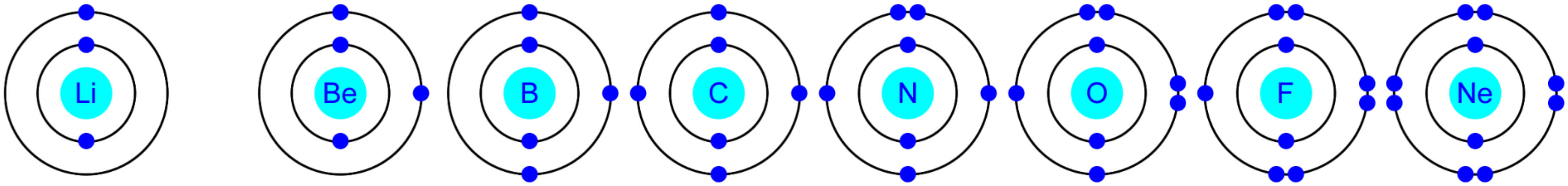
Periodic Trends – Electrostatic Forces

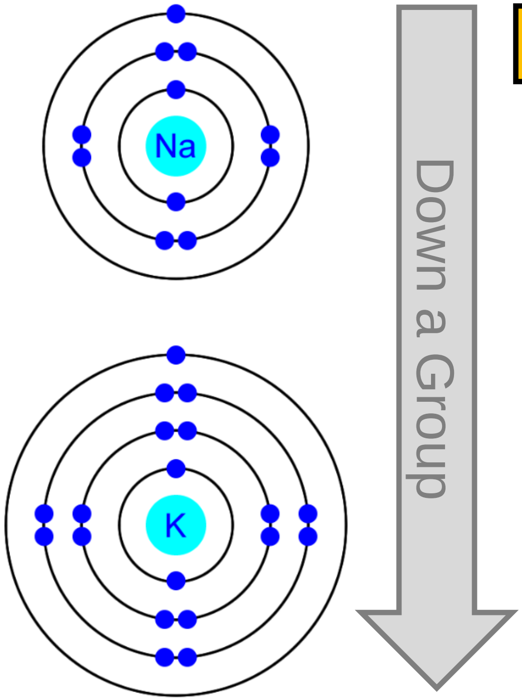


- Moving *across a Period*, there is an increase in the number of positively charged protons in the nucleus of an atom (increase in nuclear charge) but the total number of electron shells remains the same (constant).

Periodic Table of the Chemical Elements

Periodic Trends – Electrostatic Forces





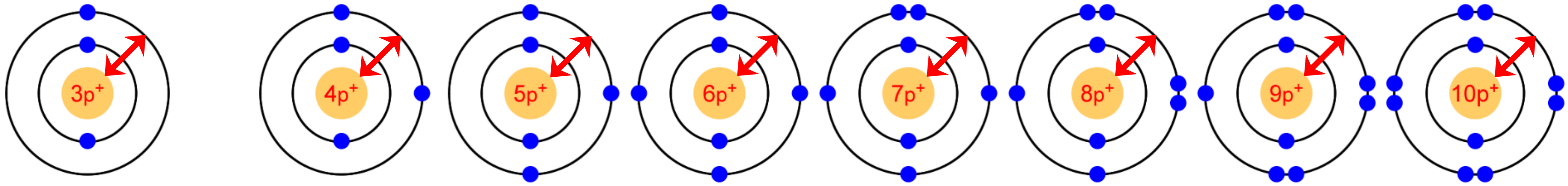
Down a Group

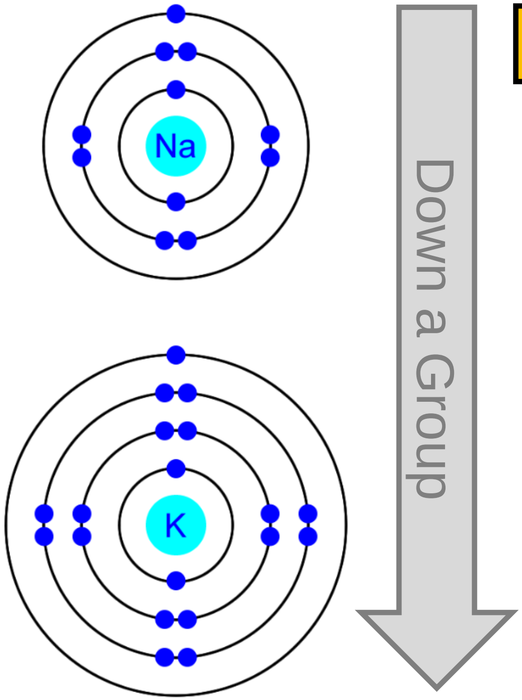
Across a Period (left to right)

- Moving across a Period, the number of electrons *in-between* the positively charged nucleus and negatively charged electrons in the valence shell of an atom remains the same (constant). This means that the number of electrons available to *shield* the valence electron(s) from the attractive force of the nucleus remains the same (constant).

Periodic Table of the Chemical Elements

Periodic Trends – Electrostatic Forces



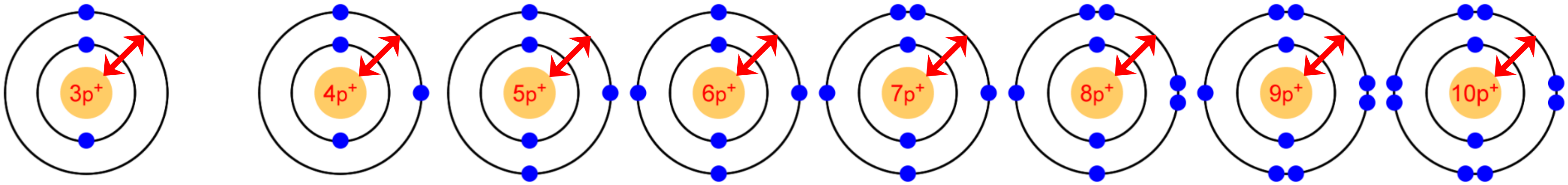


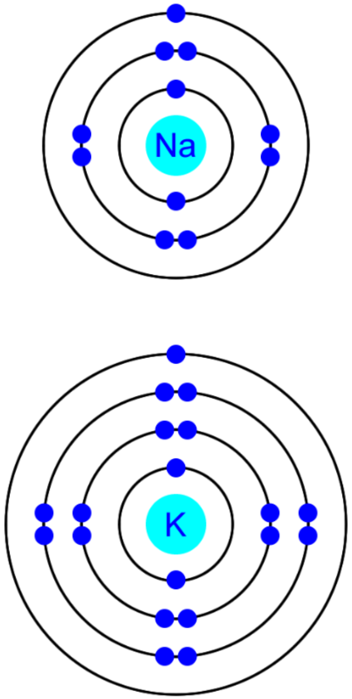
Across a Period (left to right)

- Moving across a Period, the number of protons in the nucleus of an atom (nuclear charge) increases, but the number of inner shell electrons available to *shield* the valence electron(s) from this increasing nuclear charge remains the same (constant). Electrons in the valence shell of an atom are said to experience an increasing *effective nuclear charge* – the nuclear charge that the valence electron(s) experience once the *shielding effect* has been taken into consideration.

Periodic Table of the Chemical Elements

Periodic Trends – Electrostatic Forces





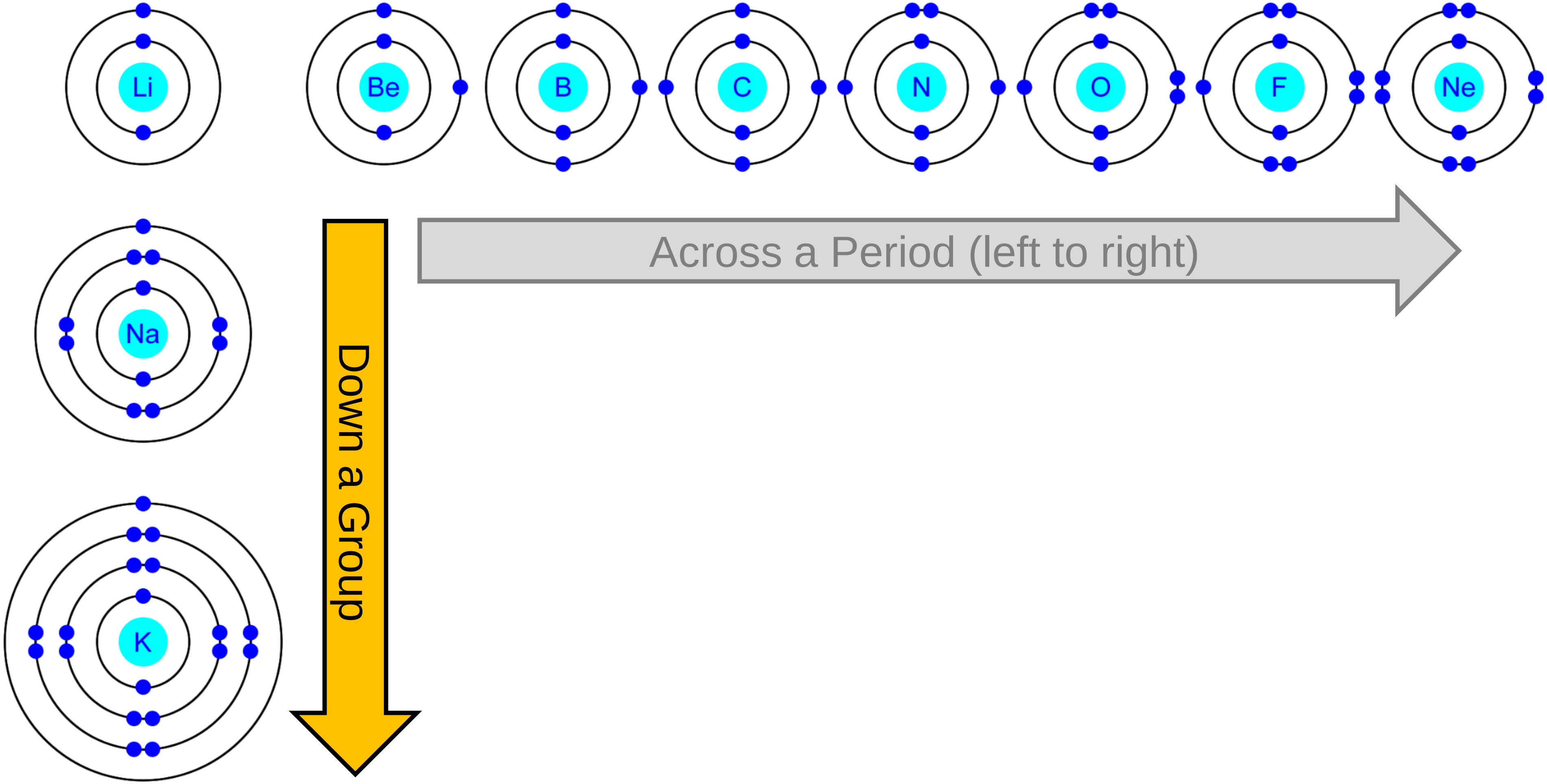
Across a Period (left to right)

Down a Group

- Due to the increasing effective nuclear charge, the *electrostatic force of attraction* between the nucleus and electron(s) in the valence shell of an atom *increases across a Period* from left to right.

Periodic Table of the Chemical Elements

Periodic Trends – Electrostatic Forces

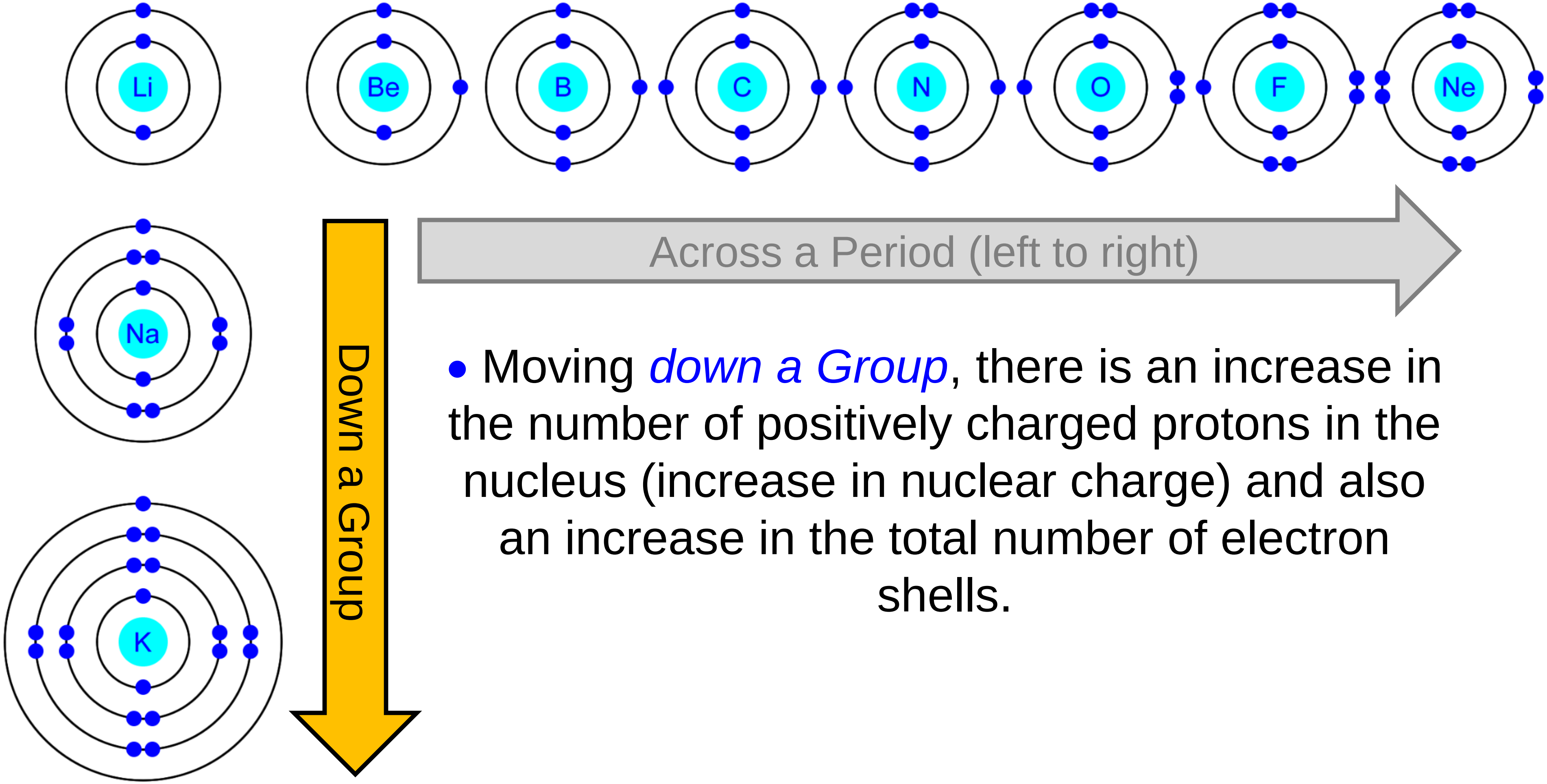


Across a Period (left to right)

Down a Group

Periodic Table of the Chemical Elements

Periodic Trends – Electrostatic Forces



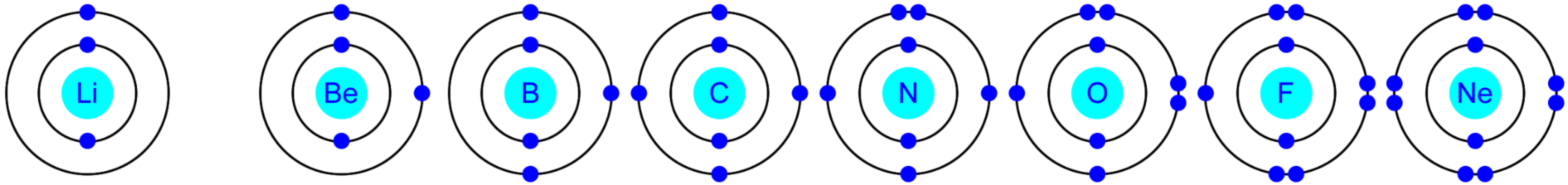
Across a Period (left to right)

Down a Group

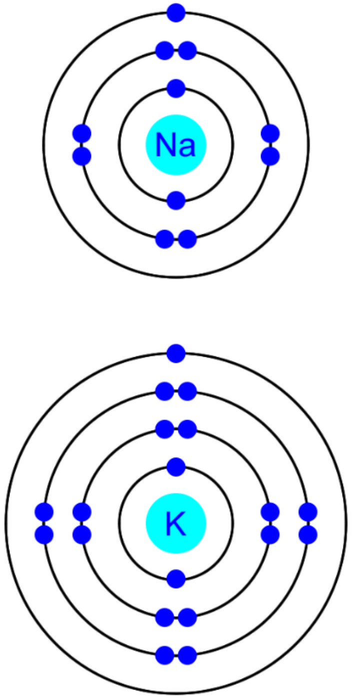
- Moving *down a Group*, there is an increase in the number of positively charged protons in the nucleus (increase in nuclear charge) and also an increase in the total number of electron shells.

Periodic Table of the Chemical Elements

Periodic Trends – Electrostatic Forces



Across a Period (left to right)



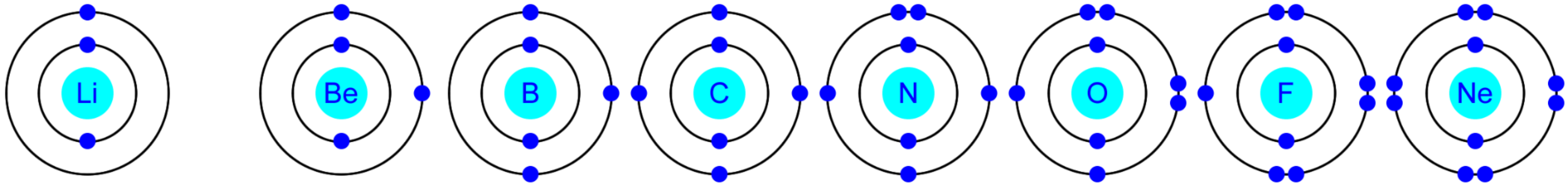
Down a Group

- Effective nuclear charge remains almost constant / unchanged moving down a Group. This is because the increase in nuclear charge is cancelled / offset by the increasing *shielding effect* due to the increasing number of electrons in-between the positively charged nucleus and negatively charged electrons in the valence shell.

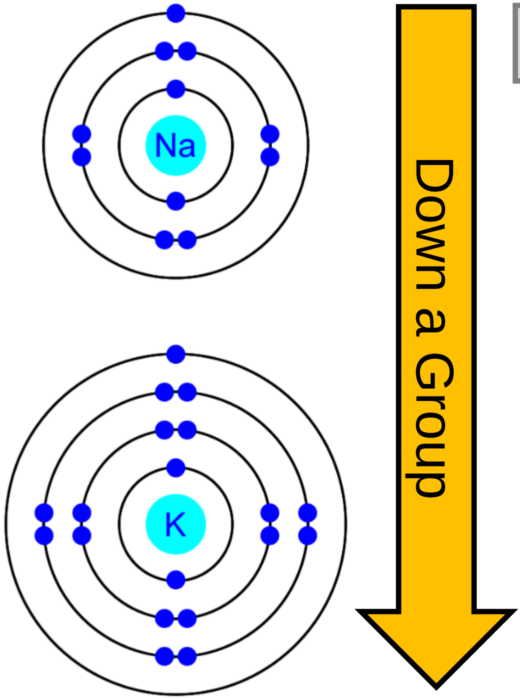
Recall, $Z_{\text{eff}} = Z - S$

Periodic Table of the Chemical Elements

Periodic Trends – Electrostatic Forces



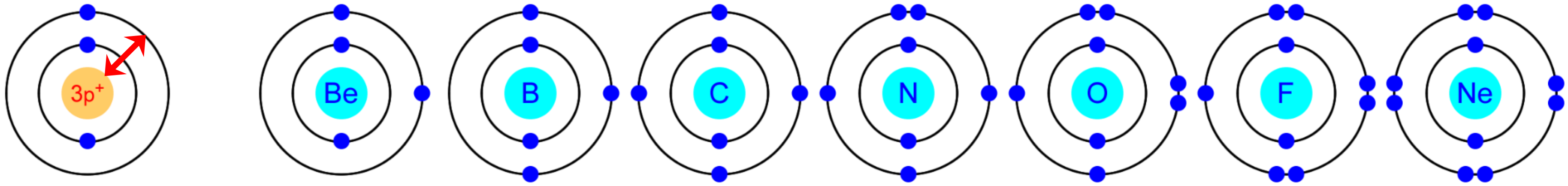
Across a Period (left to right)

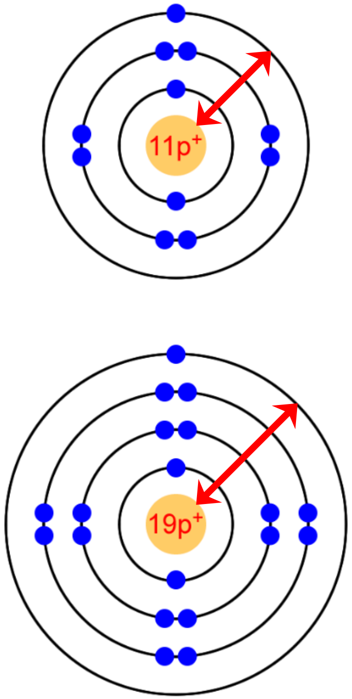


- Although there is no significant change in the effective nuclear charge moving down a Group, the increasing distance between the nucleus and valence electron(s) is very important. As the distance between the positively charged nucleus and negatively charged electrons in the valence shell *increases*, so the *electrostatic force of attraction* between the nucleus and electrons in the valence shell *decreases down a Group* (the inverse square law).

Periodic Table of the Chemical Elements

Periodic Trends – Electrostatic Forces





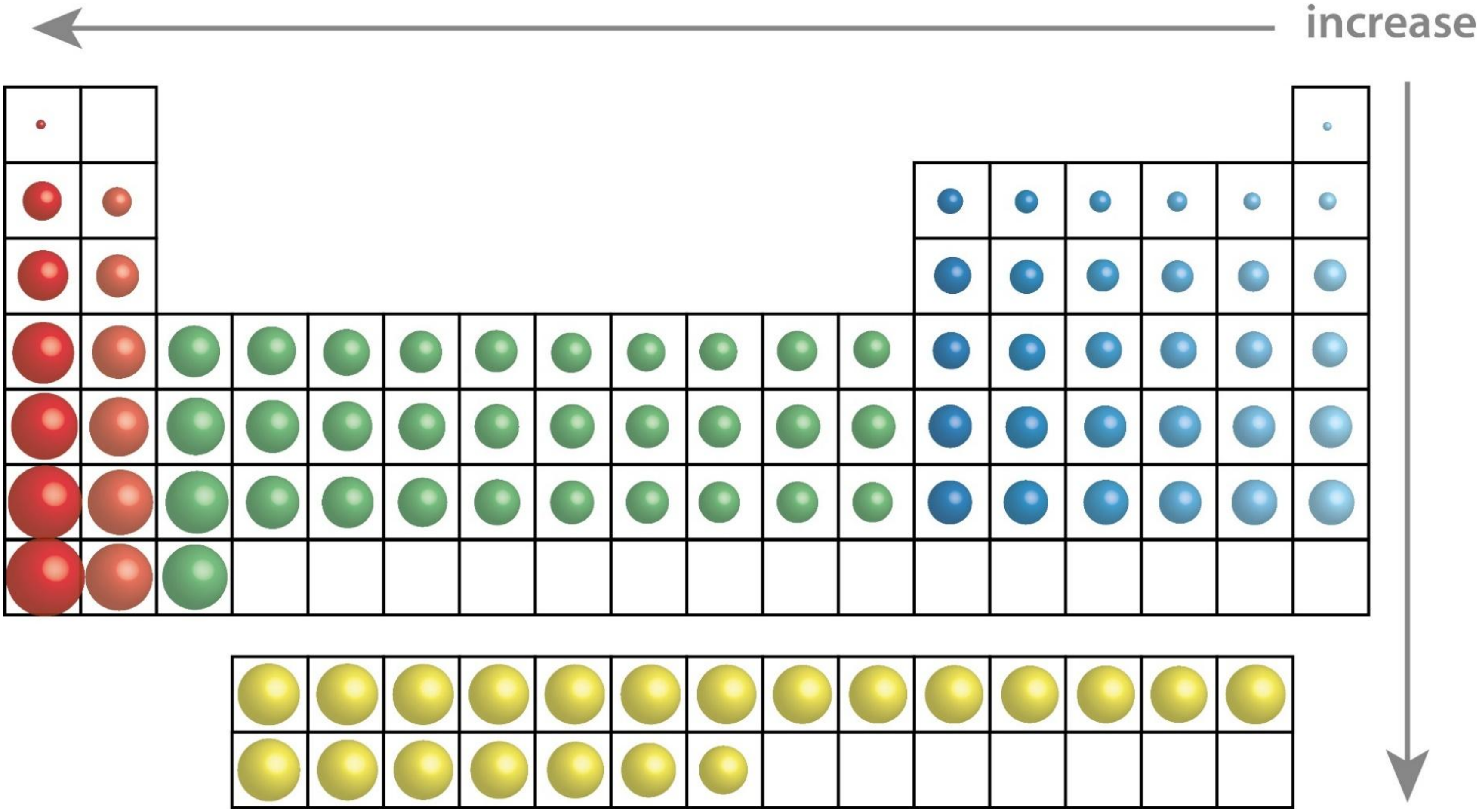
Across a Period (left to right)

Down a Group

- Although there is no significant change in the effective nuclear charge moving down a Group, the increasing distance between the nucleus and valence electron(s) is very important. As the distance between the positively charged nucleus and negatively charged electrons in the valence shell *increases*, so the *electrostatic force of attraction* between the nucleus and electrons in the valence shell *decreases down a Group* (the inverse square law).

Periodic Table of the Chemical Elements

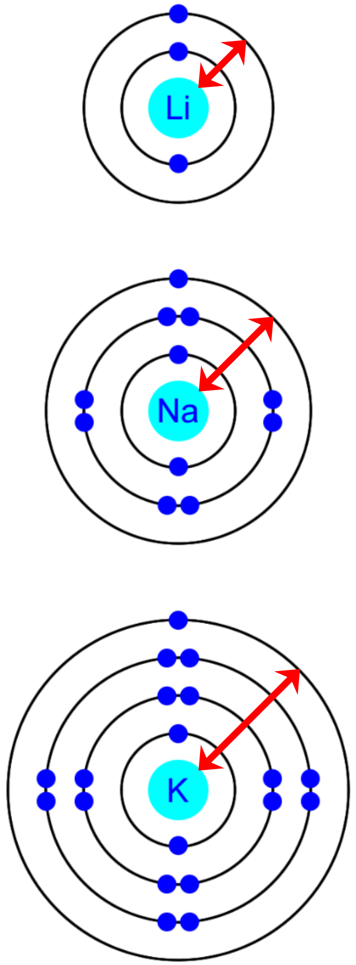
Periodic Trends – Atomic Radius



[• Return to Main Menu]

Periodic Table of the Chemical Elements

Periodic Trends – Atomic Radius



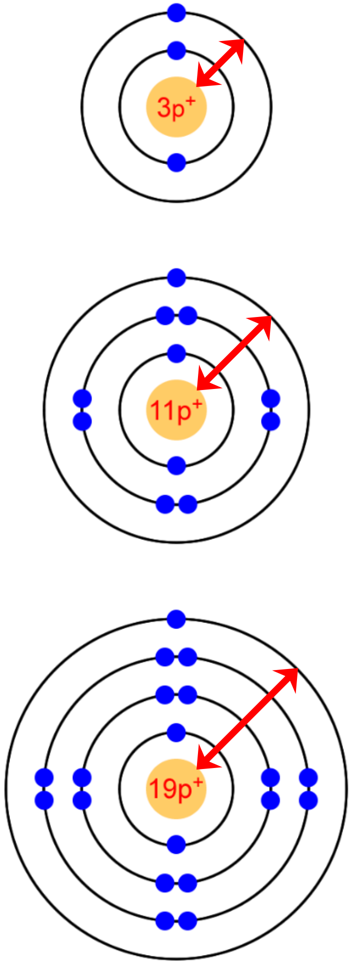
- Atomic radii *increase* from the top to the bottom of any Group of the Periodic Table.
- The number of protons in the nucleus of an atom (nuclear charge) and the number of electron shells around the nucleus of the atom *both increase* down a Group.
- Moving down a Group, there is no significant change in the effective nuclear charge that the electron(s) in the valence shell of the atom experiences, as the increasing nuclear charge and increasing shielding effect cancel each other *e.g.*

Z_{eff} (Na) = 11 – 10 = +1

Z_{eff} (K) = 19 – 18 = +1

Periodic Table of the Chemical Elements

Periodic Trends – Atomic Radius



- Atomic radii *increase* from the top to the bottom of any Group of the Periodic Table.

- The number of protons in the nucleus of an atom (nuclear charge) and the number of electron shells around the nucleus of the atom *both increase* down a Group.

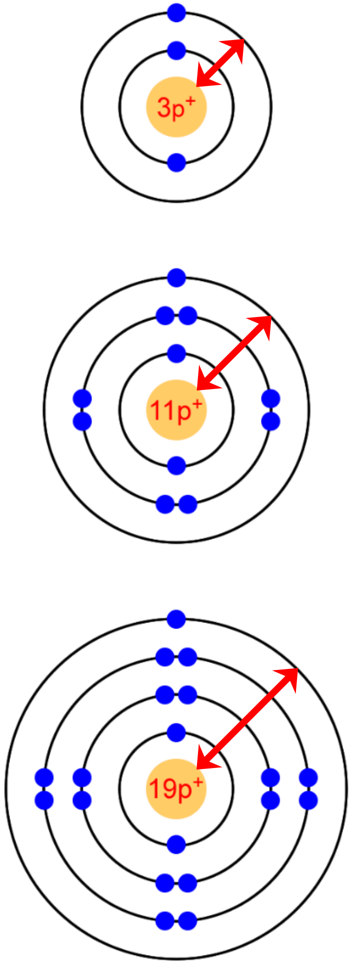
- Moving down a Group, there is no significant change in the effective nuclear charge that the electron(s) in the valence shell of the atom experiences, as the increasing nuclear charge and increasing shielding effect cancel each other *e.g.*

Z_{eff} (Na) = 11 – 10 = +1

Z_{eff} (K) = 19 – 18 = +1

Periodic Table of the Chemical Elements

Periodic Trends – Atomic Radius



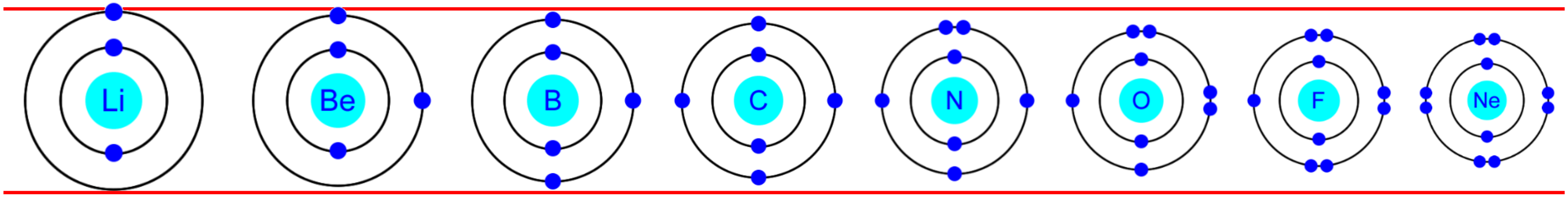
- Moving down a Group, additional protons enter the nucleus, but the additional electrons are too numerous to all fit into the same existing electron shell.

- There is the need to add a new electron shell to the atom in order to accommodate the additional electrons.

- Moving down a Group, atomic radius increases due to the *addition of a new electron shell* to the atom.

Periodic Table of the Chemical Elements

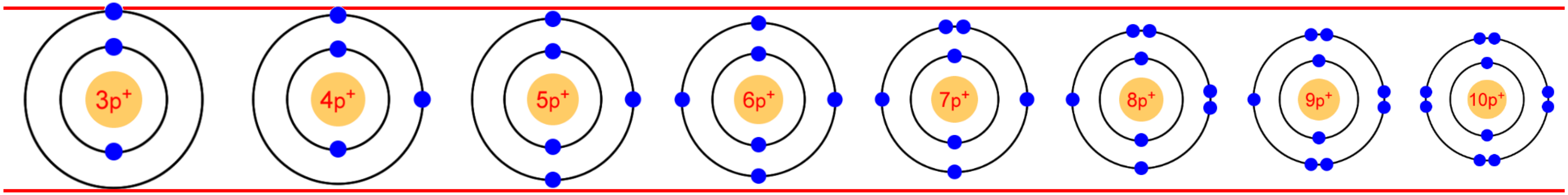
Periodic Trends – Atomic Radius



- Atomic radii *decrease* from the left-hand-side to the right-hand-side of any Period of the Periodic Table.
- The number of protons in the nucleus of an atom (nuclear charge) *increases* across a Period.
- The number of electron shells *remains constant* across a Period and therefore the number of inner shell electrons available to *shield* electrons in the valence shell from the attractive force of the nucleus *remains constant* across a Period.

Periodic Table of the Chemical Elements

Periodic Trends – Atomic Radius



- Moving across a Period, electrons in the valence shell of the atom experience a *greater effective nuclear charge*.

Z_{eff} (Li) = 3 – 2 = +1 Z_{eff} (Ne) = 10 – 2 = +8

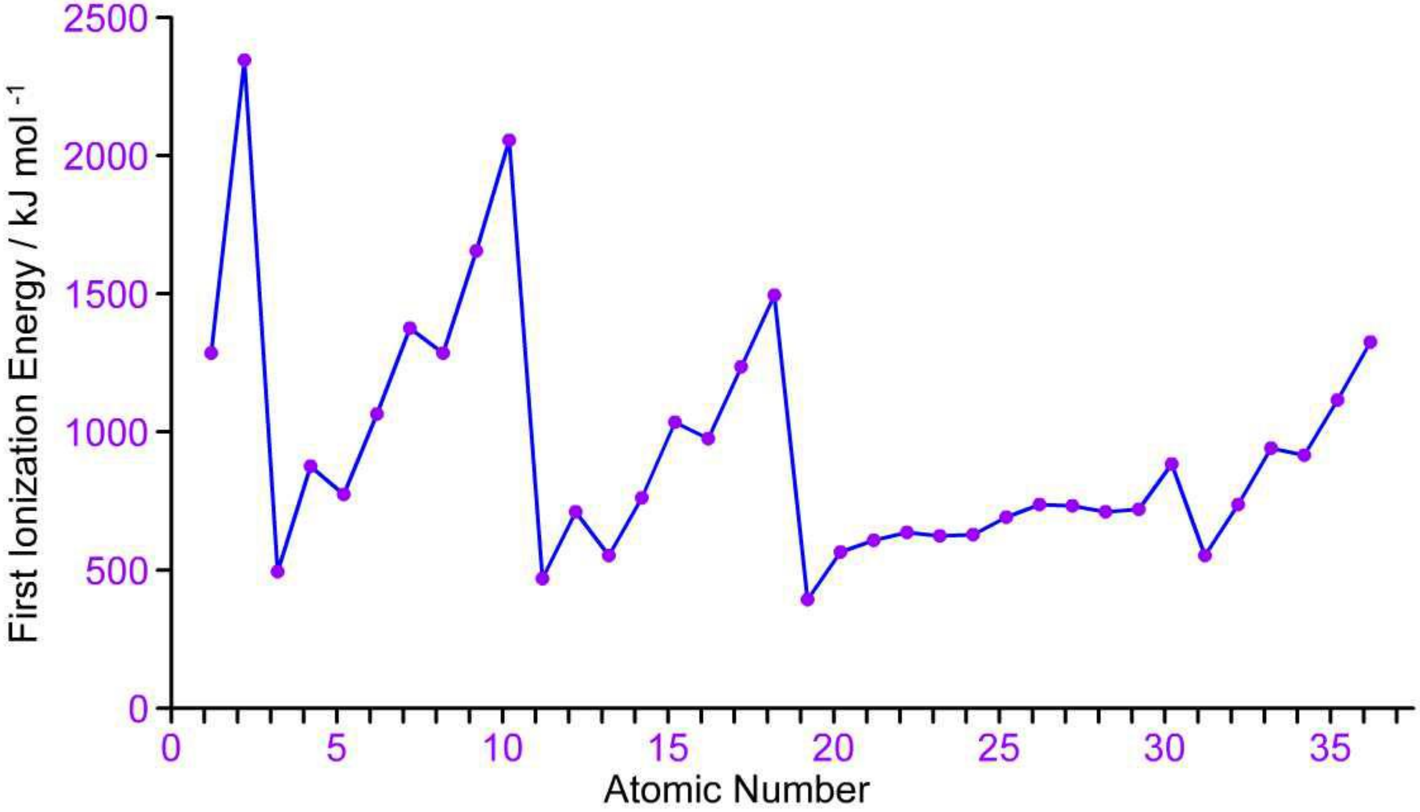
- An increase in effective nuclear charge means that there is an *increase in the electrostatic force of attraction* between the positively charged protons in the nucleus and negatively charged electrons in the valence shell of the atom, causing a steady *decrease in atomic radius across a Period*.

Periodic Table of the Chemical Elements

Periodic Trends – First Ionization Energy

- First ionization energy is the energy required to convert 1 mole (6×10^{23}) of gaseous atoms into one mole (6×10^{23}) of unipositive (1+) gaseous ions.

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



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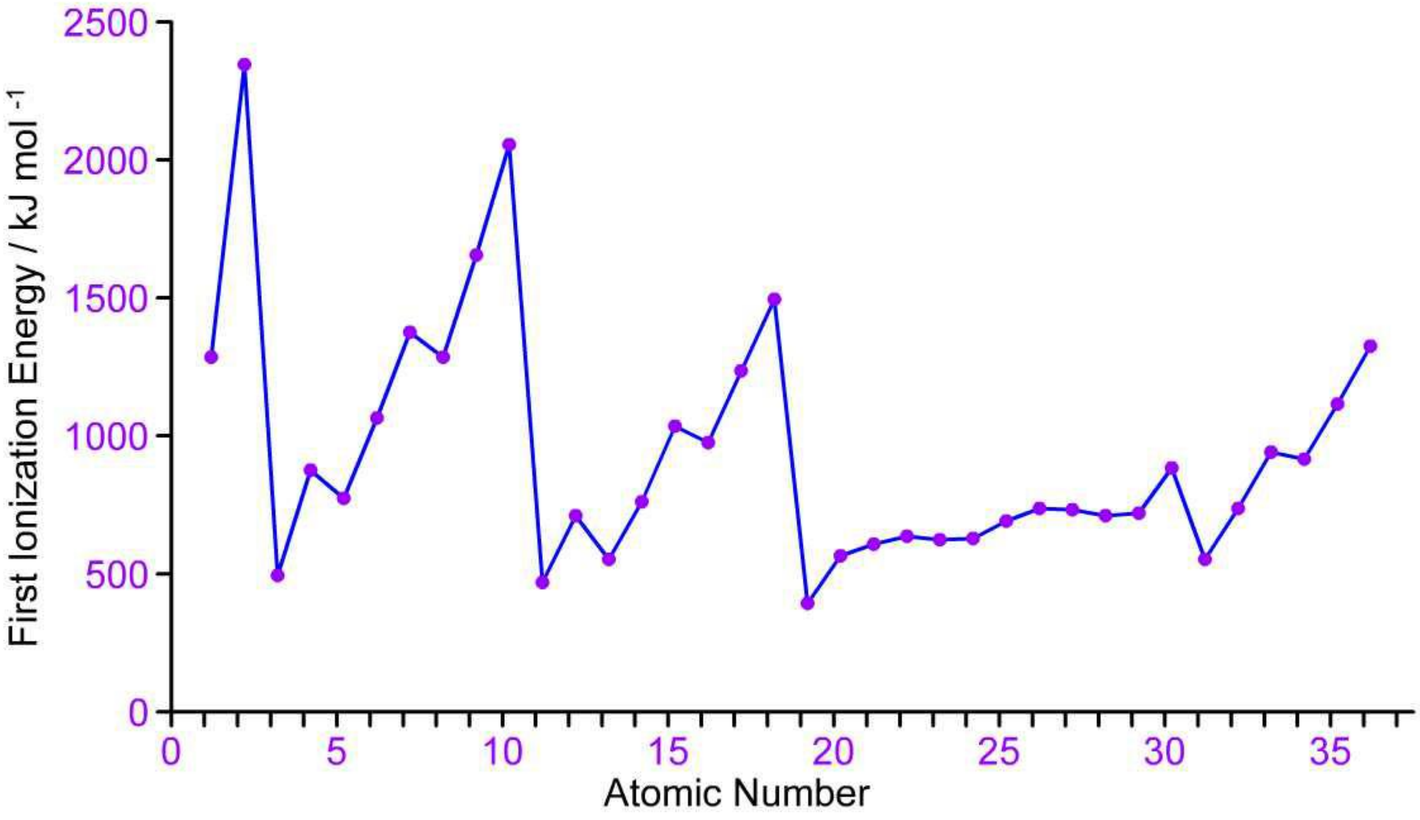
Periodic Table of the Chemical Elements

Periodic Trends – First Ionization Energy

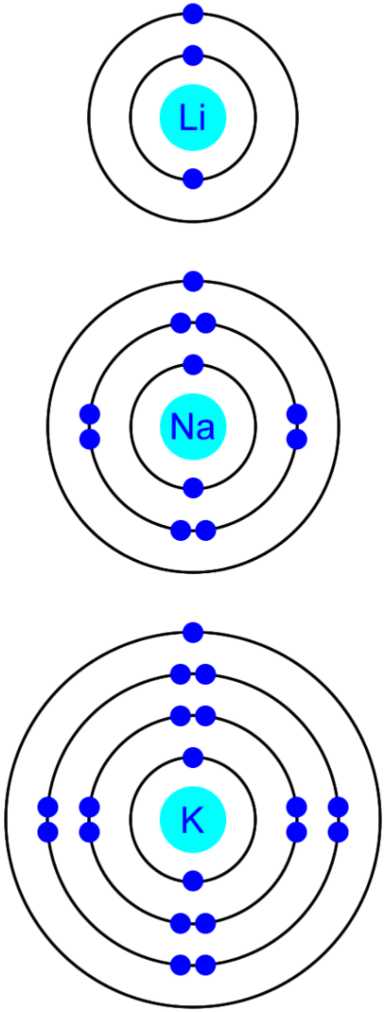
- Essentially, first ionization energy gives an indication of the amount of energy that is required to remove a single electron from the valence shell of a single atom.



Periodic Table of the Chemical Elements

Periodic Trends – First Ionization Energy

- First ionization energy *decreases down a Group*.



- The number of protons in the nucleus of an atom (nuclear charge) and the number of electron shells around the nucleus of the atom *both increase* down a Group.

- Moving down a Group, there is no significant change in the effective nuclear charge that the electron(s) in the valence shell of the atom experience, as the increasing nuclear charge and increasing shielding effect cancel each other *e.g.*

Z_{eff} (Li) = 3 – 2 = +1

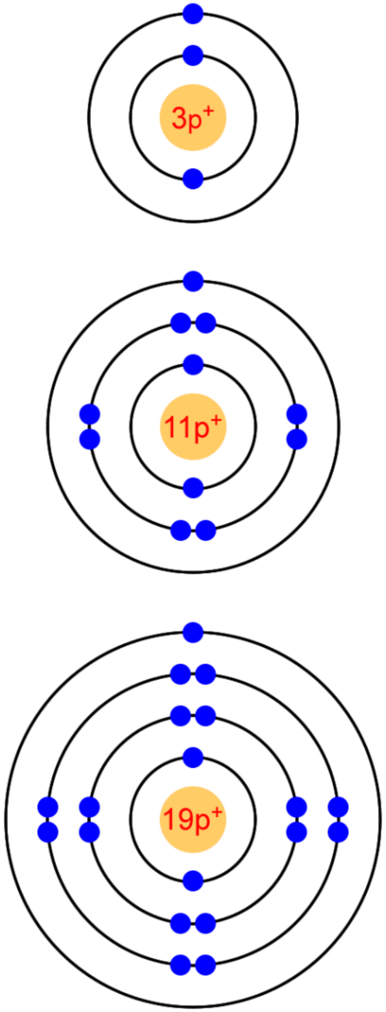
Z_{eff} (Na) = 11 – 10 = +1

Z_{eff} (K) = 19 – 18 = +1

Periodic Table of the Chemical Elements

Periodic Trends – First Ionization Energy

- First ionization energy *decreases down a Group*.



- The number of protons in the nucleus of an atom (nuclear charge) and the number of electron shells around the nucleus of the atom *both increase* down a Group.

- Moving down a Group, there is no significant change in the effective nuclear charge that the electron(s) in the valence shell of the atom experience, as the increasing nuclear charge and increasing shielding effect cancel each other *e.g.*

Z_{eff} (Li) = 3 – 2 = +1

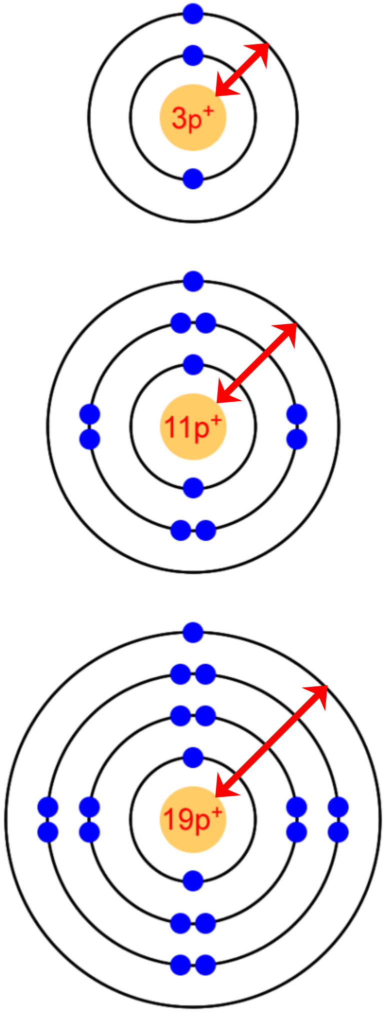
Z_{eff} (Na) = 11 – 10 = +1

Z_{eff} (K) = 19 – 18 = +1

Periodic Table of the Chemical Elements

Periodic Trends – First Ionization Energy

- First ionization energy *decreases down a Group*.



- The addition of a new electron shell to the atoms is significant because it means that the electron(s) in the valence shell (lost during ionization) is *further from the nucleus*.

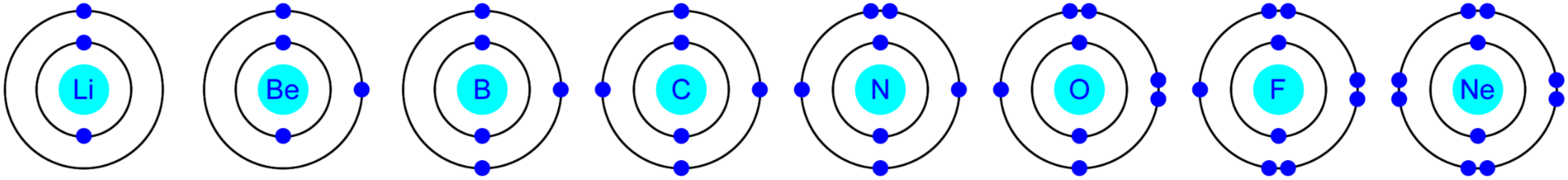
- This *reduces the electrostatic force of attraction* between the positively charged nucleus and negatively charged electron(s) in the valence shell (inverse square law).

- Less energy is required to remove an electron from the valence shell of the atom, therefore *first ionization energy decreases down a Group*.

Periodic Table of the Chemical Elements

Periodic Trends – First Ionization Energy

- First ionization energy *increases across a Period*.



- The number of protons in the nucleus of an atom (nuclear charge) *increases* across a Period.

- The number of electron shells *remains constant* across a Period and therefore the number of inner shell electrons available to *shield* electrons in the valence shell from the attractive force of the nucleus *remains constant* across a Period.

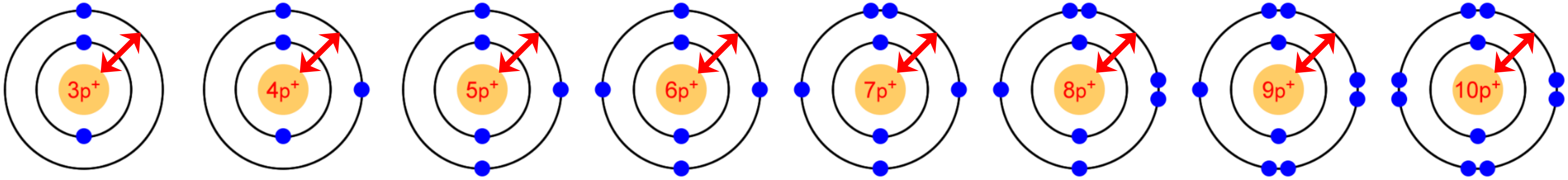
- Moving across a Period, electrons in the valence shell of the atom experience a *greater effective nuclear charge*.

Z_{eff} (Li) = 3 – 2 = +1 Z_{eff} (Ne) = 10 – 2 = +8

Periodic Table of the Chemical Elements

Periodic Trends – First Ionization Energy

- First ionization energy *increases across a Period*.



- The number of protons in the nucleus of an atom (nuclear charge) *increases* across a Period.

- The number of electron shells *remains constant* across a Period and therefore the number of inner shell electrons available to *shield* electrons in the valence shell from the attractive force of the nucleus *remains constant* across a Period.

- Moving across a Period, electrons in the valence shell of the atom experience a *greater effective nuclear charge*.

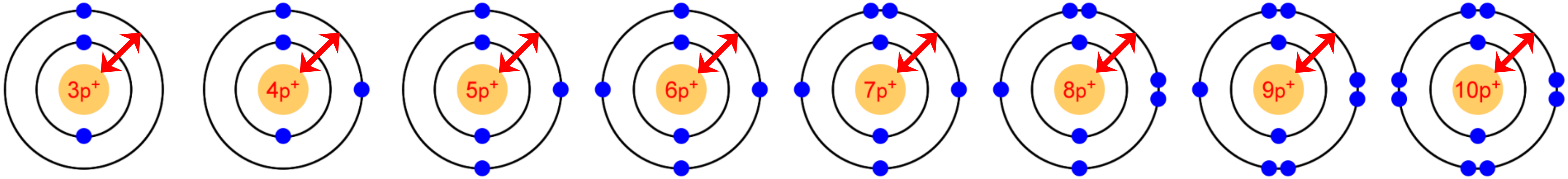
Z_{eff} (Li) = $3 - 2 = +1$ Z_{eff} (Ne) = $10 - 2 = +8$

NANYANG GIRLS' HIGH

Periodic Table of the Chemical Elements

Periodic Trends – First Ionization Energy

- First ionization energy *increases across a Period*.



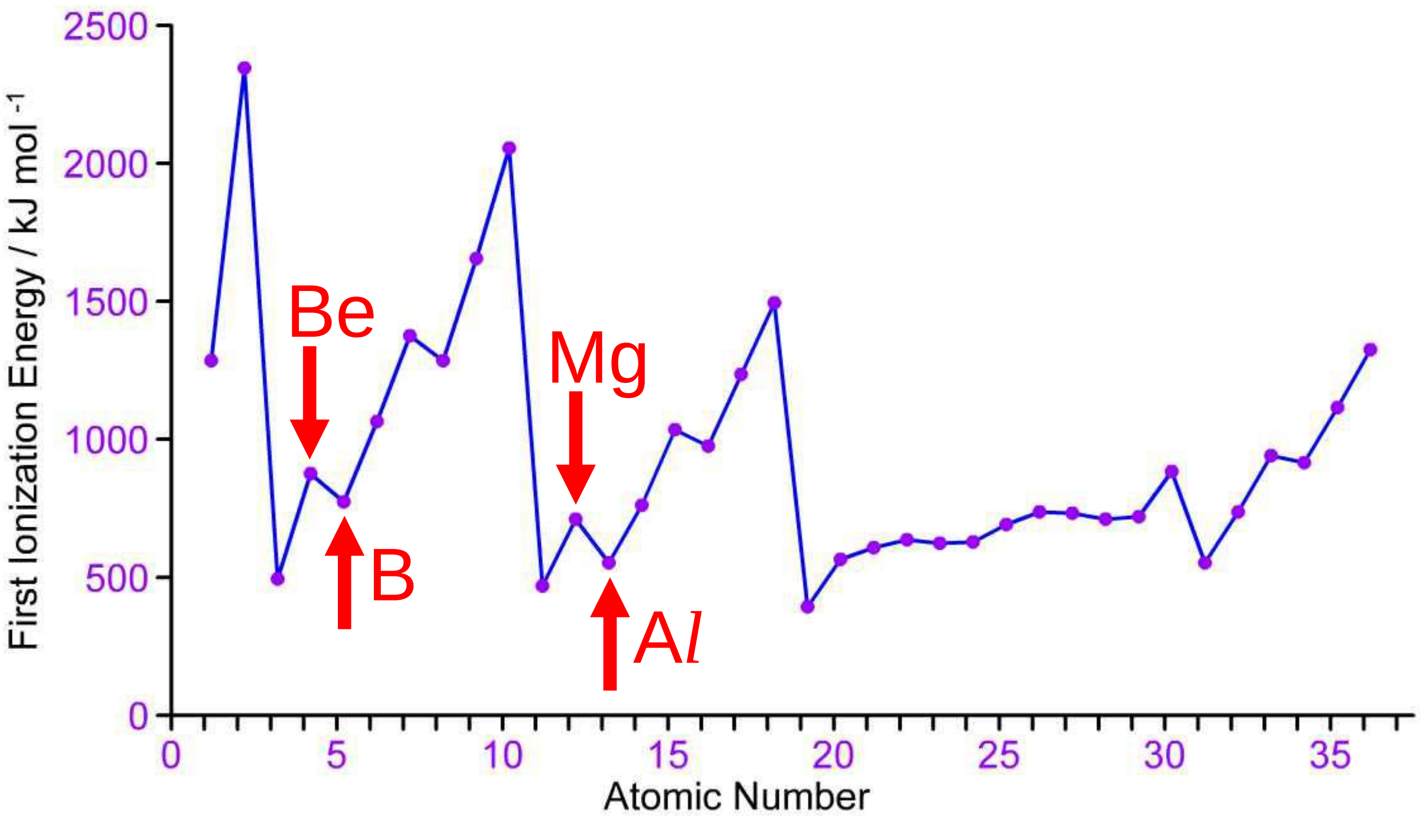
- An increase in effective nuclear charge means that there is an *increase in the electrostatic force of attraction* between the positively charged protons in the nucleus and negatively charged electron(s) in the valence shell of the atom – which are the electrons that are lost during ionization.

- Moving across a Period, more energy is required to remove an electron from the valence shell of an atom, hence *first ionization energy increases across a Period*.

Periodic Table of the Chemical Elements

Periodic Trends – First Ionization Energy

- First ionization energy *decreases* slightly between *Group 2 and Group 13* elements.



Periodic Table of the Chemical Elements

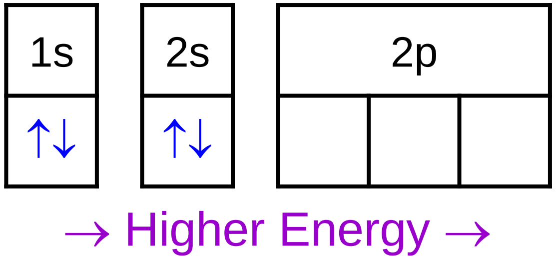
Periodic Trends – First Ionization Energy

- First ionization energy *decreases* slightly between *Group 2 and Group 13* elements.

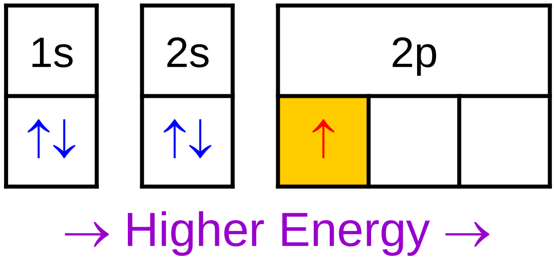
- Moving from Group 2 to Group 13, the additional electron enters a *p*-orbital of the same principle quantum shell.

- An electron in a *p*-orbital is *higher in energy* than an electron in the *s*-orbital of the same principle quantum shell. Consequently, *less energy* is required to remove the *p*-orbital electron (ionization) compared to an electron in the corresponding *s*-orbital, and first ionization energy *decreases* slightly between Group 2 and Group 13.

Beryllium
Group 2



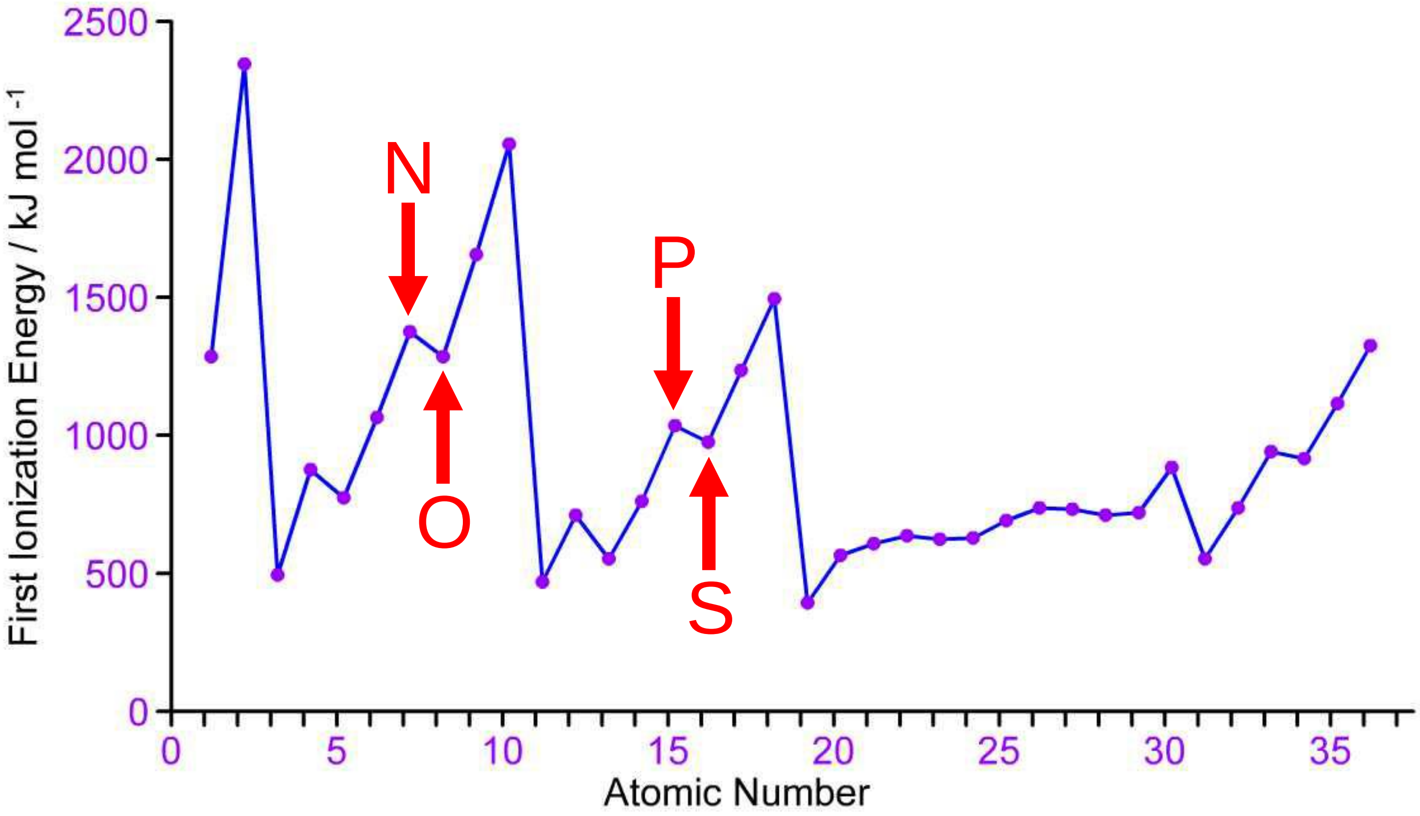
Boron
Group 3



Periodic Table of the Chemical Elements

Periodic Trends – First Ionization Energy

- First ionization energy *decreases* slightly between *Group 15* and *Group 16* elements.



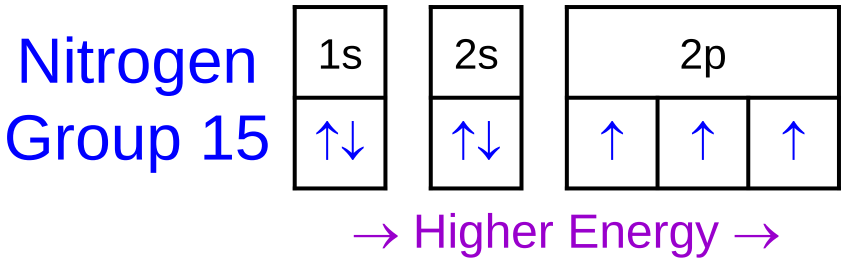
Periodic Table of the Chemical Elements

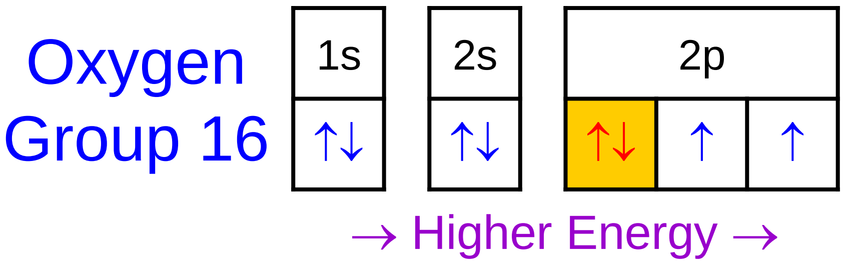
Periodic Trends – First Ionization Energy

- First ionization energy *decreases* slightly between *Group 15* and *Group 16* elements.

- Moving from Group 15 to Group 16, the additional electron must spin pair with an existing electron in one of the atom's *p*-orbitals.

- An *electrostatic force of repulsion* between the two spin paired electrons that share the same *p*-orbital means that *less energy* is required to remove (ionization) an electron from the *p*-orbital, and first ionization energy *decreases* slightly between Group 15 and Group 16.

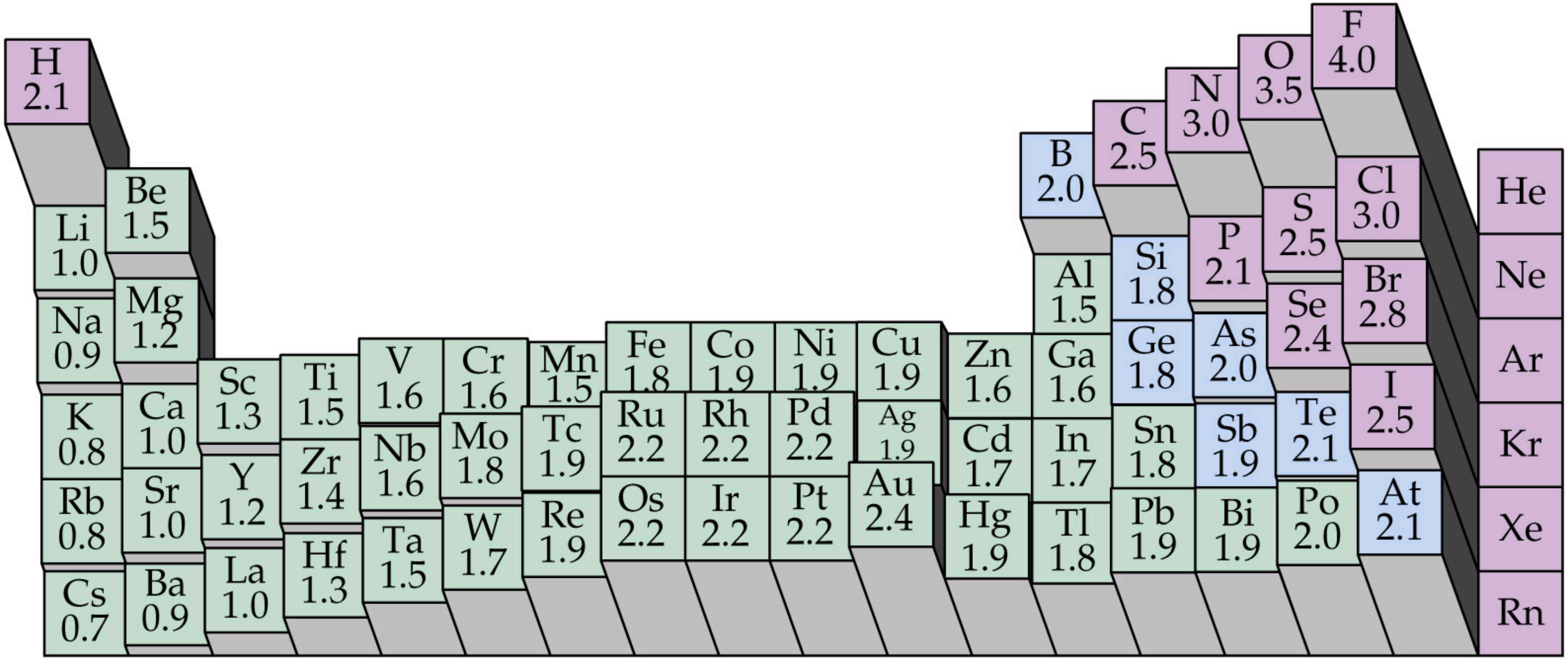




Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity

- Electronegativity Values of the Chemical Elements (Pauling Scale)



- Trends in electronegativity values.

[• Return to Main Menu]

Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity

- Definition of *Electronegativity*

→ Electronegativity is a measure of the relative tendency of an atom to attract a *shared pair* or *bonding pair of electrons*.

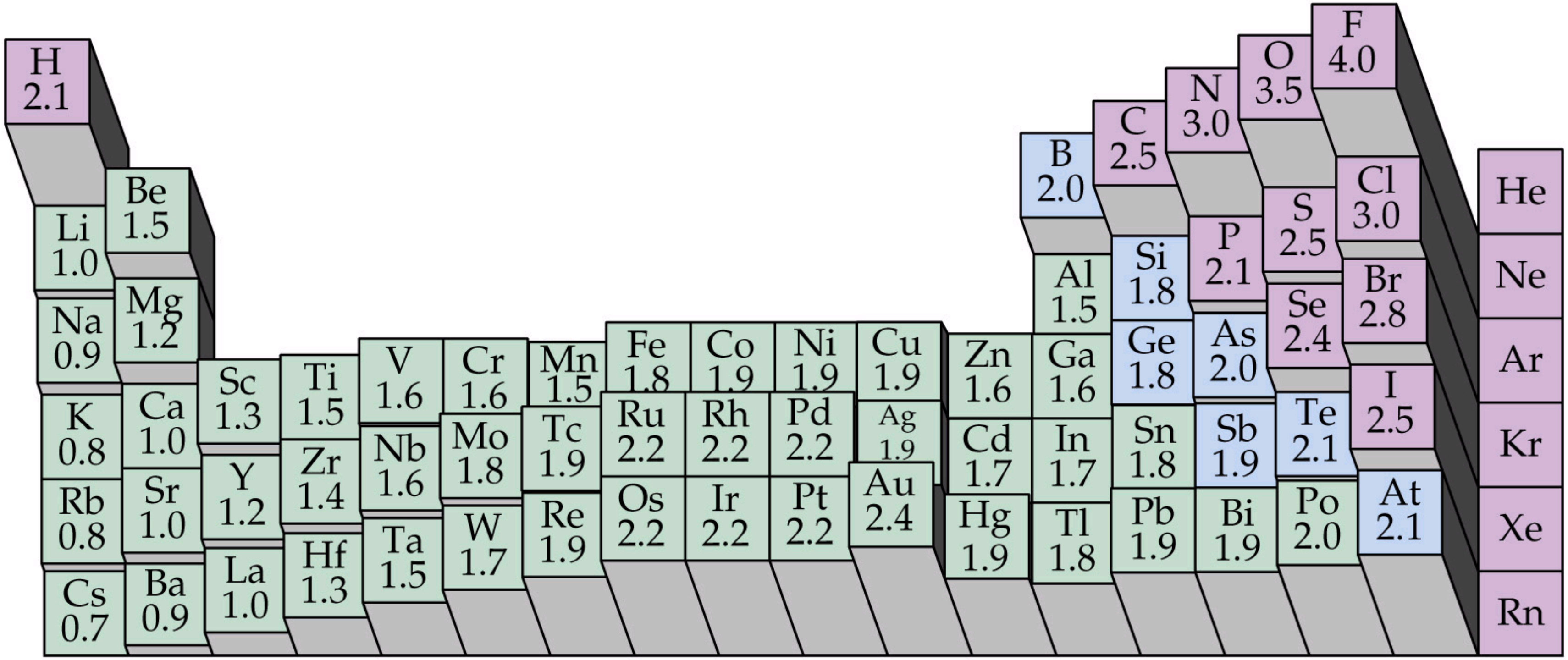
→ Electronegativity values of the chemical elements are given on a scale of 0 to 4, with 4 being the most electronegative (Pauling scale).

→ Electronegativity values are *relative* and do not have any units.

Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity

- Electronegativity Values of the Chemical Elements (Pauling Scale)

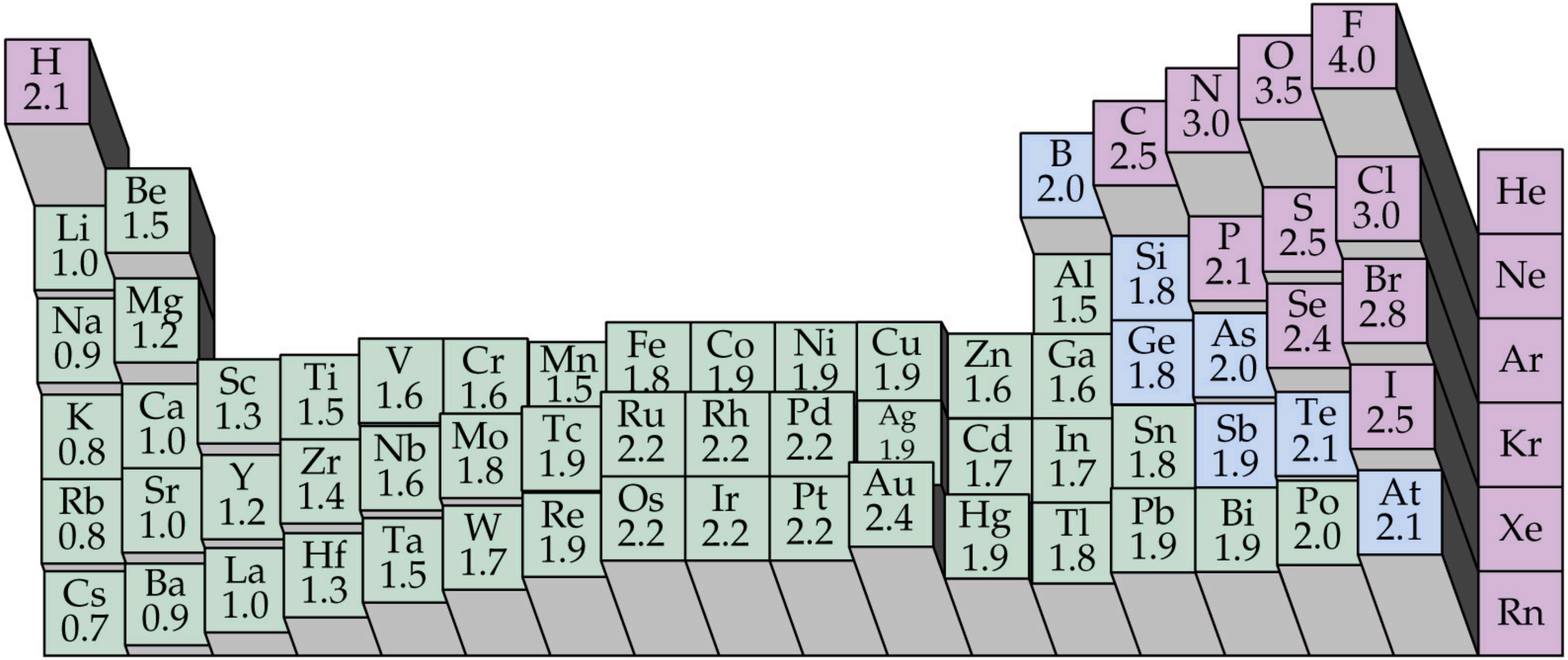


- Why are no electronegativity values assigned to the Noble Gases (Group 18)?

Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity

- Electronegativity Values of the Chemical Elements (Pauling Scale)



- Noble Gases do not form covalent bonds, *i.e.* they do not share pairs of electrons with other atoms.

Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity

- How and why does electronegativity change *across a Period*, from the left to the right?

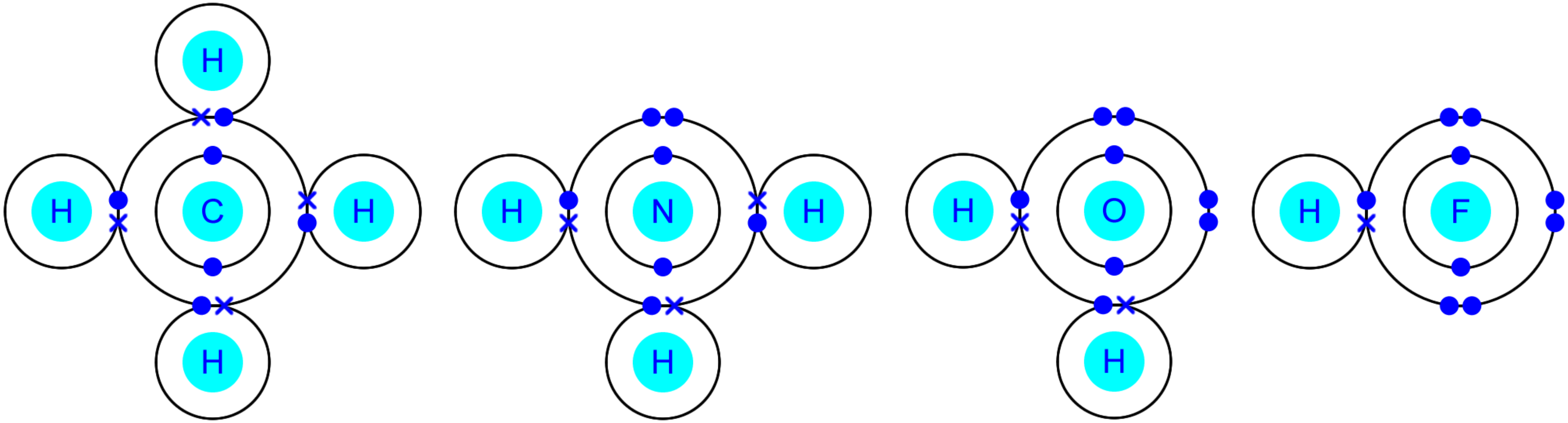
- Moving across a Period from the left-hand-side to the right-hand-side, the number of protons in the nucleus of an atom increases (nuclear charge increases), but the number of electron shells remains constant (shielding effect remains constant). *Effective nuclear charge increases across a Period*.

- The increasing effective nuclear charge will exert a *stronger electrostatic force of attraction* on a shared pair of electrons in the valence shell of the atom.

- As a consequence, electronegativity values *increase while moving across a Period* from the left-hand-side to the right-hand side.

Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity



- The increasing effective nuclear charge will exert a *stronger electrostatic force of attraction* on a shared pair of electrons in the valence shell of the atom.

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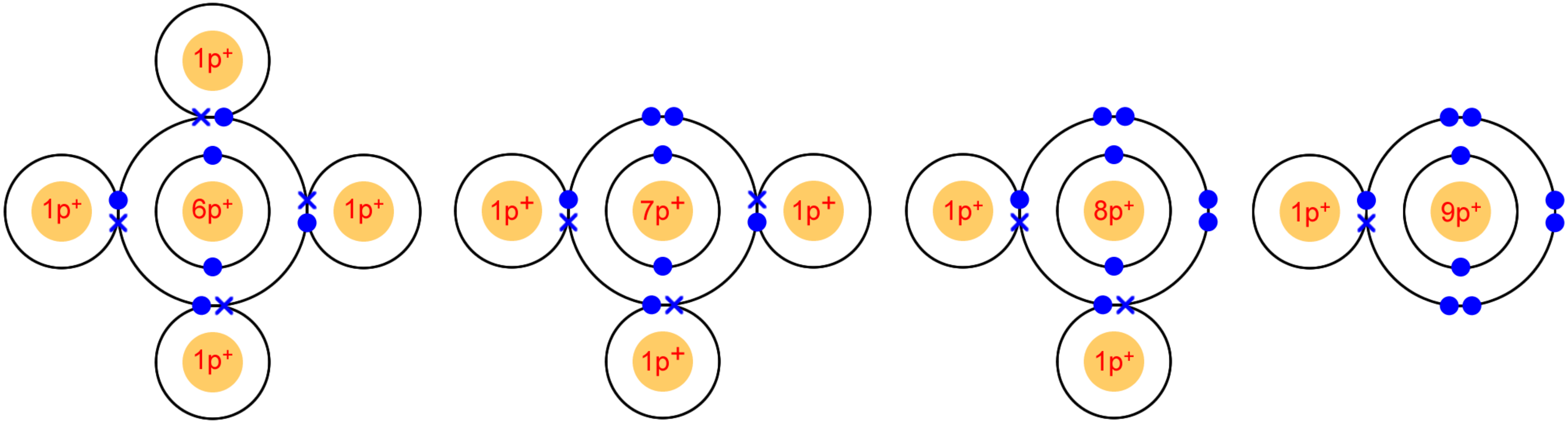
Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity

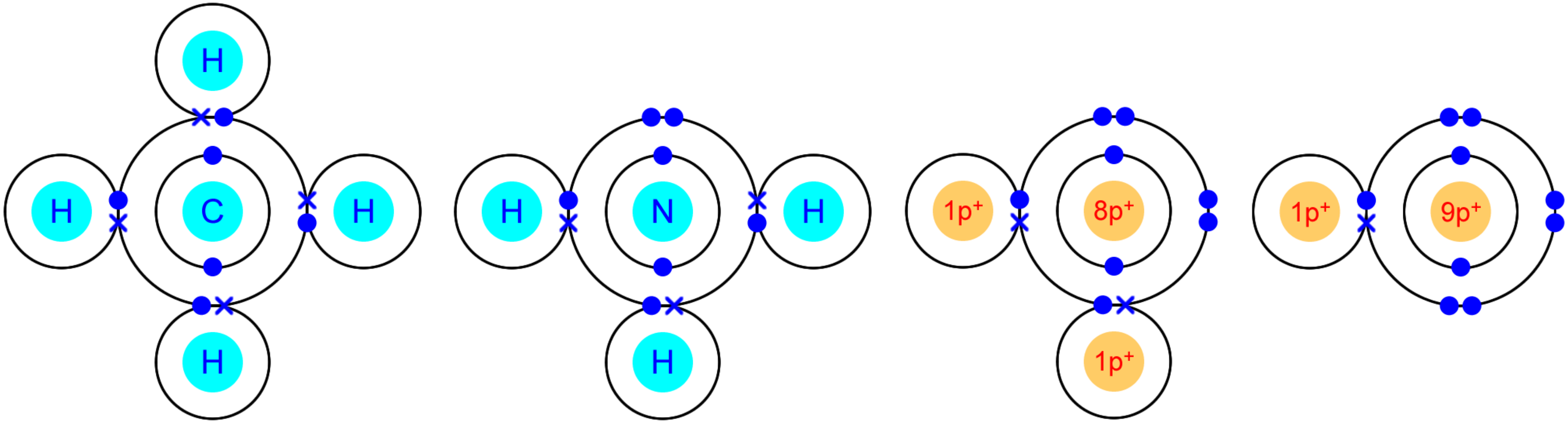


- The increasing effective nuclear charge will exert a *stronger electrostatic force of attraction* on a shared pair of electrons in the valence shell of the atom.

- As a consequence, electronegativity values *increase while moving across a Period* from the left-hand-side to the right-hand side.

Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity

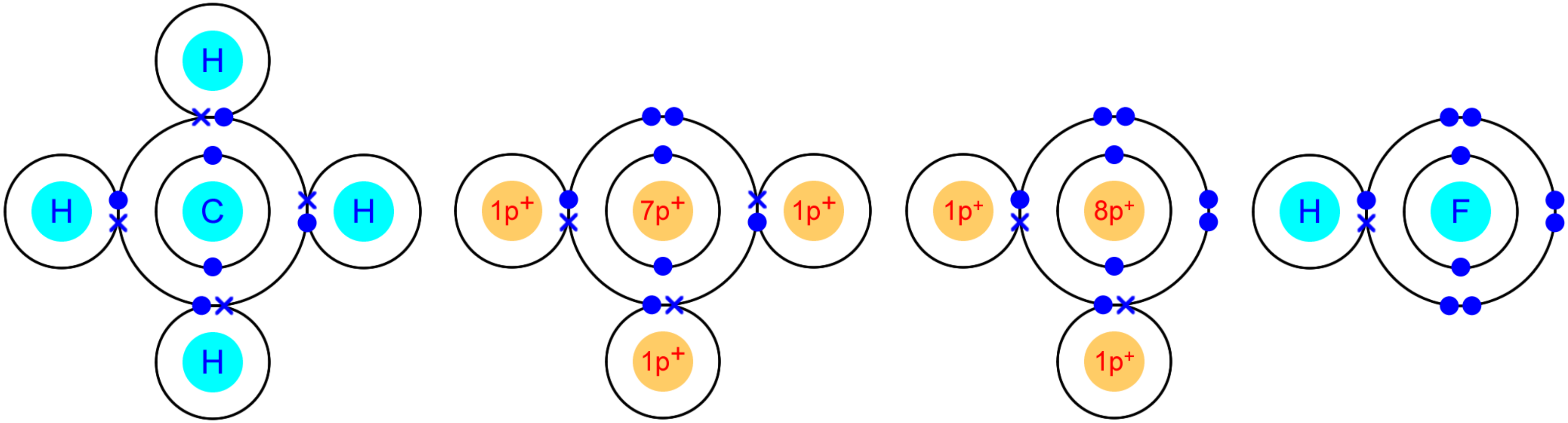


- Fluorine (with *nine* protons in its nucleus) exerts a stronger electrostatic force of attraction on a shared pair of electrons than oxygen (with only *eight* protons in its nucleus).

$$Z_{\text{eff}}\,(\text{F}) = 9 - 2 = 7$$
$$Z_{\text{eff}}\,(\text{O}) = 8 - 2 = 6$$

Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity

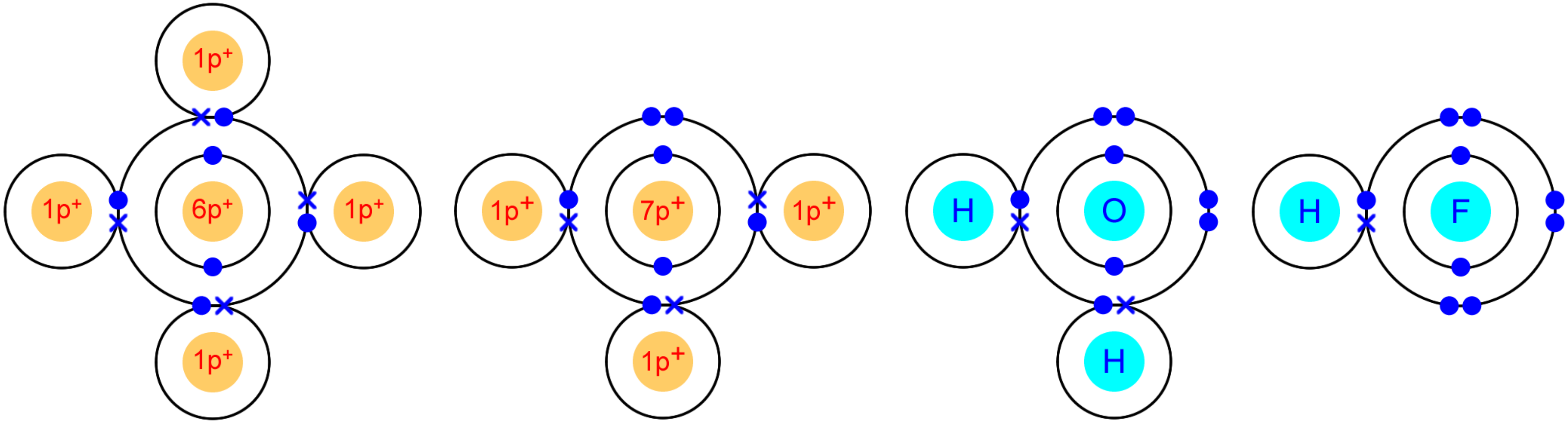


- Oxygen (with *eight* protons in its nucleus) exerts a stronger electrostatic force of attraction on a shared pair of electrons than nitrogen (with only *seven* protons in its nucleus).

$$Z_{\text{eff}}\,(\text{O}) = 8 - 2 = 6$$
$$Z_{\text{eff}}\,(\text{N}) = 7 - 2 = 5$$

Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity



- Nitrogen (with *seven* protons in its nucleus) exerts a stronger electrostatic force of attraction on a shared pair of electrons than carbon (with only *six* protons in its nucleus).

$$Z_{\text{eff}}\ (\text{N}) = 7 - 2 = 5$$
$$Z_{\text{eff}}\ (\text{C}) = 6 - 2 = 4$$

Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity

- How and why does electronegativity change *down a Group*?

- The number of protons in the nucleus of an atom (nuclear charge) and the number of electron shells around the nucleus of the atom *both increase* down a Group.

- Moving down a Group, there is no significant change in the effective nuclear charge that the electron(s) in the valence shell of the atom experience, as the increasing nuclear charge and increasing shielding effect cancel each other *e.g.*

$$Z_{\text{eff}}\ (\text{F}) = 9 - 2 = +7$$
$$Z_{\text{eff}}\ (\text{C}l) = 17 - 10 = +7$$

Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity

- How and why does electronegativity change *down a Group*?

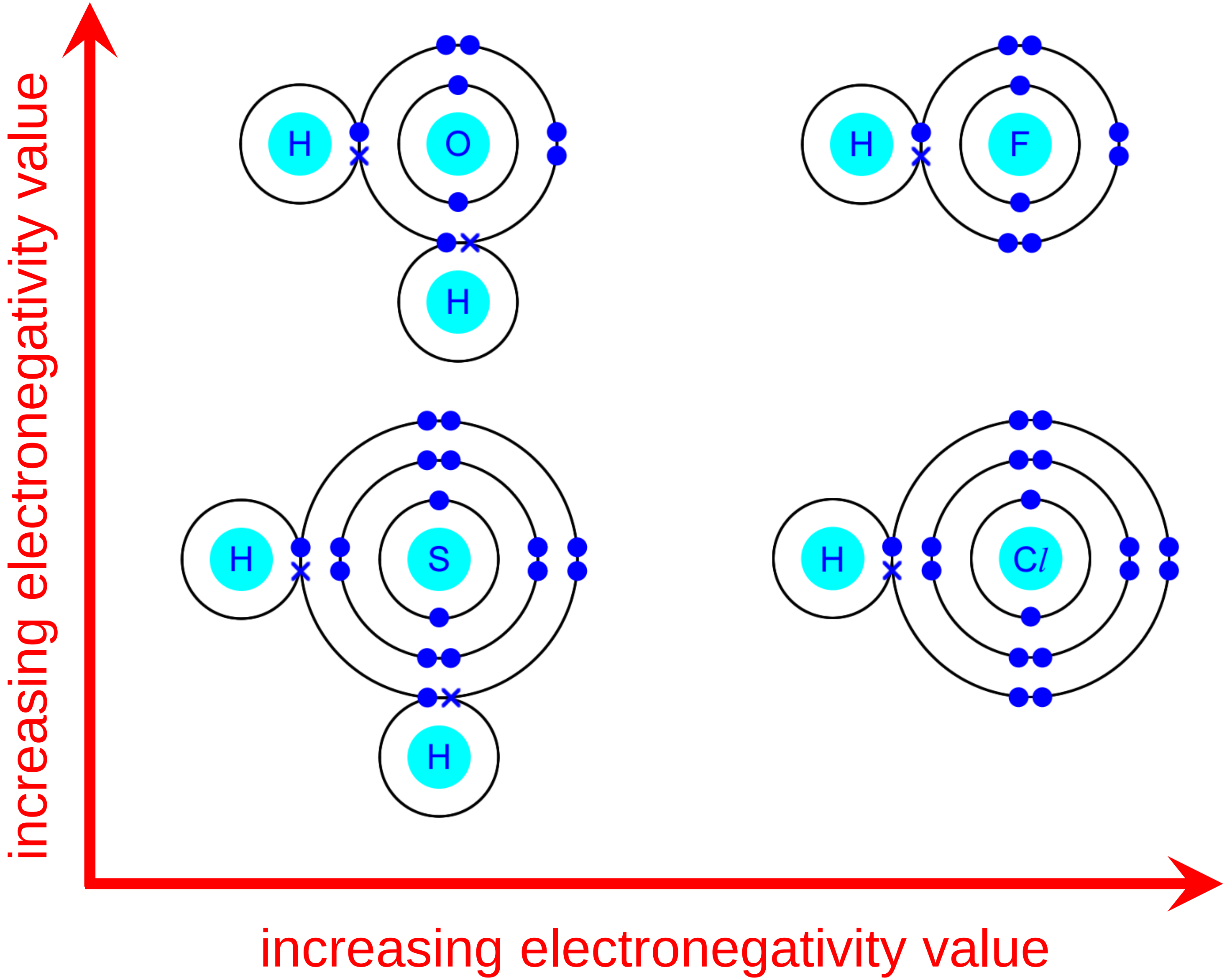
- The addition of a new electron shell to the atoms is significant because it means that the electron(s) in the valence shell (shared during covalent bonding) are *further from the nucleus*.

- This *reduces the electrostatic force of attraction* between the positively charged nucleus and a bonding pair of electrons in the valence shell of the atom (inverse square law).

- Moving gown a Group, the relative tendency / ability of an atom to attract a bonding pair of electrons decreases, and so *electronegativity decreases down a Group* of elements.

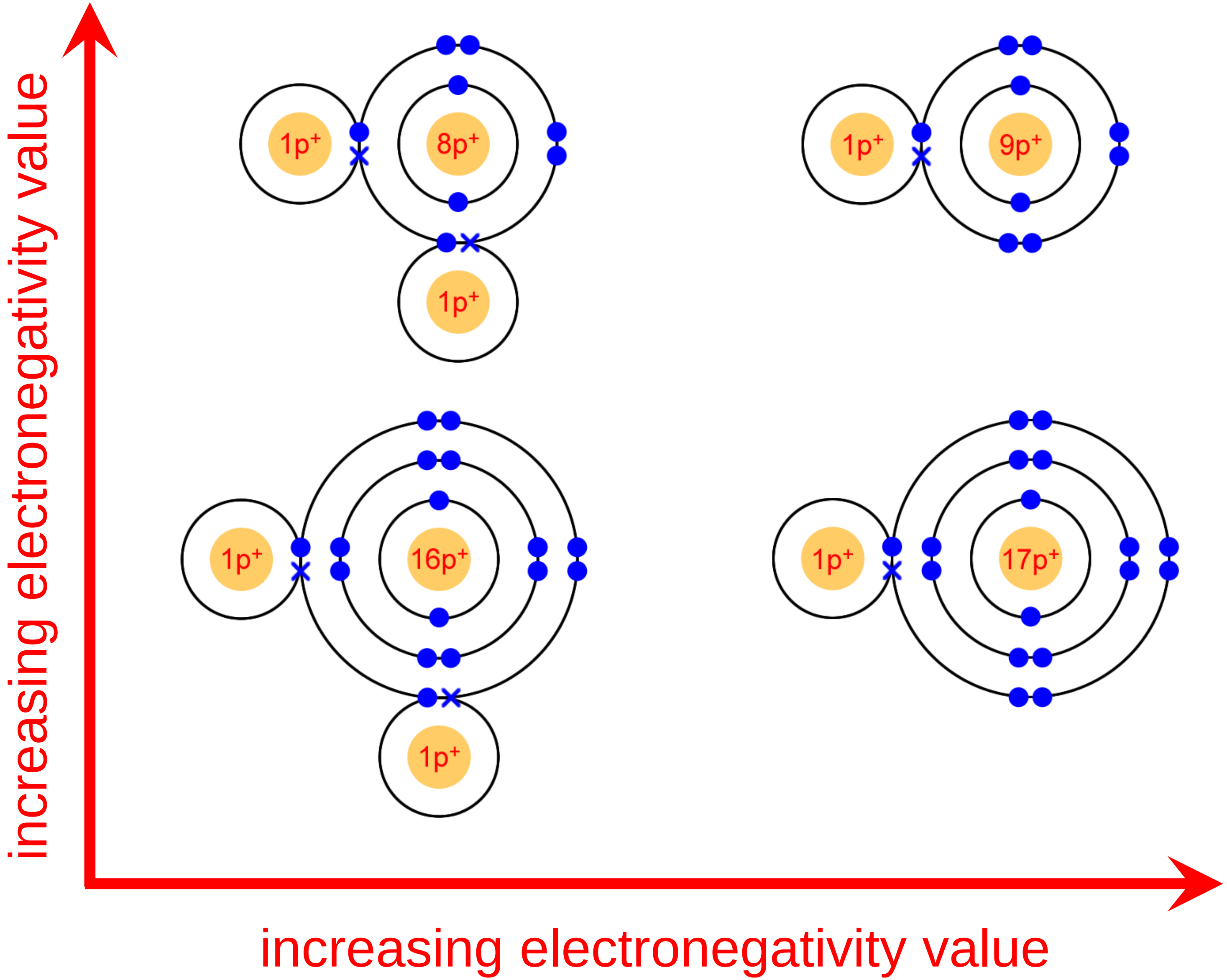
Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity



Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity



Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity

- When two atoms of different elements are held together by a covalent bond, if the difference in electronegativity values of the two elements is greater than ~0.5, then the covalent bond will be *polar*.

- The atom of the element with the *greater* electronegativity value, because it is pulling the negatively charged bonding pair of electrons *towards* it, will gain a *slight negative charge*, written as $\delta-$ (delta negative).

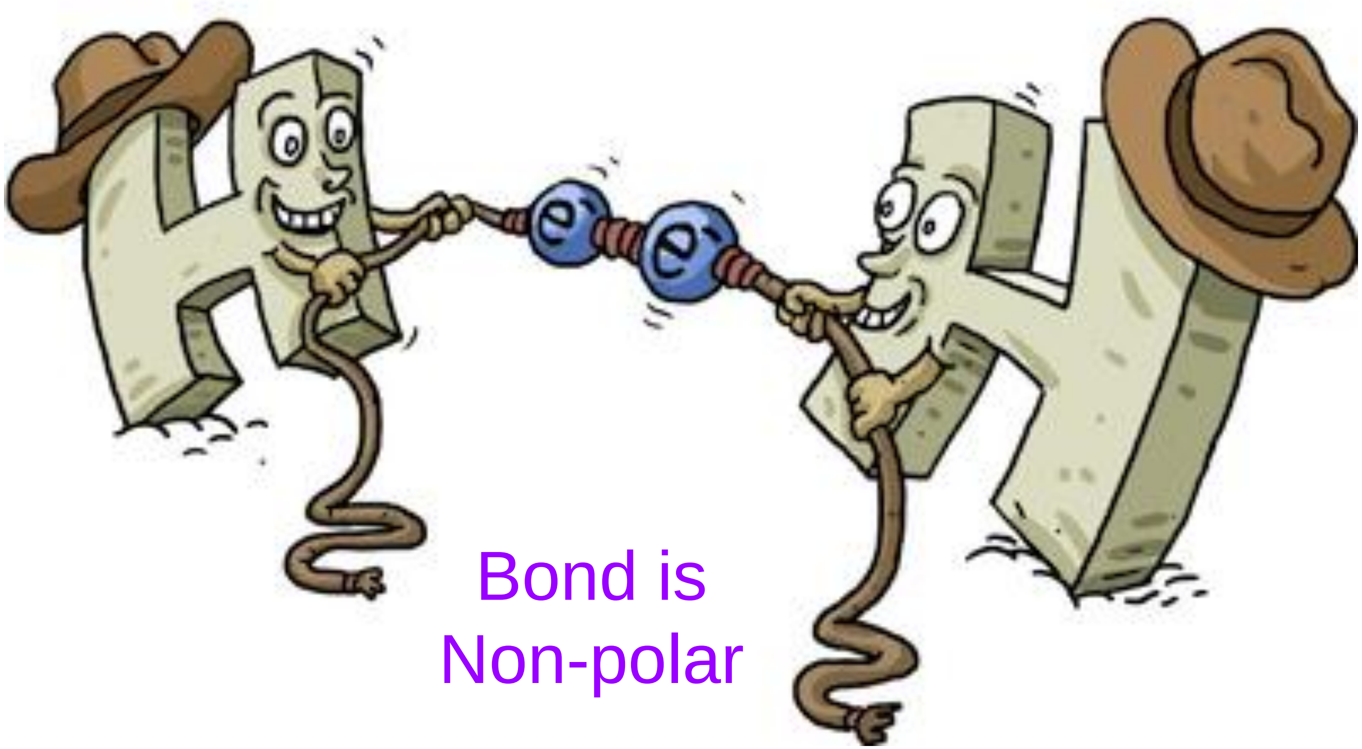
- The atom of the element with the *smaller* electronegativity value, because it has the negatively charged bonding pair of electrons pulled *away* from it, will gain a *slight positive charge*, written as $\delta+$ (delta positive).

Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity

Hydrogen = 2.1

Hydrogen = 2.1



Bond is
Non-polar

Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity

Chlorine = 3.0

Hydrogen = 2.1

δ–

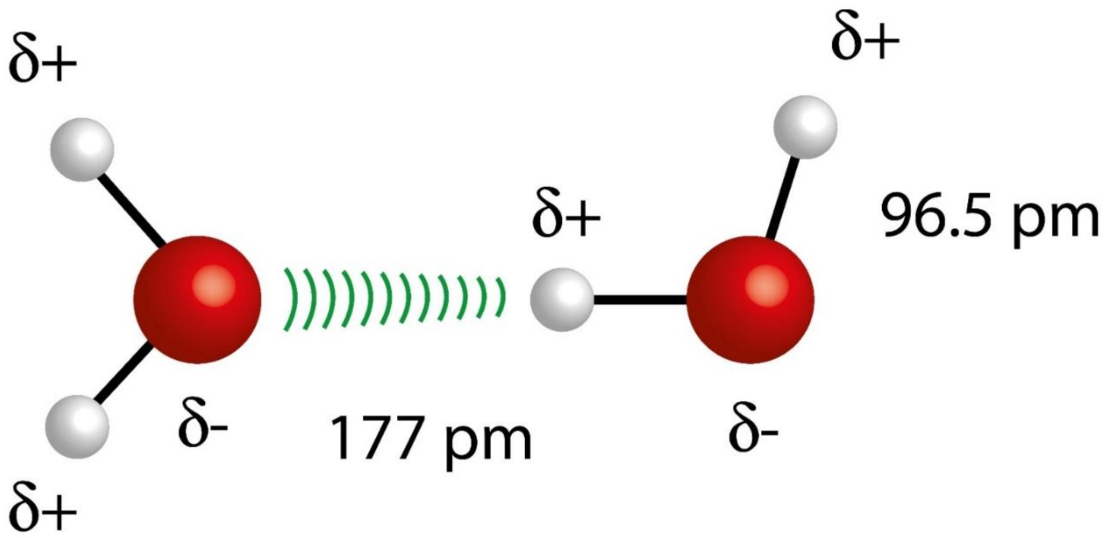
δ+

Bond is Polar

Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity

- Hydrogen Bonding Between Water Molecules

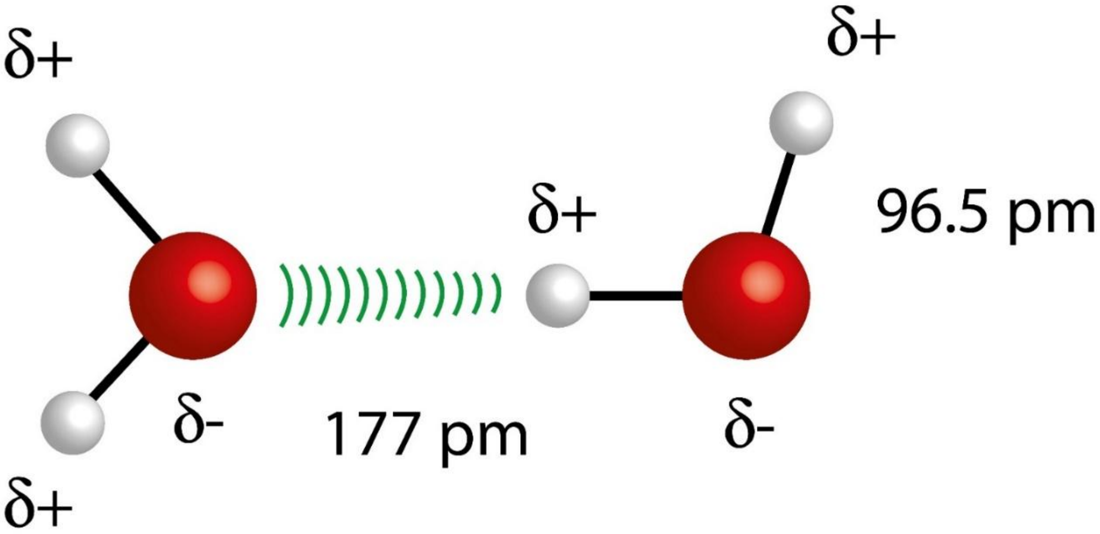


- The bond between oxygen (electronegativity value = *3.5*) and hydrogen (electronegativity value = *2.1*) in water is *polar*.

Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity

- Hydrogen Bonding Between Water Molecules

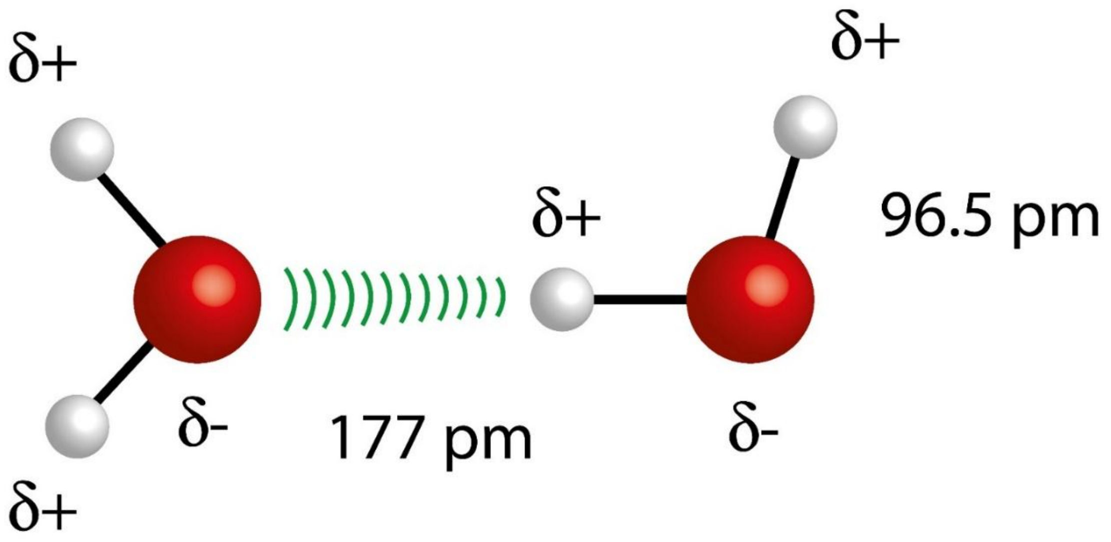


- The oxygen atom attracts the bonding pair of electrons towards itself, away from the hydrogen atom.

Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity

- Hydrogen Bonding Between Water Molecules

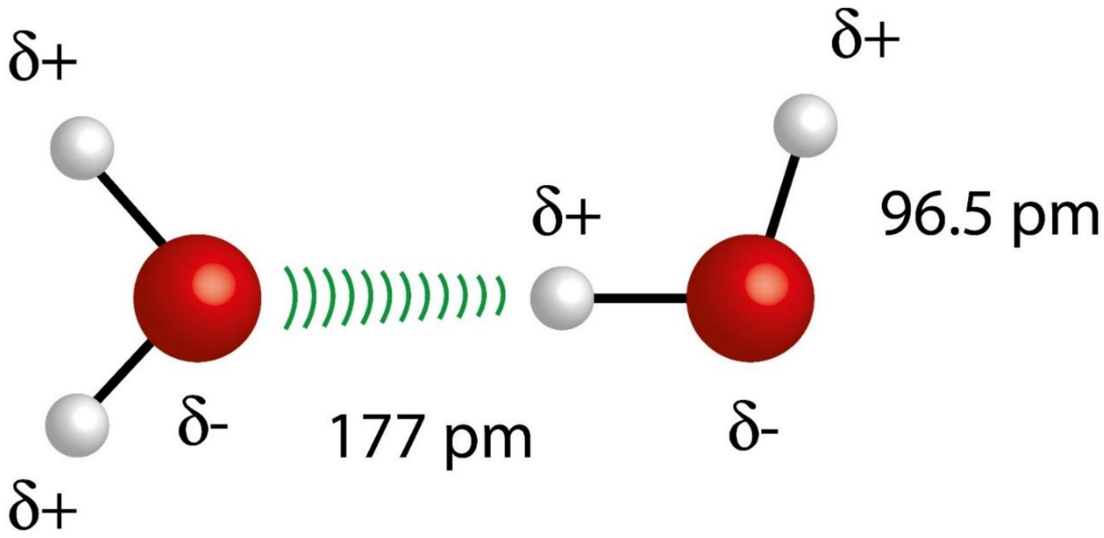


- The oxygen atom gains a slight negative charge written $\delta-$ (delta negative) while the hydrogen atom gains a slight positive charge, written $\delta+$ (delta positive).

Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity

- Hydrogen Bonding Between Water Molecules

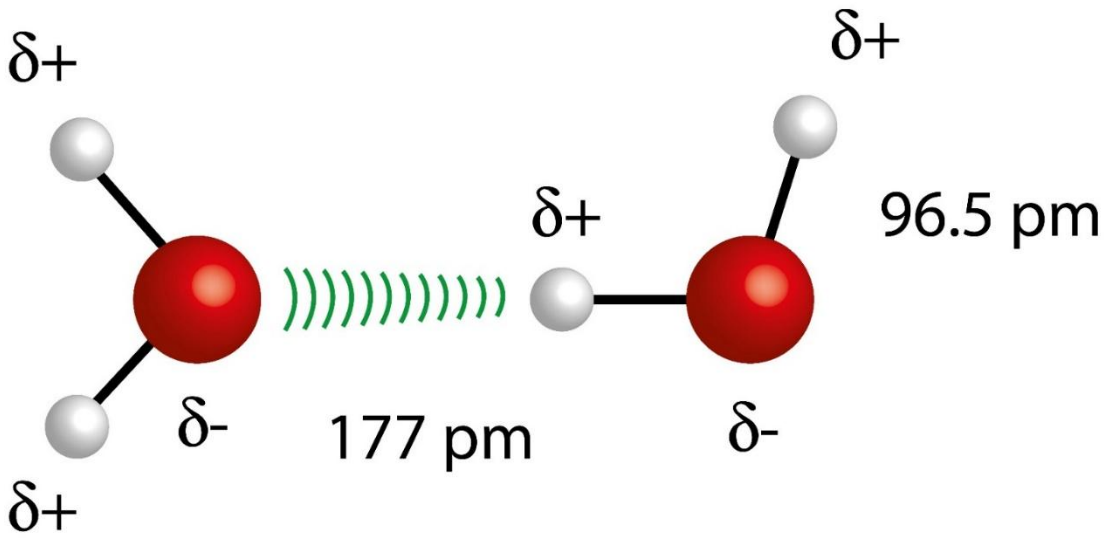


- A weak electrostatic force of attraction between the $\delta+$ hydrogen atom of one water molecule and a lone pair of electrons on the $\delta-$ oxygen atom of another water molecule creates an intermolecular force of attraction between the two water molecules.

Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity

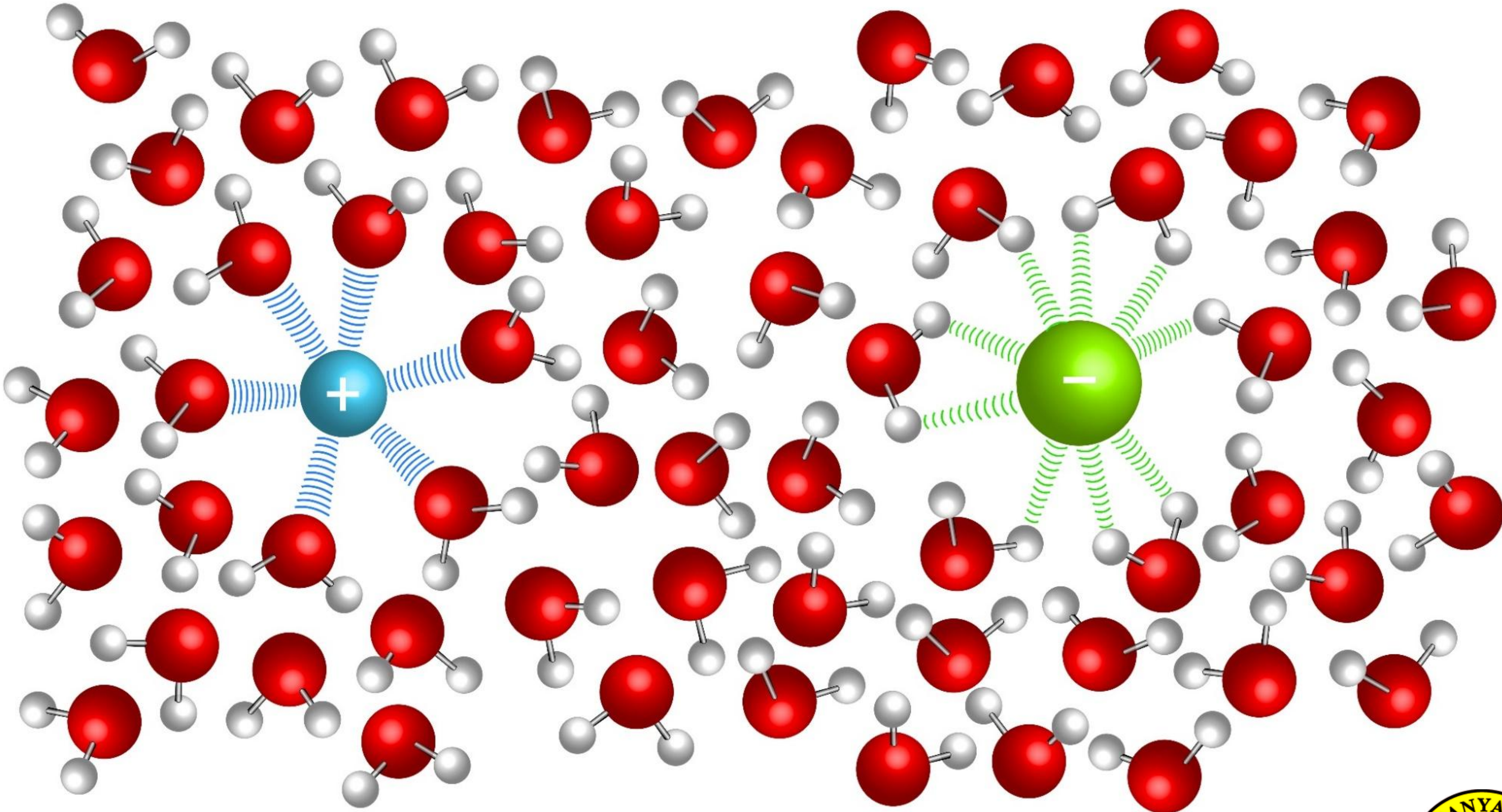
- Hydrogen Bonding Between Water Molecules



- This special intermolecular force of attraction is called a *hydrogen bond*. It is stronger that the van der Waals force of attraction, and requires more energy to overcome, causing water to be a liquid at r.t.p. while other compounds with a simple molecular structure are gases.

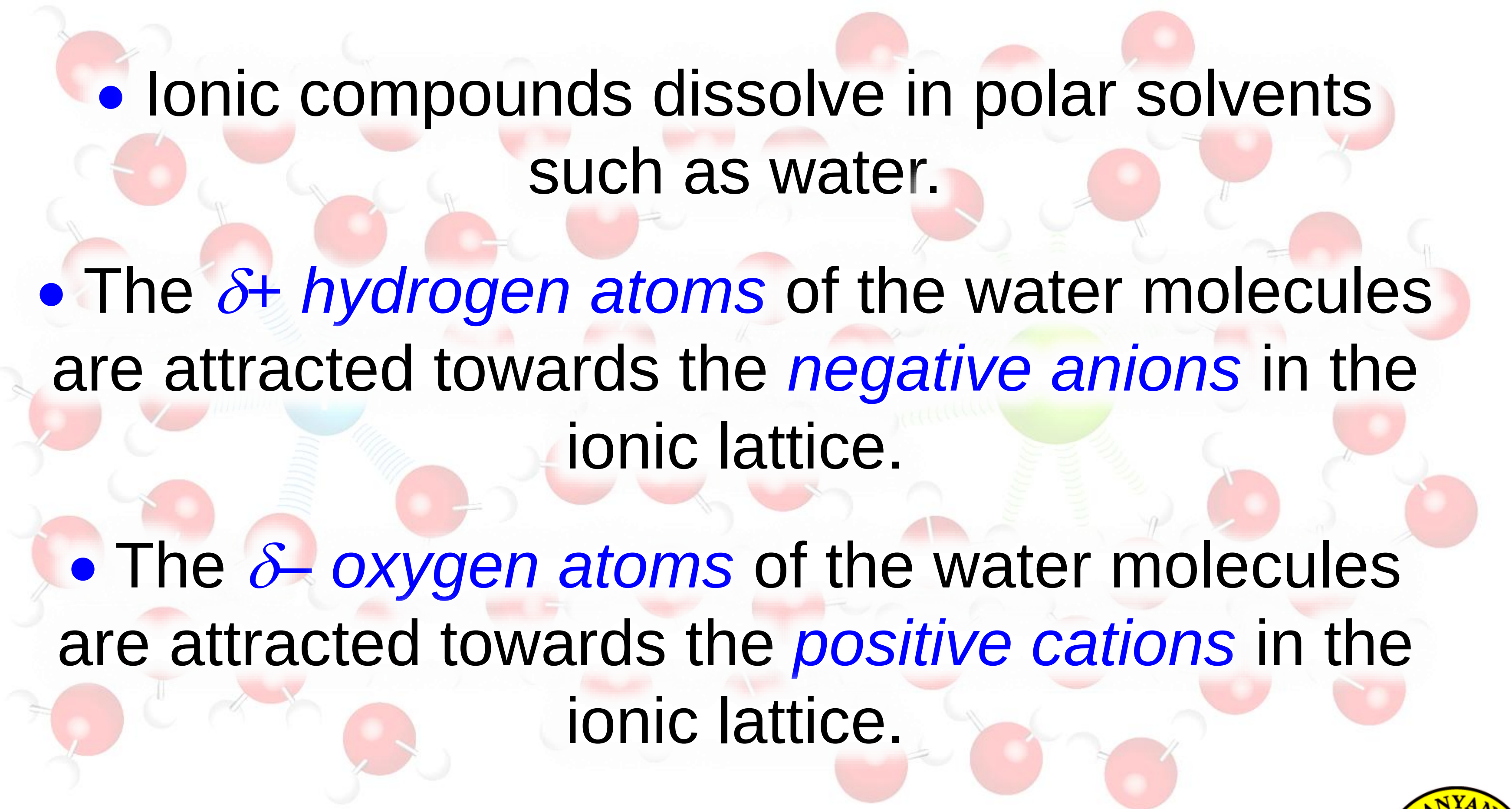
Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity



Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity

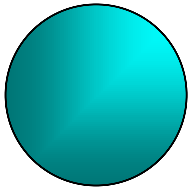
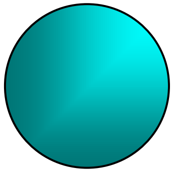
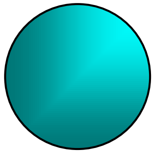
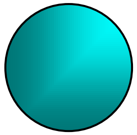
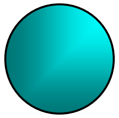
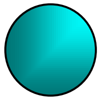
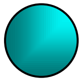


- Ionic compounds dissolve in polar solvents such as water.

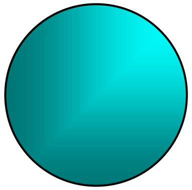
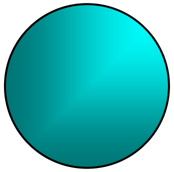
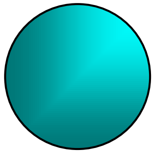
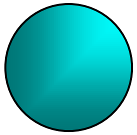
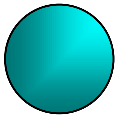
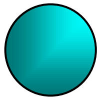
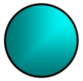
- The $\delta+$ *hydrogen atoms* of the water molecules are attracted towards the *negative anions* in the ionic lattice.

- The $\delta-$ *oxygen atoms* of the water molecules are attracted towards the *positive cations* in the ionic lattice.

Periodic Table of the Chemical Elements

Elements of Third Period	Na Group 1	Mg Group 2	Al Group 13	Si Group 14	P Group 15	S Group 16	Cl Group 17
Atomic Number	11	12	13	14	15	16	17
Atomic Radius / nm	0.157 	0.136 	0.125 	0.117 	0.110 	0.104 	0.099 
Electro-negativity Value	0.9	1.2	1.5	1.8	2.1	2.5	3.0
First Ionization Energy / kJ mol^{-1}	494	736	577	786	1060	1000	1260

Periodic Table of the Chemical Elements

Elements of Third Period	Na Group 1	Mg Group 2	Al Group 13	Si Group 14	P Group 15	S Group 16	Cl Group 17
Atomic Number	• Number of protons within the nucleus of the atom increases. → • Positive charge within the nucleus of the atom increases. → • Electrostatic force of attraction between the positive nucleus and negative electrons orbiting the nucleus increases. →						
Atomic Radius / nm	0.157 	0.136 	0.125 	0.117 	0.110 	0.104 	0.099 
Electro-negativity Value	0.9	1.2	1.5	1.8	2.1	2.5	3.0
First Ionization Energy / kJ mol^{-1}	494	736	577	786	1060	1000	1260

Periodic Table of the Chemical Elements

Presentation on
The Periodic Table of Chemical Elements

By Dr. Chris Slatter
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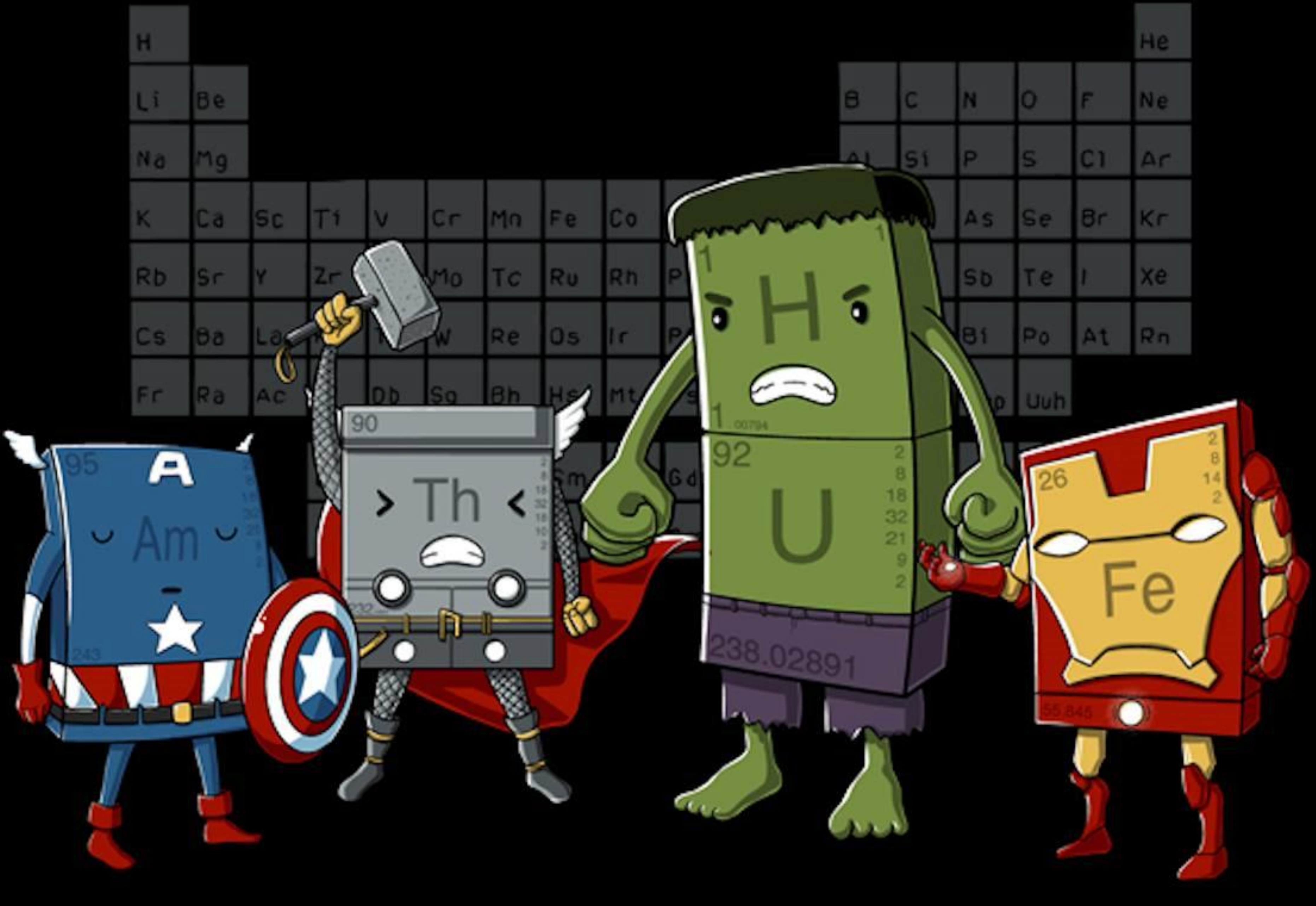
Singapore
288683

28th January 2017

- Photographs of the chemical elements taken from Theodore Gray's website: www.periodictable.com
- Information about the uses of the chemical elements taken from: http://www.rsc.org/periodic-table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