

A young girl with brown hair in braids, wearing a white lab coat, is looking down at a book she is holding. She is in a chemistry laboratory setting. In the background, there is a chalkboard with various chemical formulas and diagrams drawn on it, including $Mg-DM+SO_2$, $NaBH_4$, H_2 , $HO-NH_2$, and C_2H_5OH . In the foreground, there are several pieces of laboratory glassware, including flasks and test tubes containing colored liquids (yellow, red, green).

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

Photographs show samples of the pure or nearly pure element except as follows: At, Rn, Fr, Ac, Pa, and No show radioactive elements; boron shows natural boron; the element Po, Ra, Fr, Pu, and Am show artificial elements containing traceable amounts of the element. Technetium shows a 10.66 microgram hydrogen above a Huber Space Telescope image of the Capri Nebula, which is mostly hydrogen. Se-110 shows the parent or stable alpha which the element is named. 110-118 had not been named yet in 2006.

Poster and photography by Theodore W. Gray, RGR Research, Ltd.
All rights reserved © 2006 Theodore W. Gray, RGR Research, Ltd. No portion of this poster may be reproduced without written permission from RGR Research, Ltd. All other rights reserved. For more information, please contact RGR Research, Ltd. at 10000 10th Street, Suite 100, Golden, CO 80401, USA. Tel: 303-261-1000. Fax: 303-261-1001. Email: info@rgrresearch.com

Poster Copyright © 2006 Theodore W. Gray all rights reserved.
Other sizes of this poster: periodictable.com
Real samples like these: element-collection.com



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.



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 1 and 17 using the Periodic Table.
- Describe lithium, sodium and potassium in Group 1 (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 17 (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 18 (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

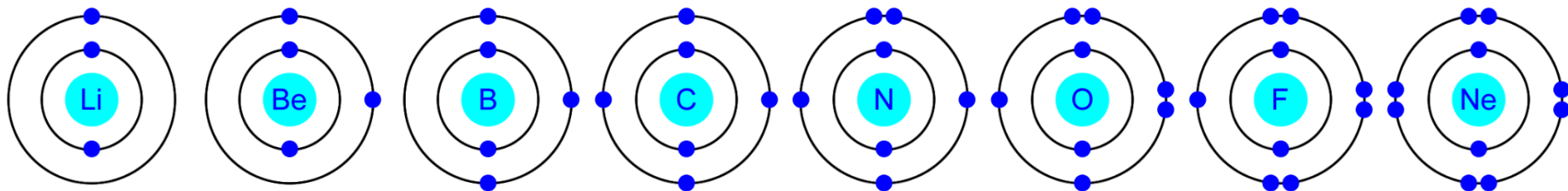
- Periodic trends are specific patterns that are present in the Periodic Table. These trends and patterns illustrate different aspects of a certain chemical element. Major periodic trends include:
 - atomic radius
 - electronegativity
 - first electron affinity
 - first ionization energy
 - melting point 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

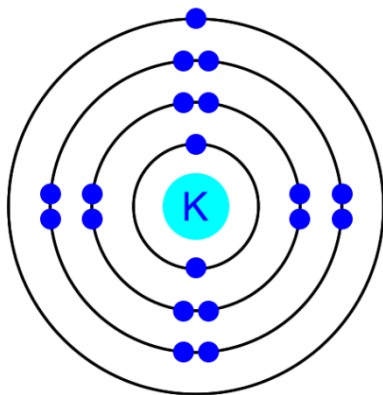
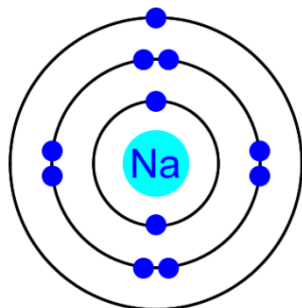
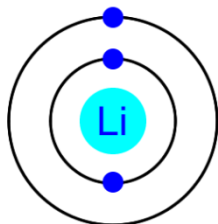
Introduction to Periodicity

- 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*.

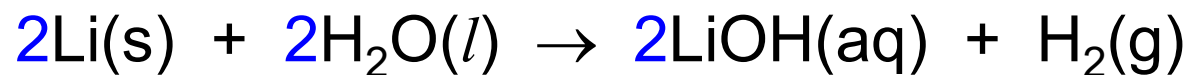


Periodic Table of the Chemical Elements

Introduction to Periodicity



- The reaction between *lithium* and water.

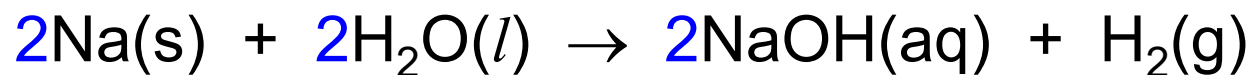


Periodic Table of the Chemical Elements

Introduction to Periodicity



- The reaction between *sodium* and water.

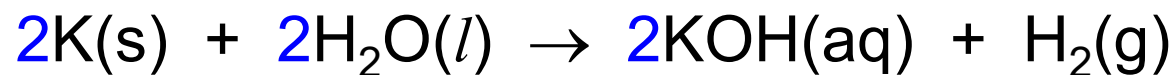


Periodic Table of the Chemical Elements

Introduction to Periodicity

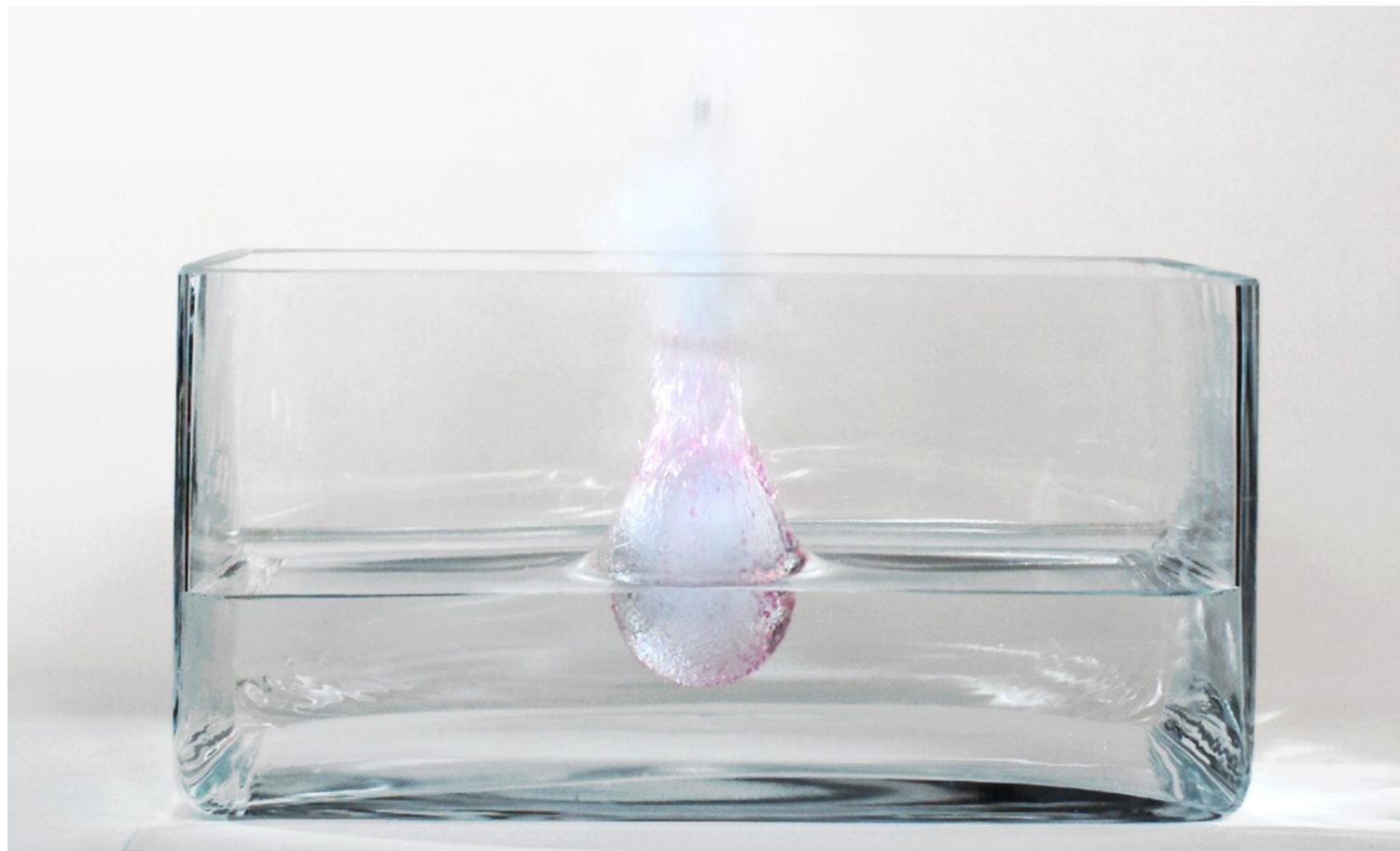


- The reaction between *potassium* and water.

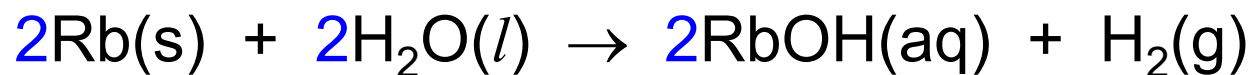


Periodic Table of the Chemical Elements

Introduction to Periodicity



- The reaction between *rubidium* and water.



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 / cm³.



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

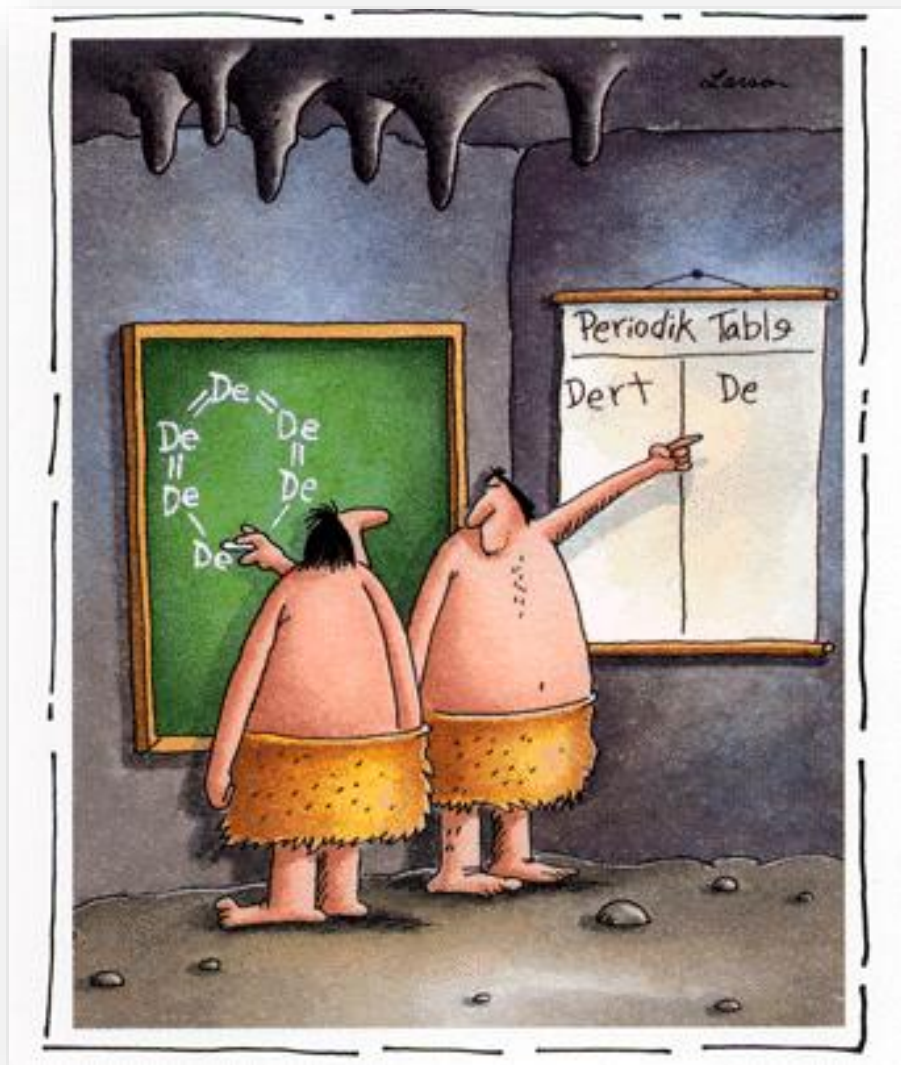
Some definitions:

- **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:

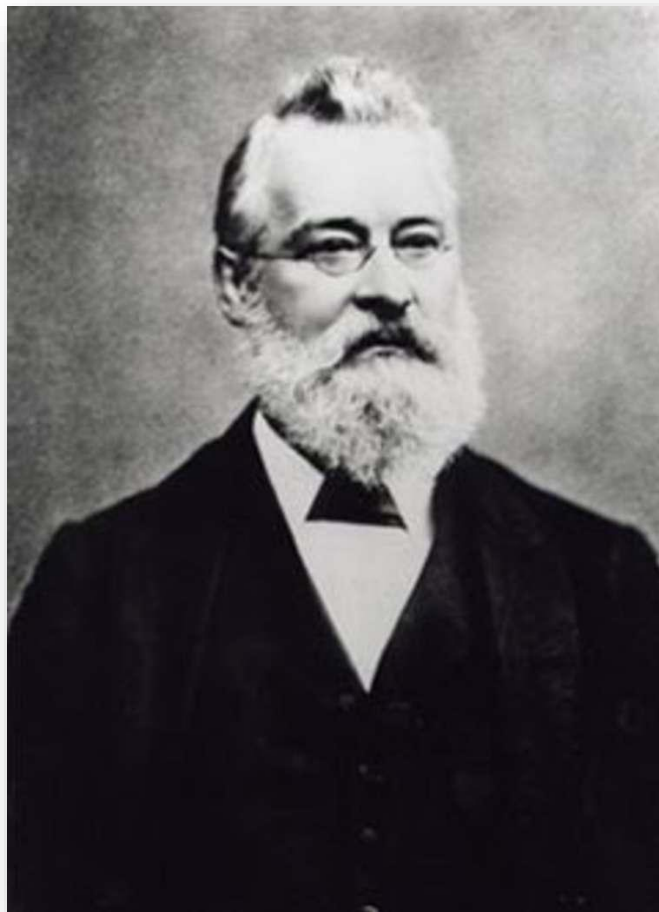
Lithium 7	Sodium 23	Potassium 39
Chlorine 35.5	Bromine 80	Iodine 127

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

T a b e l l e II.

Reihen	Gruppe I. — R ² O	Gruppe II. — RO	Gruppe III. — R ² O ³	Gruppe IV. RH ⁴ RO ²	Gruppe V. RH ³ R ² O ⁵	Gruppe VI. RH ² RO ³	Gruppe VII. RH R ² O 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

T a b e l l e II.

Reihen	Gruppe I. — R ² O	Gruppe II. — RO	Gruppe III. — R ² O ³	Gruppe IV. RH ⁴ RO ²	Gruppe V. RH ³ R ² O ⁵	Gruppe VI. RH ² RO ³	Gruppe VII. RH R ² O 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



- 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.



THE WOMEN OF THE PERIODIC TABLE



MARIE CURIE

Co-discoverer of polonium and radium. Curium is named after her and Pierre Curie.



IDA NODDACK

Co-discovered rhenium; made an unproven claim for the discovery of technetium.



YVETTE CAUCHOIS

Contributed to the discovery of astatine, identifying one of its natural isotopes.



DARLEANE HOFFMAN

Helped confirm the discoveries of seaborgium, livermorium and oganesson.



HARRIET BROOKS

Working with Ernest Rutherford, she identified a radioactive gas that later work confirmed as the element radon.



CLARICE PHELPS

Part of the team that discovered tennessine. The first African-American woman to be involved with the discovery of an element.



DAWN SHAUGHNESSY

Part of a team involved in the discovery and confirmation of elements 113-118.



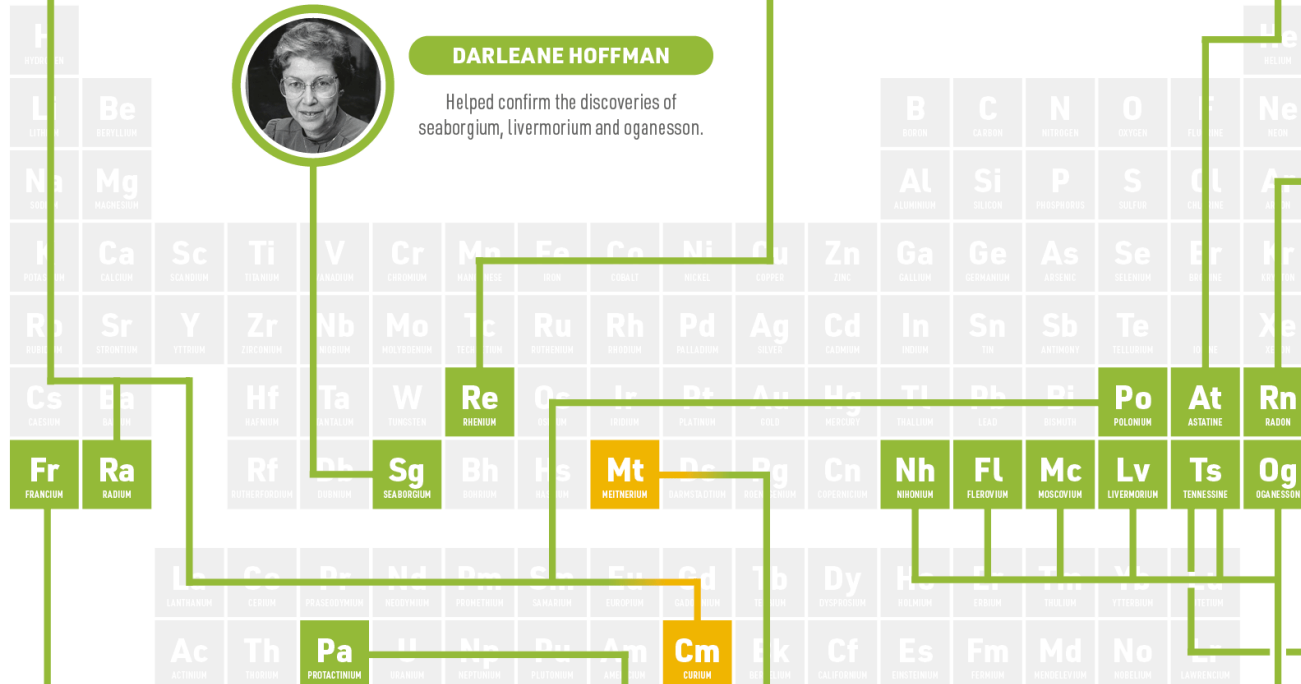
MARGUERITE PEREY

Discovered francium - the only element discovered solely by a woman.



LISE MEITNER

Co-discovered protactinium. Meitnerium is named after her.



Periodic Table of the Chemical Elements



Could I please
have an overview
of the modern
Periodic Table?

Overview of the Modern Periodic Table

[Return to Main Menu](#)



Periodic Table of the Chemical Elements

The Modern Periodic Table

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															

Period



Periodic Table of the Chemical Elements

The Modern Periodic Table

Group

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

Period

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

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

Period

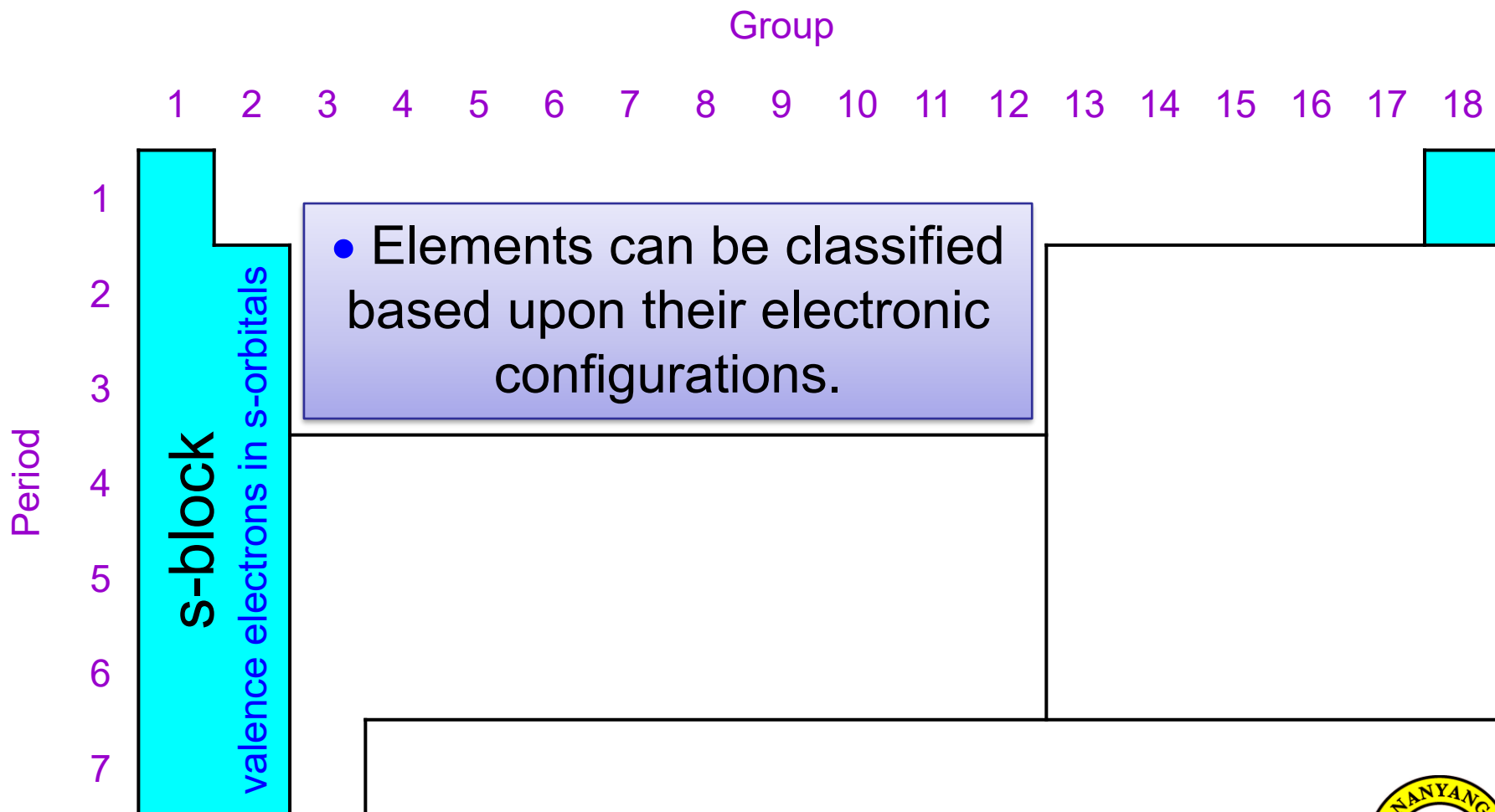
1	1s																1s
2	2s	2s										2p	2p	2p	2p	2p	2p
3	3s	3s										3p	3p	3p	3p	3p	3p
4	4s	4s	3d	3d	3d	3d	3d	3d	3d	3d	3d	4p	4p	4p	4p	4p	4p
5	5s	5s	4d	4d	4d	4d	4d	4d	4d	4d	4d	5p	5p	5p	5p	5p	5p
6	6s	6s	5d	5d	5d	5d	5d	5d	5d	5d	5d	6p	6p	6p	6p	6p	6p
7	7s	7s	6d														

- Elements can be classified based upon their electronic configurations.



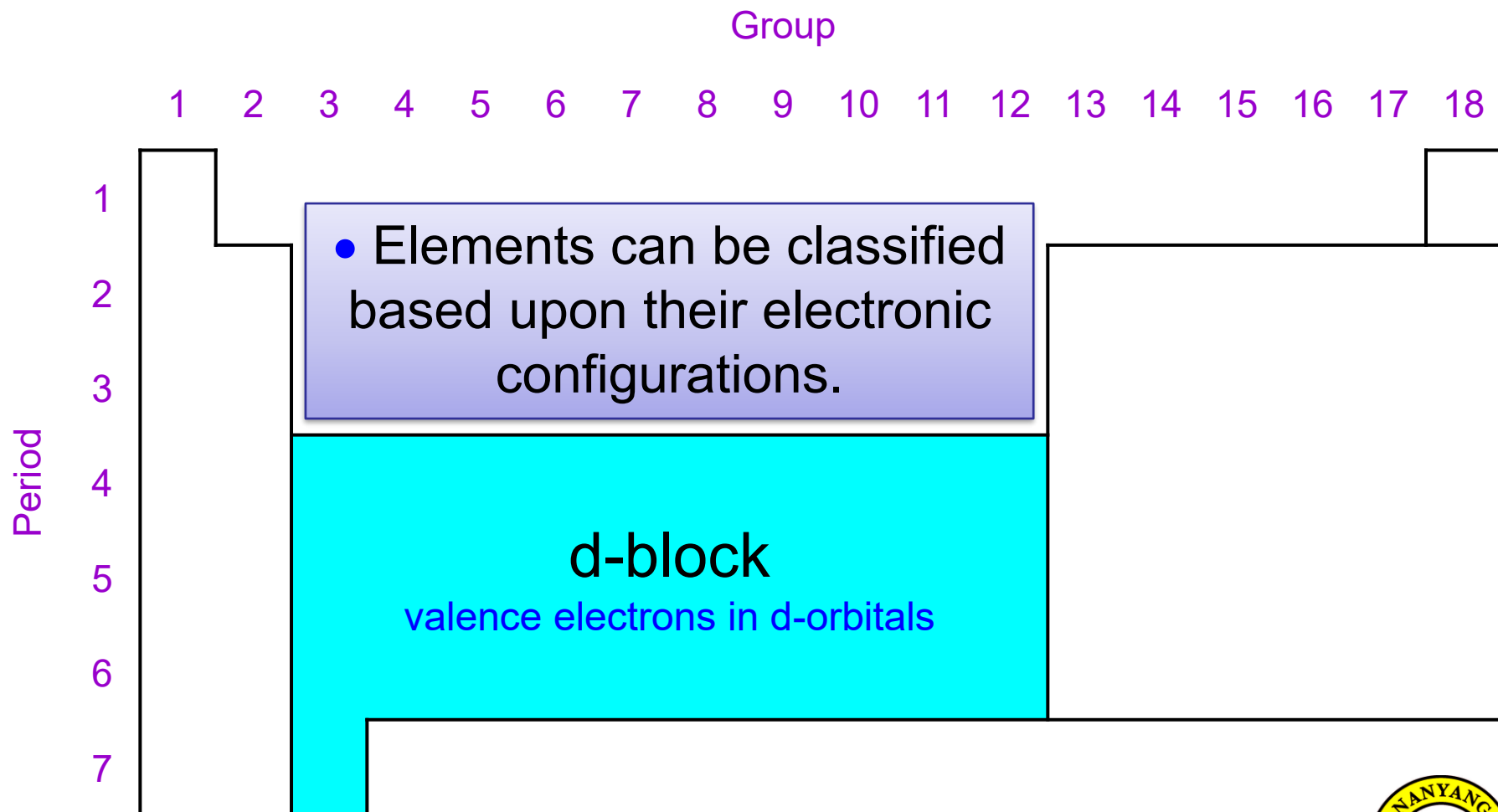
Periodic Table of the Chemical Elements

The Modern Periodic Table



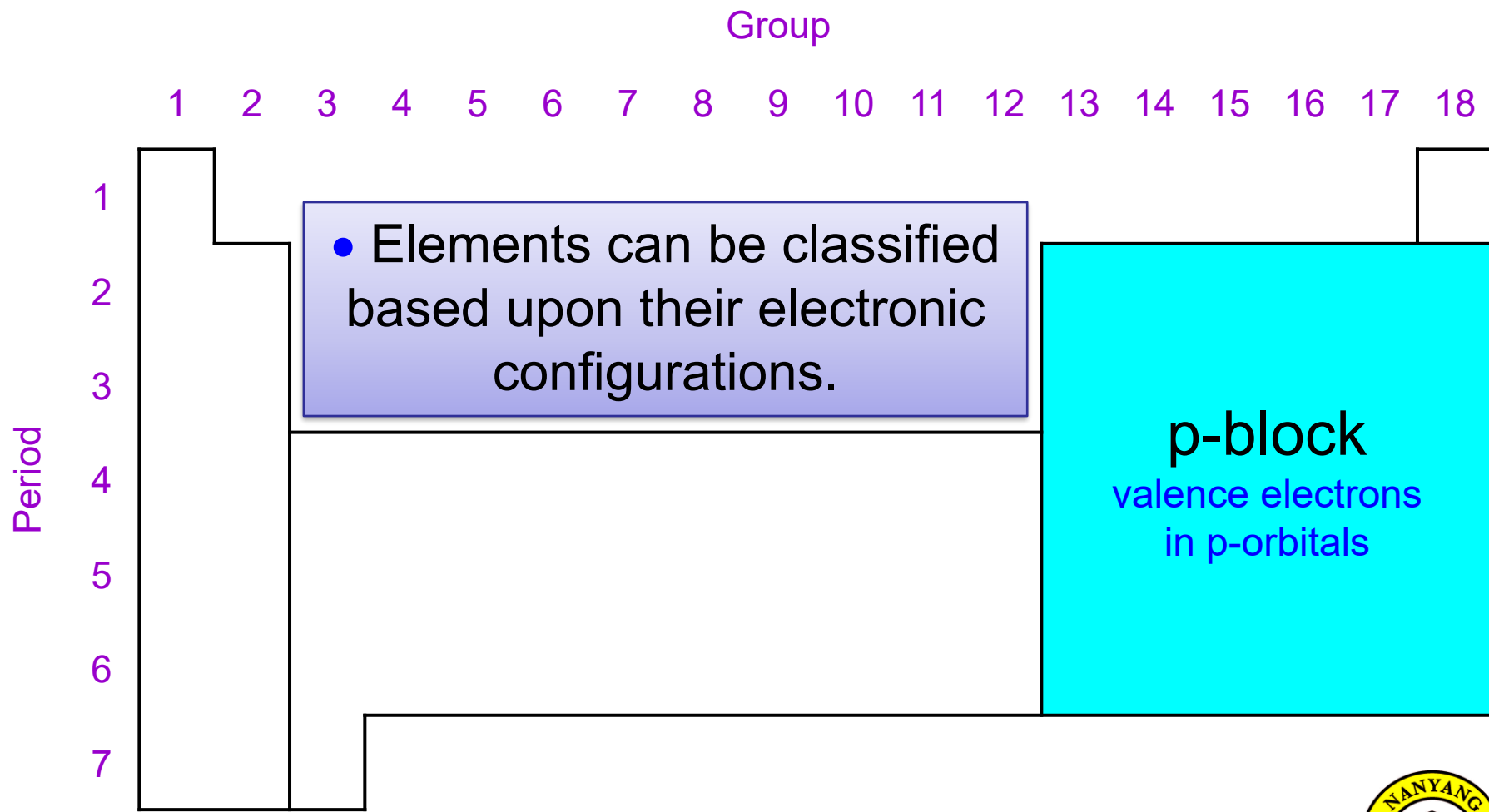
Periodic Table of the Chemical Elements

The Modern Periodic Table



Periodic Table of the Chemical Elements

The Modern Periodic Table



Periodic Table of the Chemical Elements

The Modern Periodic Table

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

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

Period

1	H																He	
2	Li	Be	<ul style="list-style-type: none">• A vertical column of elements is known as a Group.										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																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Period	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

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

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

Period

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

	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.

Period



Periodic Table of the Chemical Elements

The Modern Periodic Table

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	<div style="border: 1px solid black; padding: 10px; text-align: center;"> <ul style="list-style-type: none"> • In the centre of the Periodic Table are the transition metals. </div>										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															

Period



Periodic Table of the Chemical Elements

The Modern Periodic Table

Group

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

Period

1	H																He	
2	Li	Be	<ul style="list-style-type: none">Group VII (Group 17) are known as the halogens.										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

	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.

Period



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*.

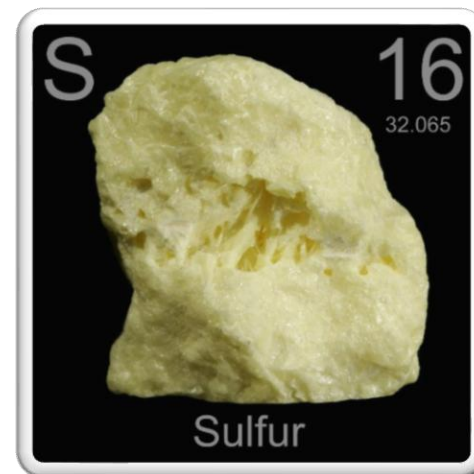
- Magnesium
Group 2 (II)
Metallic



- Silicon
Group 14 (IV)
Metalloid



- Sulfur
Group 16 (VI)
Non-metallic



Periodic Table of the Chemical Elements

Metals, Metalloids and Non-metals

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															

Period



Periodic Table of the Chemical Elements

Metals, Metalloids and Non-metals

Group

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

Period

1

2

3

4

5

6

7

• Metallic elements.

	H																He	
	Li	Be										B	C	N	O	F	Ne	
	Na	Mg										Al	Si	P	S	Cl	Ar	
	K	Ca	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
	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
	Fr	Ra	Ac															



Periodic Table of the Chemical Elements

Metals, Metalloids and Non-metals

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	<ul style="list-style-type: none">• Metalloids or semimetals.										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															

Period



Periodic Table of the Chemical Elements

Metals, Metalloids and Non-metals

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	• Non-metallic elements.										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															

Period



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

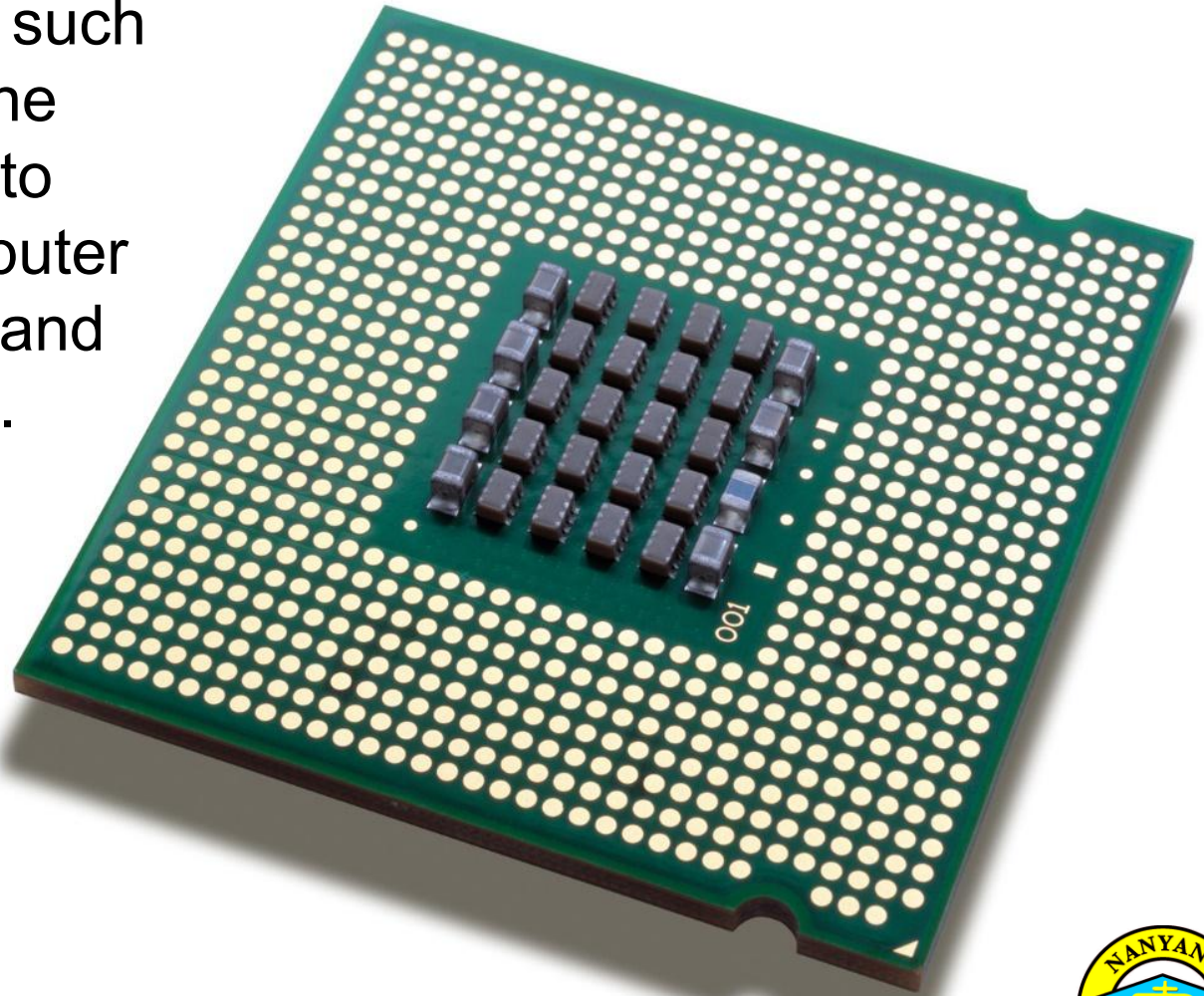
- What are the typical properties of metalloids?
 - Metalloids are *semiconductors*. A semiconductor is a substance that conducts electricity under some conditions, but behaves as an electrical insulator under other conditions.
 - The oxides of metalloids are *amphoteric*. Under some conditions they are acidic in nature while under other conditions they are basic in nature.



Periodic Table of the Chemical Elements

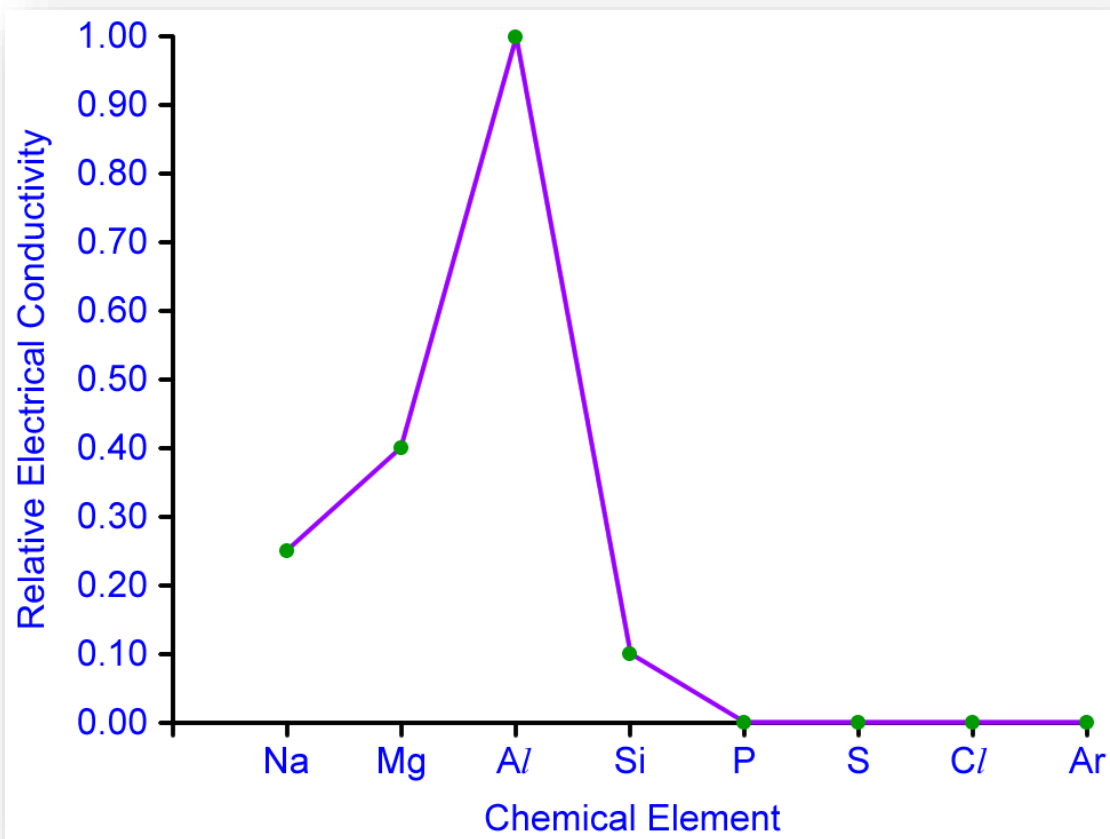
Metals, Metalloids and Non-metals

- 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](#)

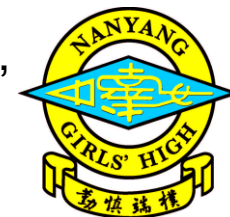


Periodic Table of the Chemical Elements

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

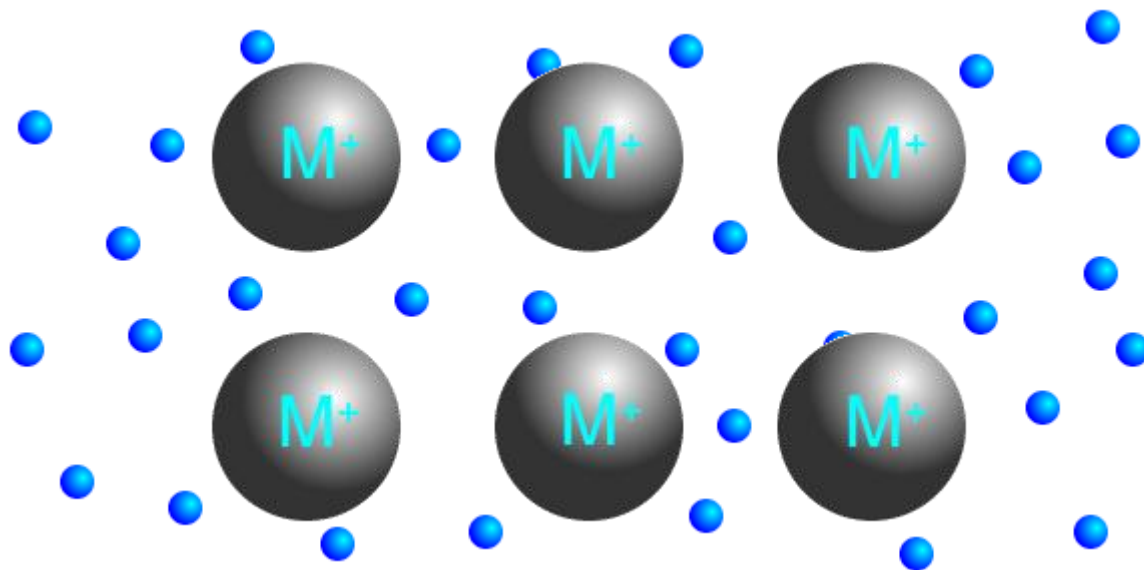
- Sodium, magnesium and aluminium are all *metallic elements*. They are composed of positively charged ions (cations) arranged in a crystal lattice, surrounded by a sea of *delocalised electrons*.
- The delocalised electrons are free to move, and function as charge carrying particles.
- Moving from sodium 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



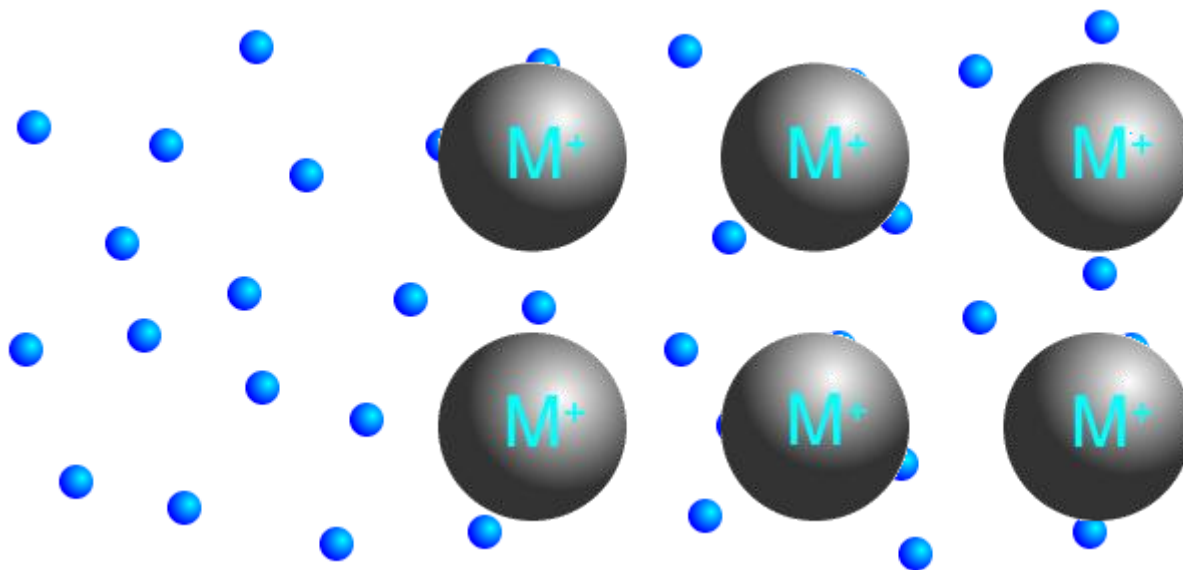
- A metallic element is composed of cations surrounded by a sea of delocalised electrons. The sea of delocalised electrons is formed when the metal atoms lose their valence electron(s) in order to obtain a noble gas electronic configuration.



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

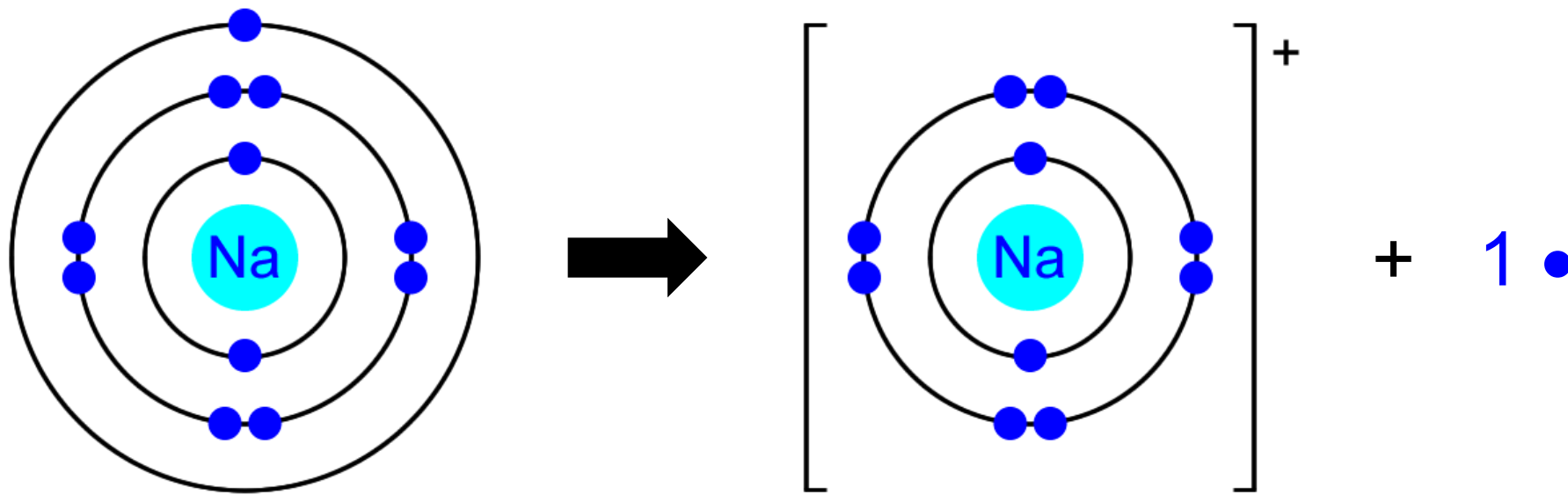
- In metallic bonding, atoms of metallic elements lose their valence electron(s) to form the delocalised sea of electrons, hence an atom of *sodium* will lose *one* electron, an atom of *magnesium* will lose *two* electrons and an atom of *aluminium* will lose *three* electrons.
 - As the number of electrons 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

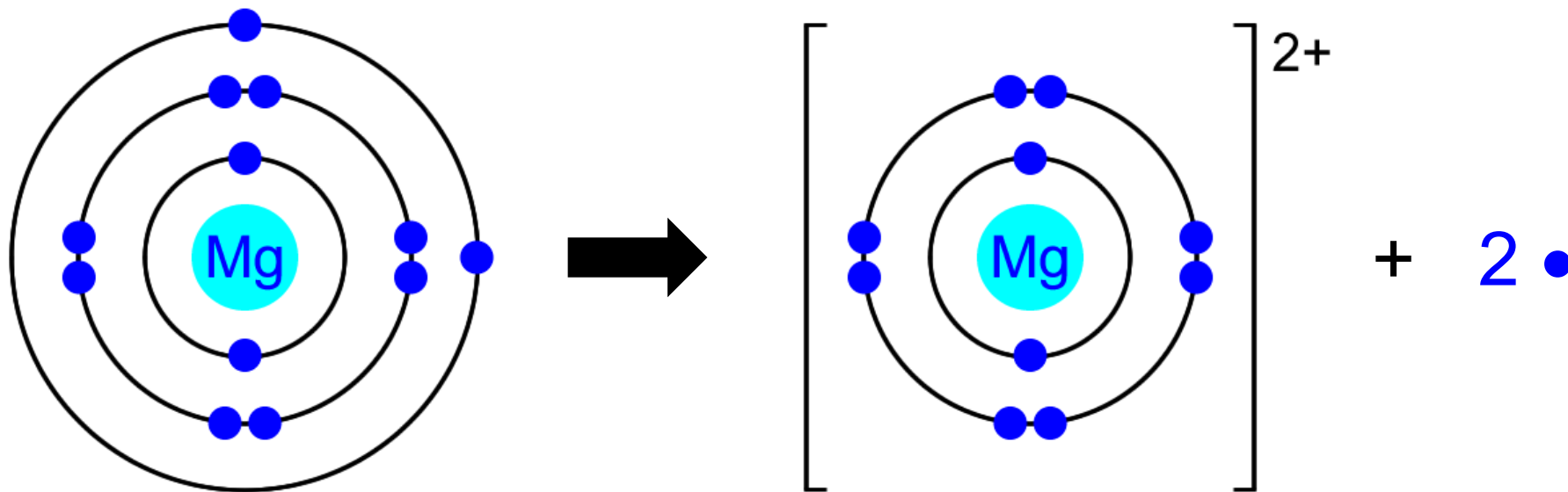


- Each sodium atom loses *one* electron to form the delocalised sea of electrons.

Periodic Table of the Chemical Elements

Periodic Trends – Electrical Conductivity

Sodium, Magnesium and Aluminium



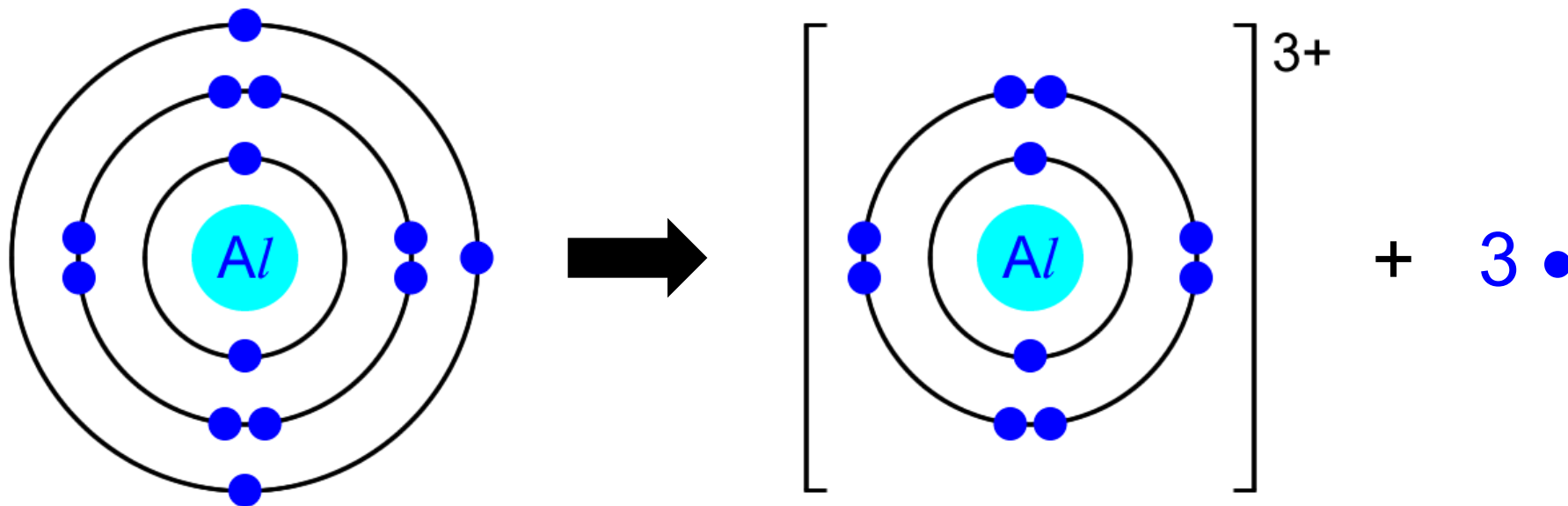
- Each magnesium atom loses *two* electrons to form the delocalised sea of electrons. Magnesium is a better conductor of electricity than sodium.



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.

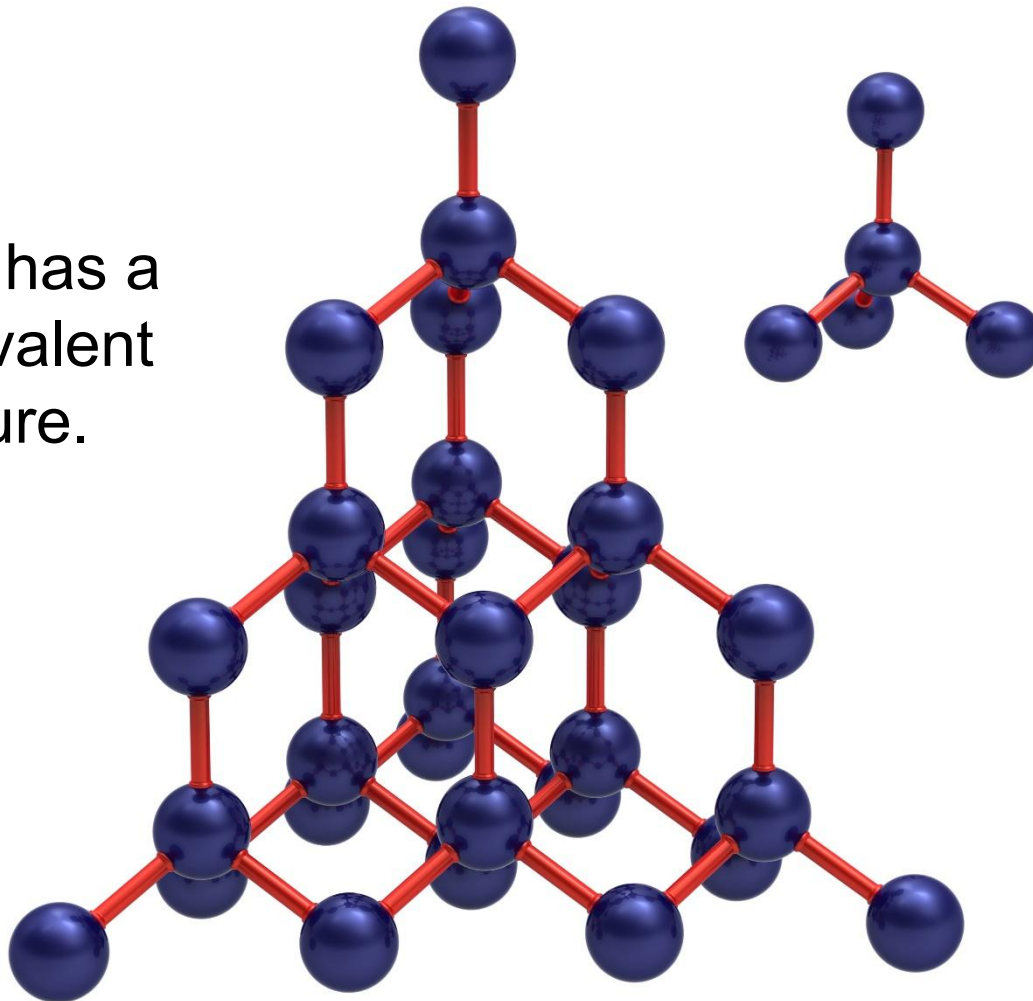


Periodic Table of the Chemical Elements

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

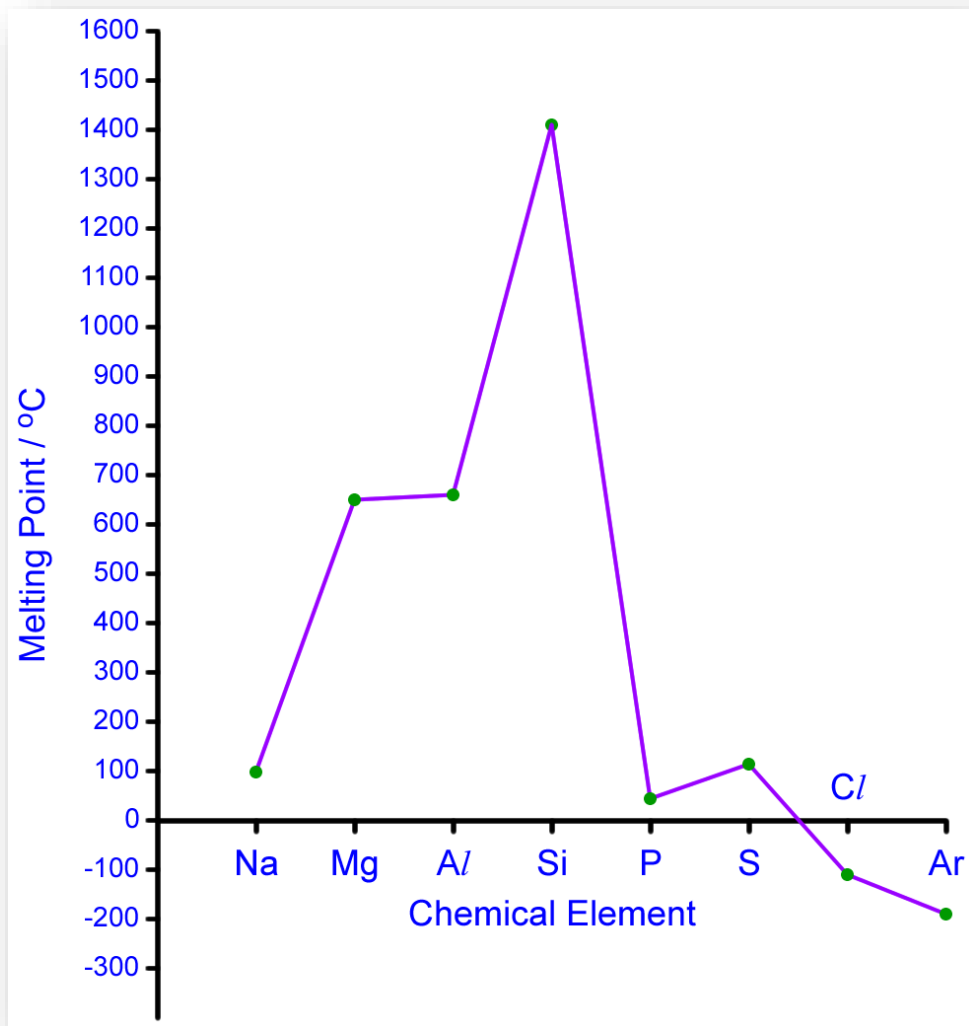
Phosphorus, Sulfur, Chlorine and Argon

- Phosphorus, sulfur, chlorine and 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 delocalised 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.

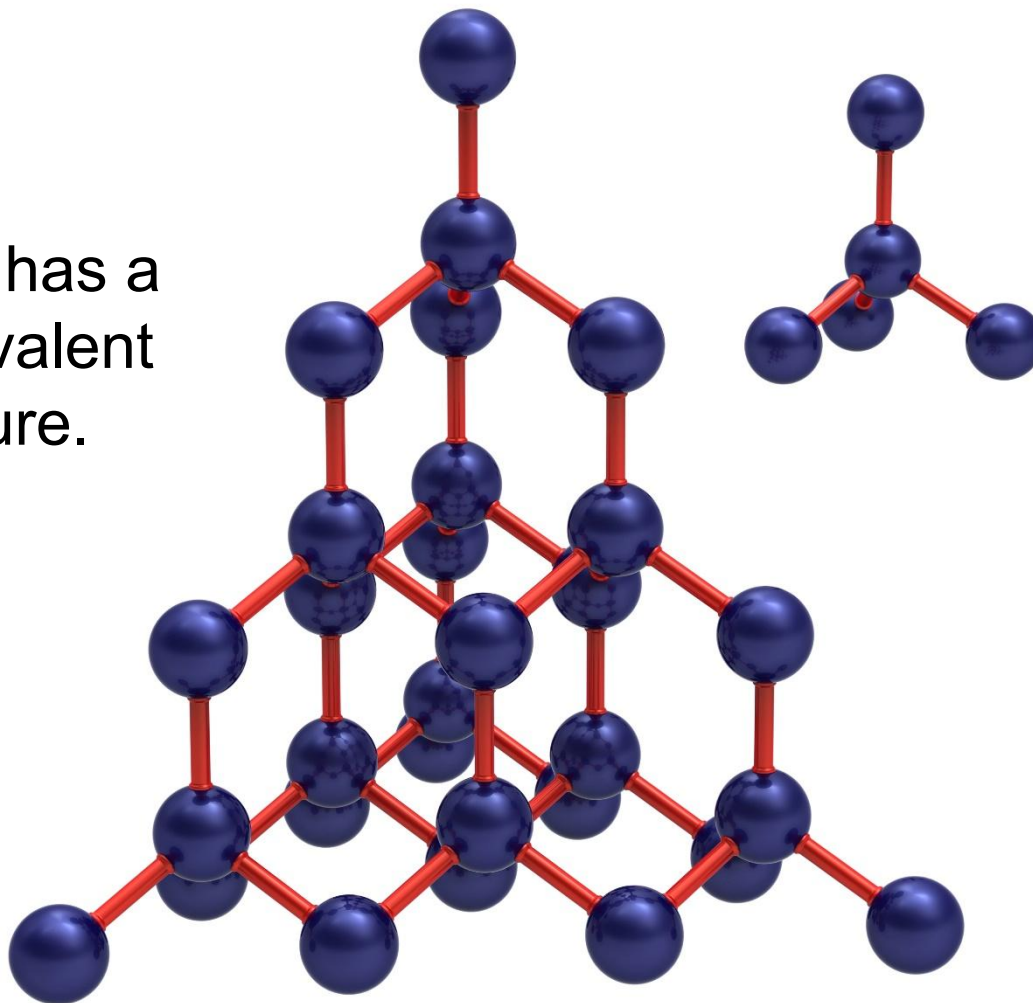


Periodic Table of the Chemical Elements

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

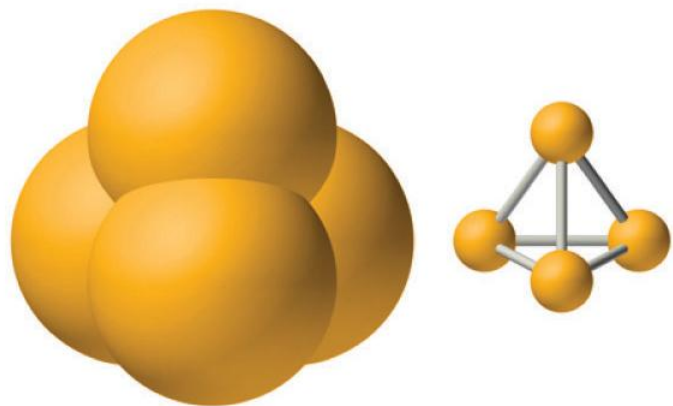
- Phosphorus, sulfur, chlorine and argon are all *non-metallic elements*. Phosphorus (P_4), sulfur (S_8) and chlorine (Cl_2) exist as simple covalent molecules while argon (Ar) is monatomic.
- Weak *instantaneous dipole-induced dipole forces of attraction* (London dispersion forces) exist between the 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*.



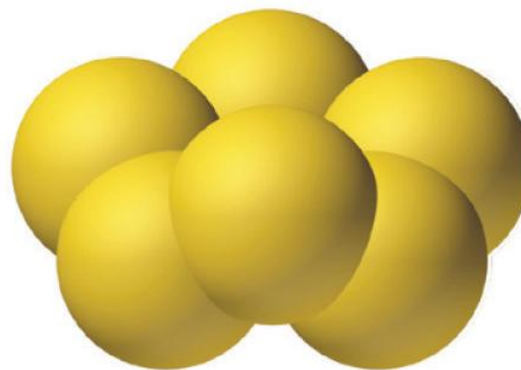
Periodic Table of the Chemical Elements

Periodic Trends – Melting Points

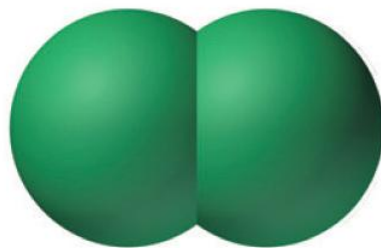
Phosphorus, Sulfur, Chlorine and Argon



• Phosphorus, P_4



• Sulfur, S_8



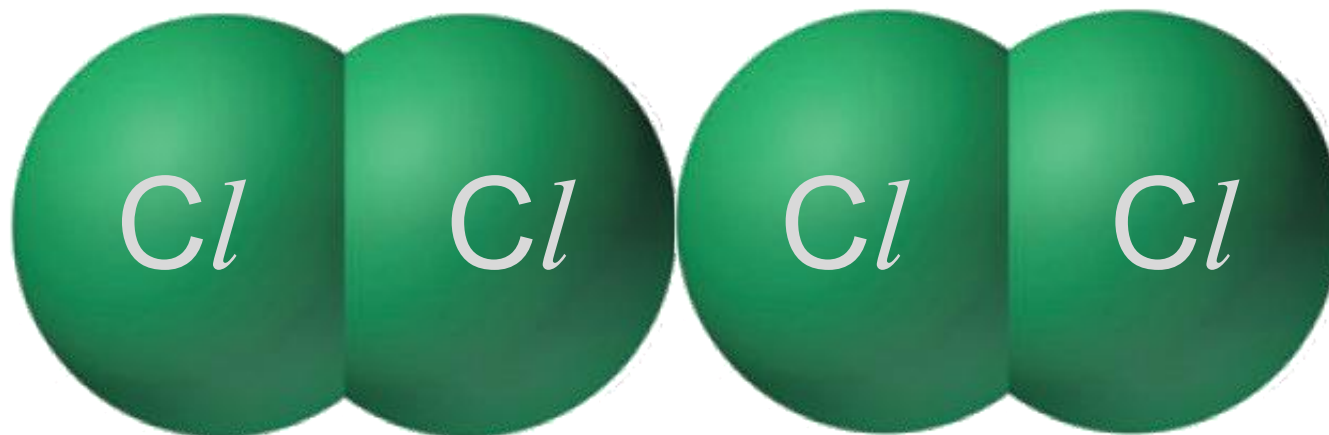
• Chlorine, Cl_2



Periodic Table of the Chemical Elements

Periodic Trends – Melting Points

Phosphorus, Sulfur, Chlorine and Argon



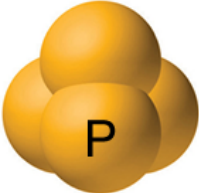
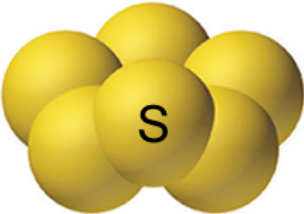
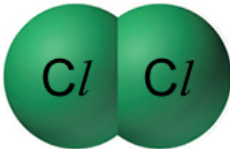

- Weak London dispersion forces only require a small amount of thermal energy to weaken and hence these non-metallic elements have low melting points.



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	$4 \times 15 = 60$	124.0
	115	445	$8 \times 16 = 128$	256.8
	-101	-35.0	$2 \times 17 = 34$	71.0
	-189	-186	$1 \times 18 = 18$	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 than 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:

$$F = \frac{1}{4 \times \pi \times \epsilon_0} \times \frac{q_1 \times q_2}{r^2}$$

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

Periodic Table of the Chemical Elements

Periodic Trends – Electrostatic Forces

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

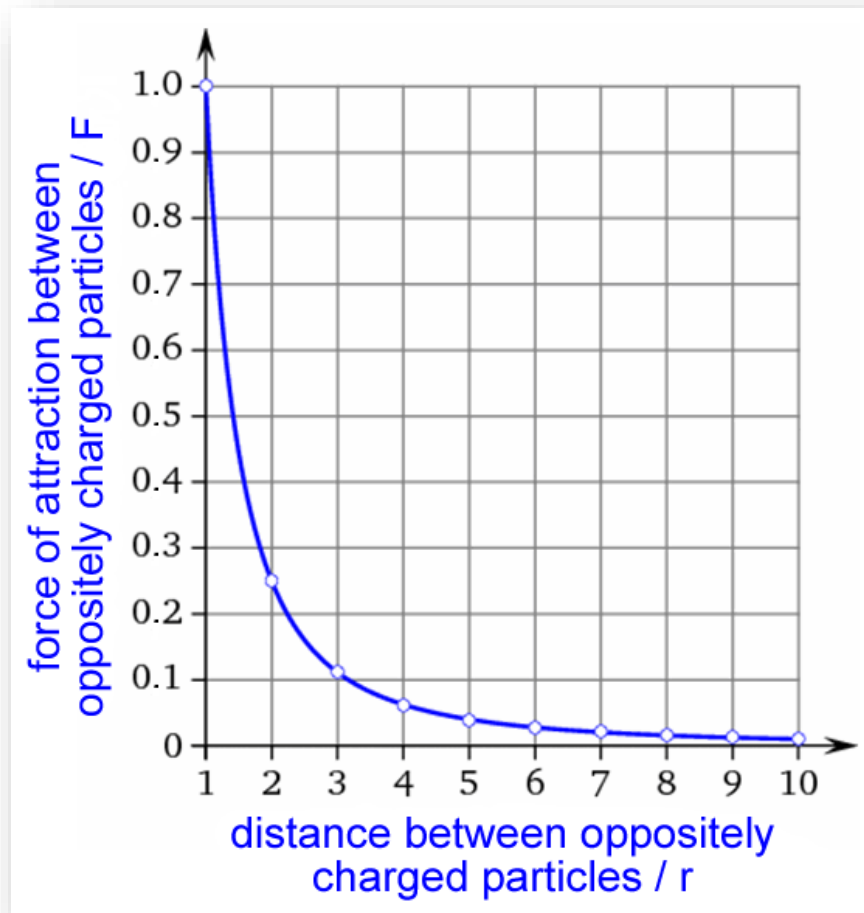
$$F \propto \frac{q_1 \times q_2}{r^2}$$

- 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



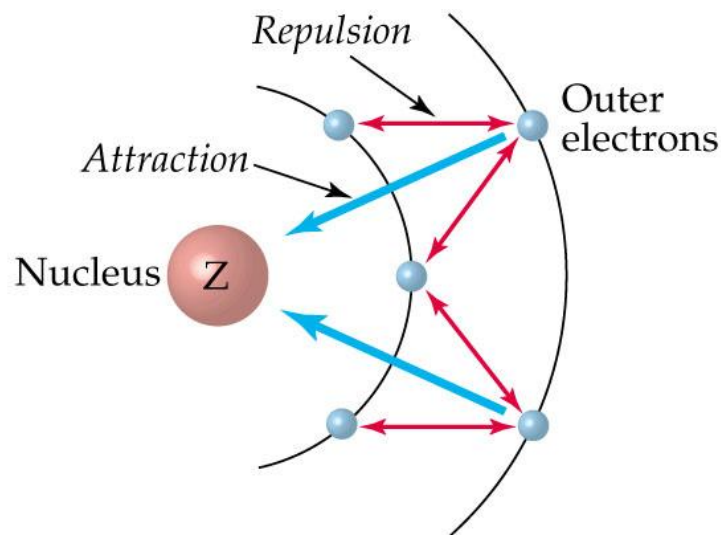
- The force of attraction (F) between two oppositely charged particles decreases rapidly as the distance between the particles (r) increases – inverse square law.



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.

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

Large amount of shielding. Large distance from the nucleus.

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

Weak electrostatic force of attraction.

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.

Small amount of shielding. Small distance from the nucleus.

Strong electrostatic force of attraction.

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

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

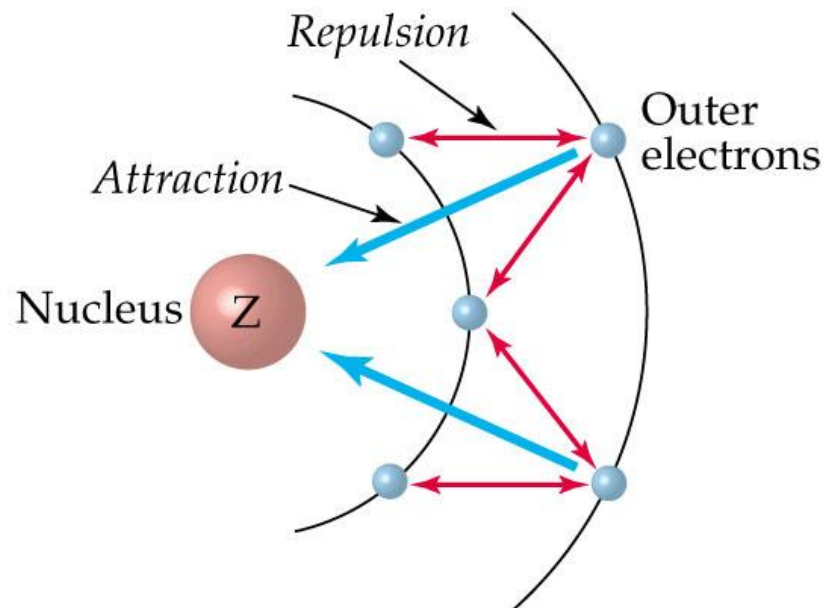
The atmosphere in here is great, I could stay all night.



Periodic Table of the Chemical Elements

Periodic Trends – Electrostatic Forces

- A note about *shielding effect*.



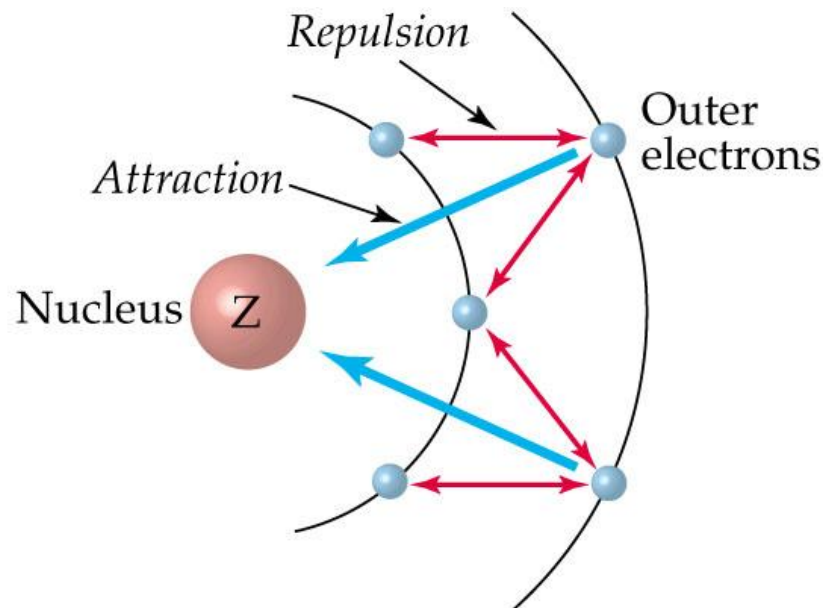
- Electrons in the valence shell of the atom are *shielded* from the positively charged nucleus by negatively charged electrons of the inner electron shells. *Shielding* results in the valence electrons experiencing a *weaker effective nuclear charge*.



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

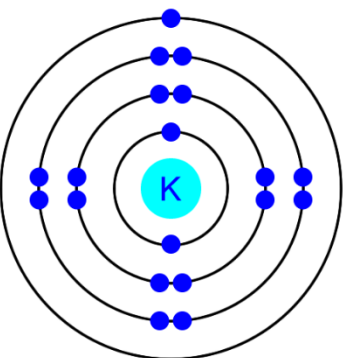
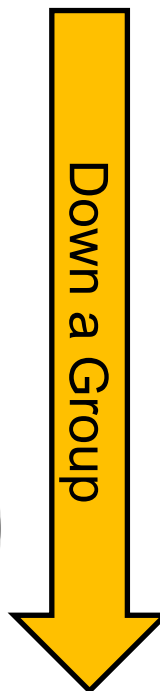
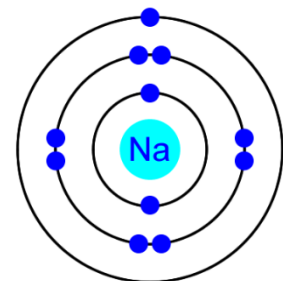
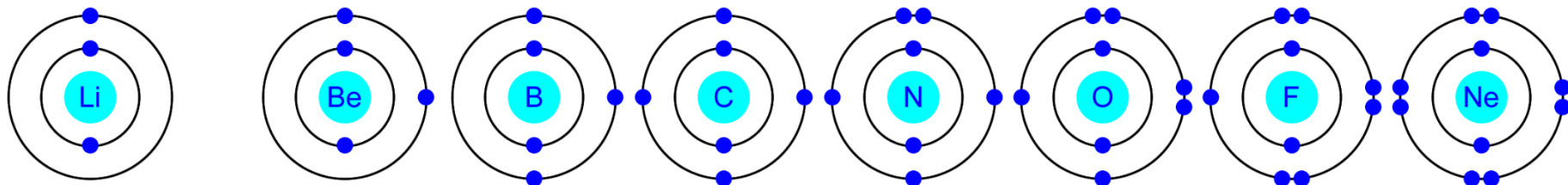
- An analogy for shielding effect:

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



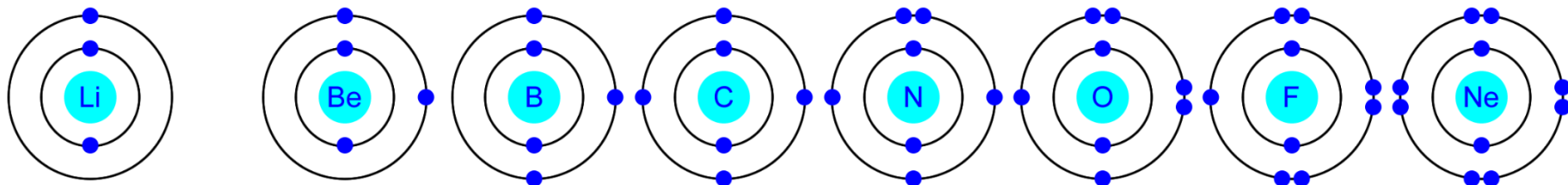
Periodic Table of the Chemical Elements

Periodic Trends – Electrostatic Forces



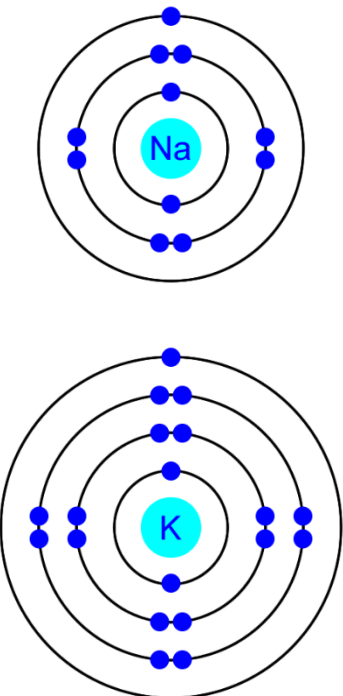
Periodic Table of the Chemical Elements

Periodic Trends – Electrostatic Forces



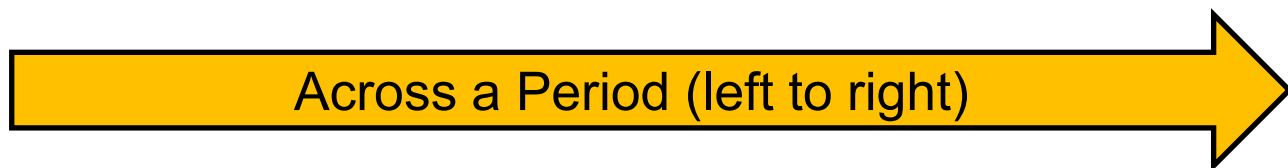
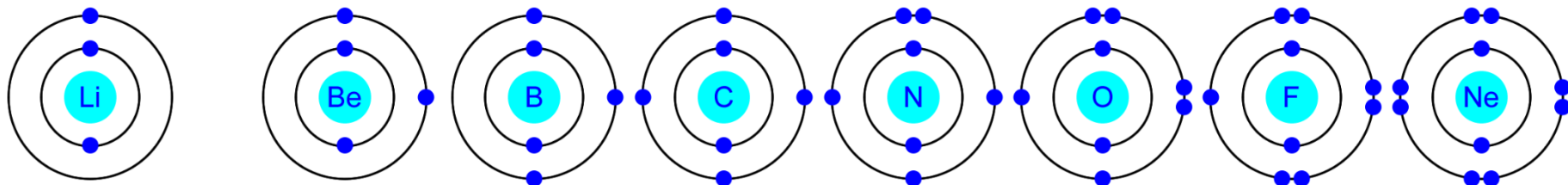
- Moving *across a Period*, there is an increase in the number of positively charged protons in the nucleus of an atom (increase in nuclear charge) but the total number of electron shells remains the same (constant).

Down a Group

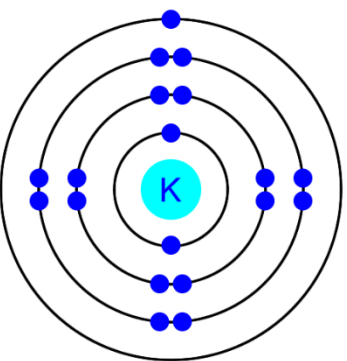
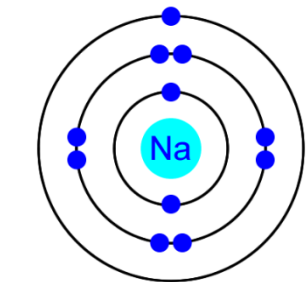


Periodic Table of the Chemical Elements

Periodic Trends – Electrostatic Forces

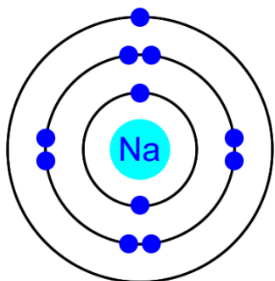
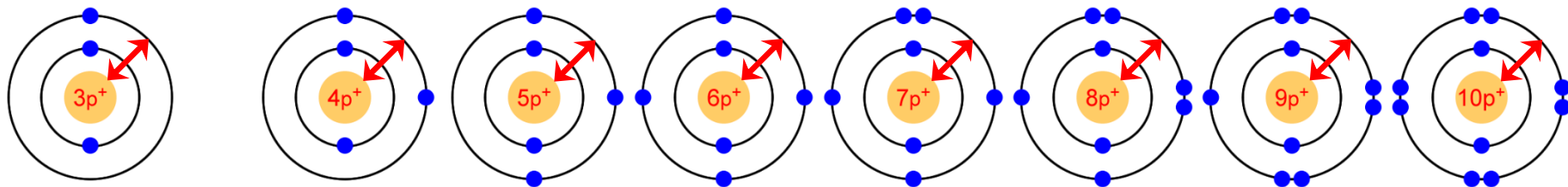


- Moving across a Period, the number of electrons *in-between* the positively charged nucleus and negatively charged electrons in the valence shell of an atom remains the same (constant). This means that the number of electrons available to *shield* the valence electron(s) from the attractive force of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

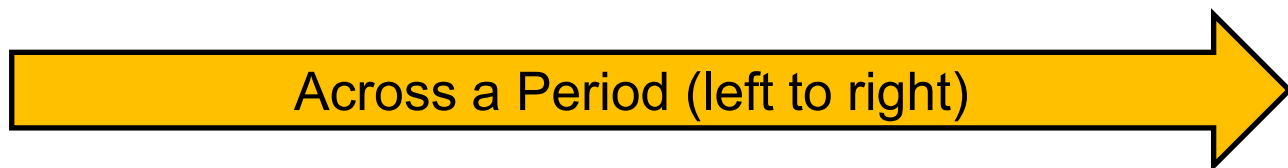


Periodic Table of the Chemical Elements

Periodic Trends – Electrostatic Forces



Down a Group

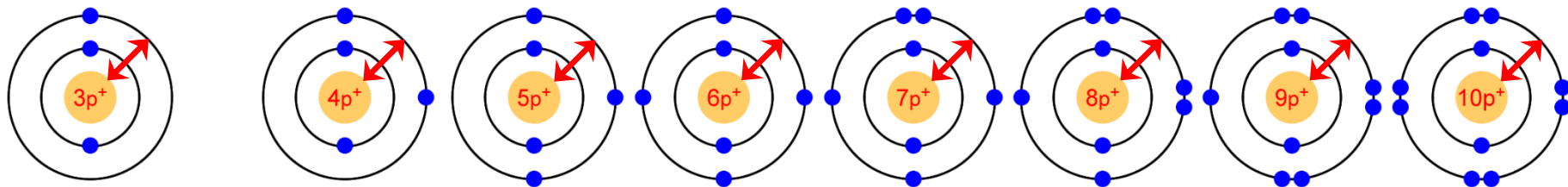


- Moving across a Period, the number of protons in the nucleus of an atom (nuclear charge) increases, but the number of inner shell electrons available to *shield* the valence electron(s) from this increasing nuclear charge remains the same (constant). Electrons in the valence shell of an atom are said 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

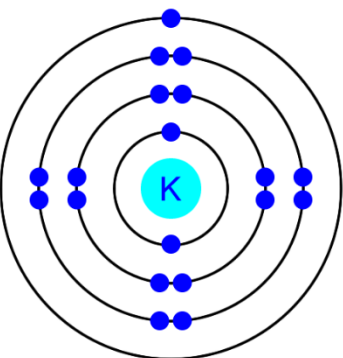
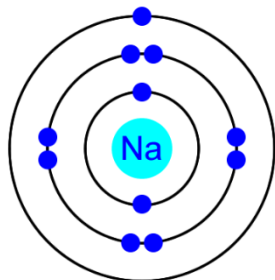
Periodic Trends – Electrostatic Forces



Across a Period (left to right)

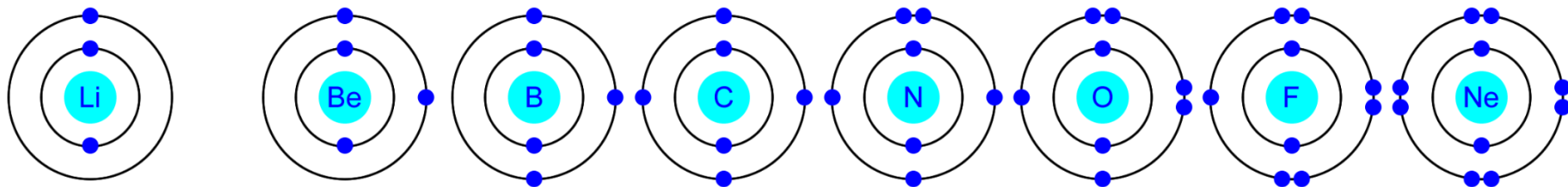
- Due to the increasing effective nuclear charge, the *electrostatic force of attraction* between the nucleus and electron(s) in the valence shell of an atom *increases across a Period* from left to right.

Down a Group

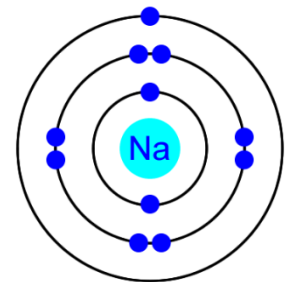


Periodic Table of the Chemical Elements

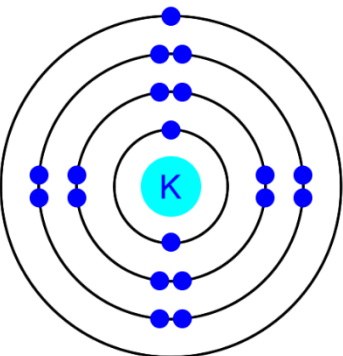
Periodic Trends – Electrostatic Forces



Across a Period (left to right)

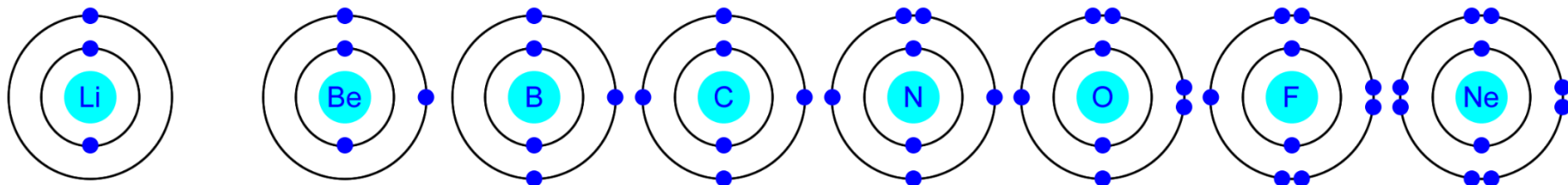


Down a Group



Periodic Table of the Chemical Elements

Periodic Trends – Electrostatic Forces



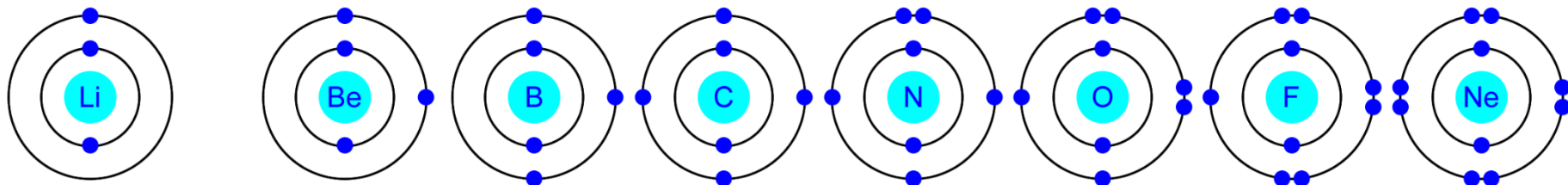
- Moving *down a Group*, there is an increase in the number of positively charged protons in the nucleus (increase in nuclear charge) and also an increase in the total number of electron shells.

Down a Group



Periodic Table of the Chemical Elements

Periodic Trends – Electrostatic Forces



Across a Period (left to right)

- 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.

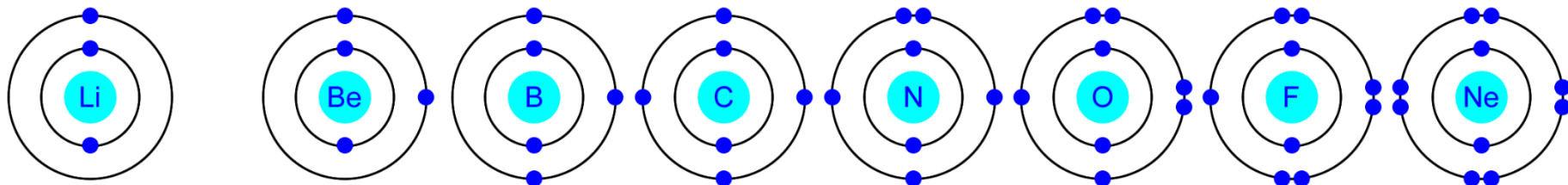
Down a Group

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



Periodic Table of the Chemical Elements

Periodic Trends – Electrostatic Forces



Across a Period (left to right)

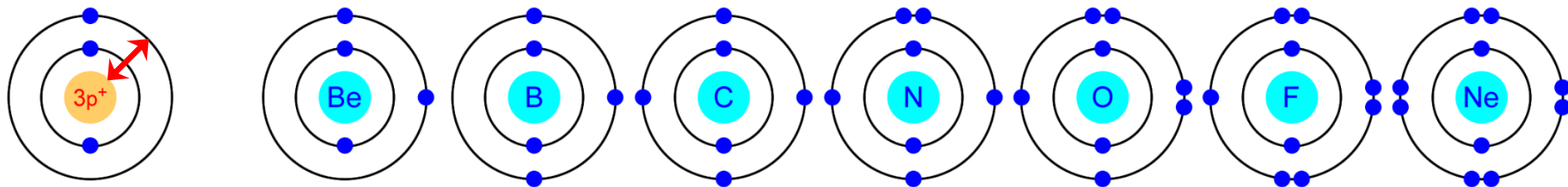
- Although there is no significant change in the effective nuclear charge moving down a Group, the increasing distance between the nucleus and valence electron(s) is very important. As the distance between the positively charged nucleus and negatively charged electrons in the valence shell *increases*,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

Down a Group



Periodic Table of the Chemical Elements

Periodic Trends – Electrostatic Forces



- 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).

Down a Group



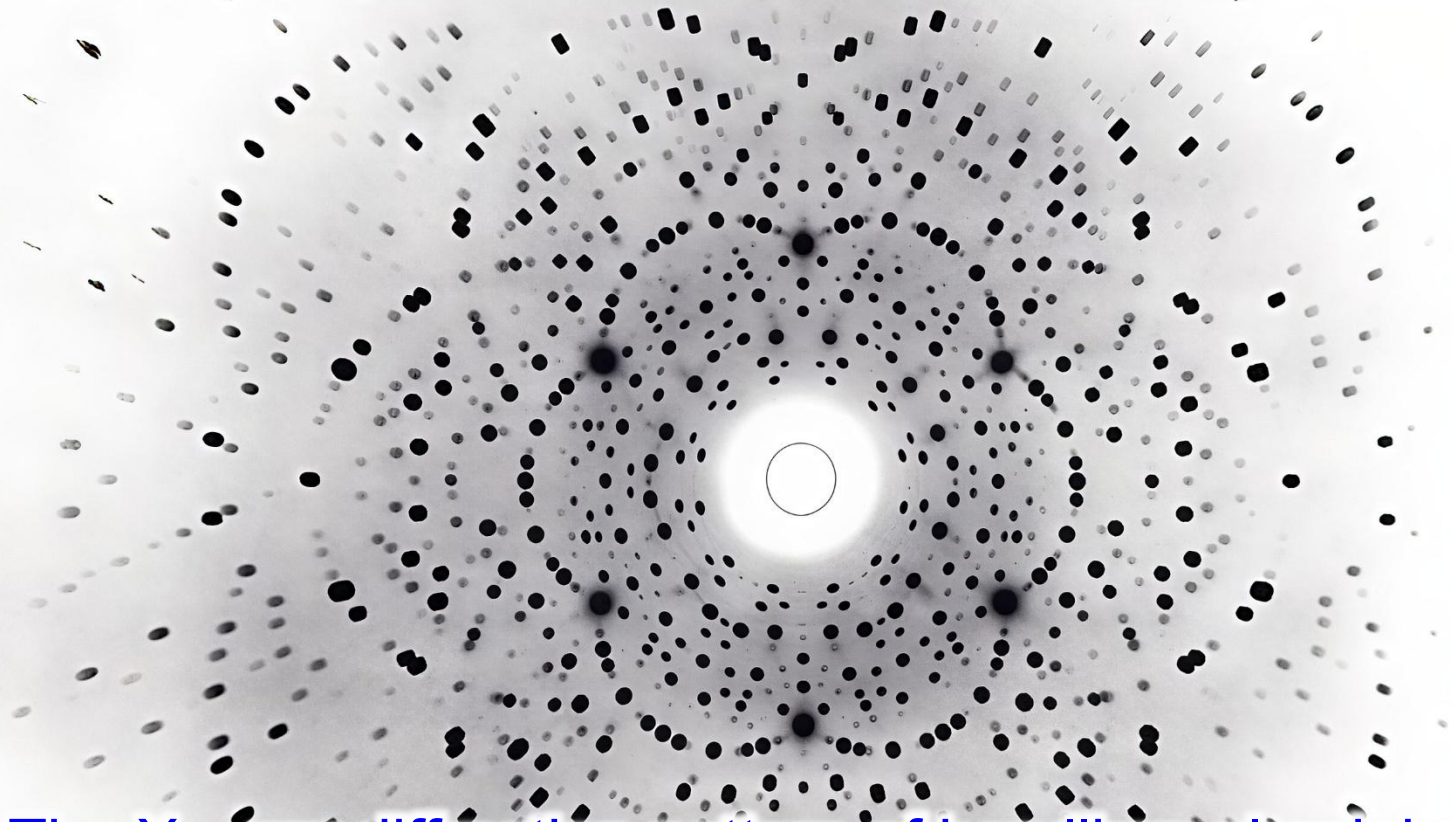
Periodic Table of the Chemical Elements

Periodic Trends – Atomic Radius

- To measure an atom's radius, Scientists determine the distance between the nuclei of two adjacent atoms or ions and divide the value by two. Atoms and ions can interact in different ways, leading to different types of atomic radii: *covalent*, *metallic*, *ionic* and *van der Waals*. The distance between nuclei is measured using analytical techniques such as *X-ray crystallography*.
 - *X-ray crystallography* is a scientific technique used to determine the arrangement of atoms or ions in a crystal by analyzing how X-rays are diffracted by the crystal lattice. The process involves directing a beam of X-rays through a crystal, which causes the X-rays to scatter in a specific pattern. This diffraction pattern is then used to create an electron density map, which helps Scientists to reconstruct the three-dimensional arrangement of atoms or ions within the crystal.

Periodic Table of the Chemical Elements

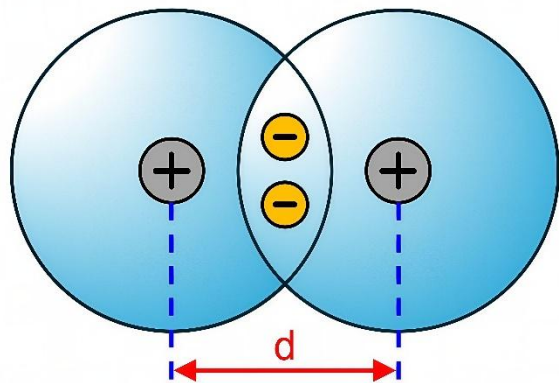
Periodic Trends – Atomic Radius



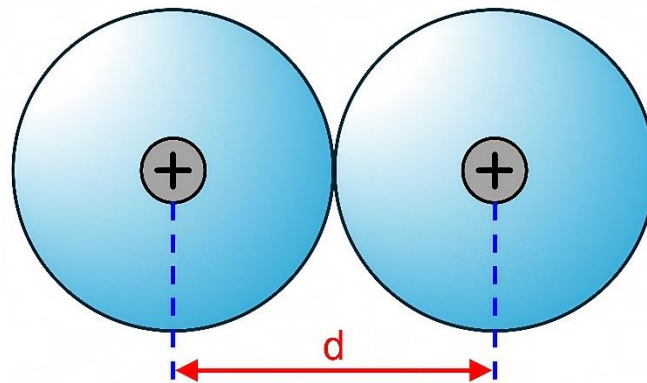
- The X – ray diffraction pattern of beryllium aluminium silicate, $\text{Be}_3\text{Al}_2(\text{SiO}_3)_6$. X – rays are diffracted through the crystal, producing a pattern which is interpreted to give the arrangement of atoms and ions in the crystal.

Periodic Table of the Chemical Elements

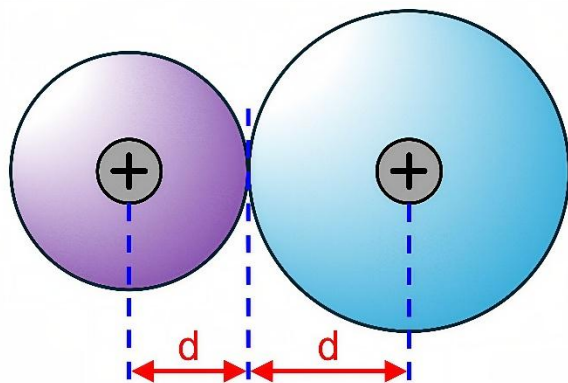
Periodic Trends – Atomic Radius



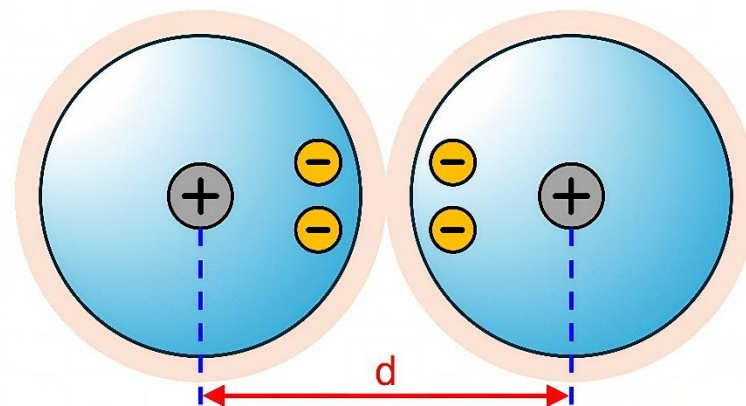
- covalent radius (C_r) = $d \div 2$
e.g. for H_2 $d = 74$ pm, $74 \div 2 = 37$ pm



- metallic radius (M_r) = $d \div 2$
e.g. for Mg $d = 360$ pm, $360 \div 2 = 180$ pm



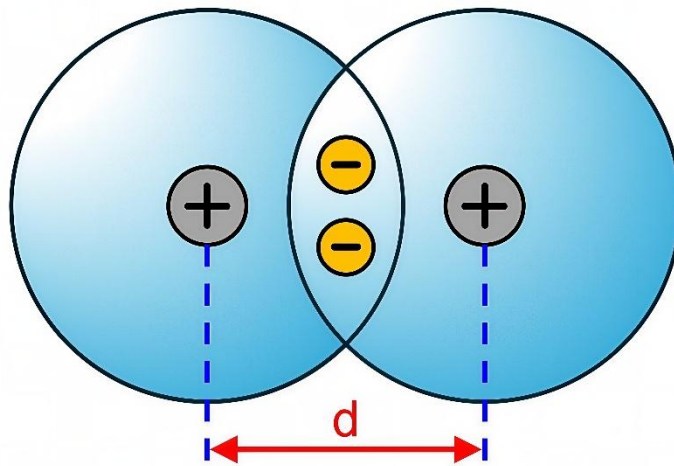
- ionic radii (I_r)
e.g. (I_r) for Na^+ = 102 pm
e.g. (I_r) for Cl^- = 181 pm



- Van der Waals radius (VdW_r) = $d \div 2$
e.g. for He $d = 280$ pm, $280 \div 2 = 140$ pm

Periodic Table of the Chemical Elements

Periodic Trends – Atomic Radius



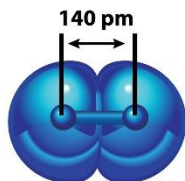
- covalent radius (C_r) = $d \div 2$
e.g. for H_2 $d = 74$ pm, $74 \div 2 = 37$ pm

- The covalent radius is half the distance between the nuclei of two identical atoms bonded together by a single covalent bond. It is a measure of an atom's size when it is part of a covalent bond and is typically measured in picometers ($1 \text{ pm} = 1 \times 10^{-12} \text{ m}$). This value helps predict the length of the bond between two atoms; in theory, the sum of two covalent radii should equal the length of the covalent between them.

Periodic Table of the Chemical Elements

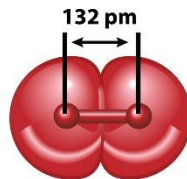
Periodic Trends – Atomic Radius

Atomic Radius



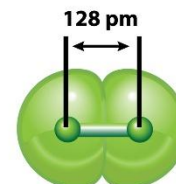
Nitrogen (N₂)

$$\text{N radius} = \frac{140 \text{ pm}}{2} = 70 \text{ pm}$$



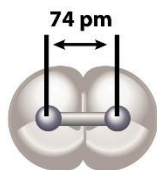
Oxygen (O₂)

$$\text{O radius} = \frac{132 \text{ pm}}{2} = 66 \text{ pm}$$



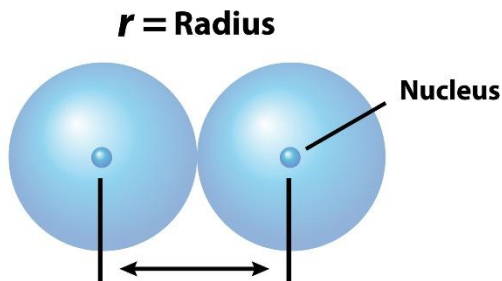
Fluorine (F₂)

$$\text{F radius} = \frac{128 \text{ pm}}{2} = 64 \text{ pm}$$



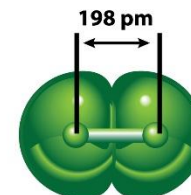
Hydrogen (H₂)

$$\text{H radius} = \frac{74 \text{ pm}}{2} = 37 \text{ pm}$$



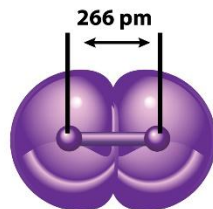
d = Distance Between Nuclei

$$r = d/2$$



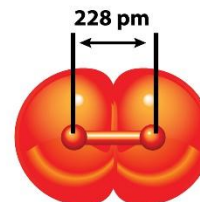
Chlorine (Cl₂)

$$\text{Cl radius} = \frac{198 \text{ pm}}{2} = 99 \text{ pm}$$



Iodine (I₂)

$$\text{I radius} = \frac{266 \text{ pm}}{2} = 133 \text{ pm}$$

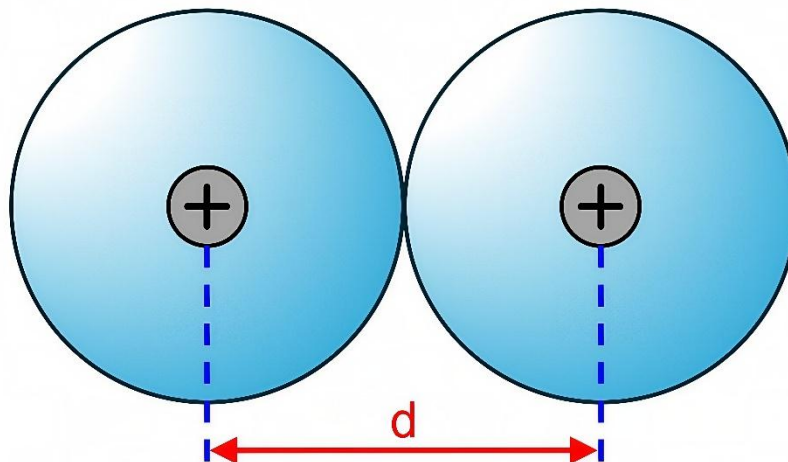


Bromine (Br₂)

$$\text{Br radius} = \frac{228 \text{ pm}}{2} = 114 \text{ pm}$$

Periodic Table of the Chemical Elements

Periodic Trends – Atomic Radius



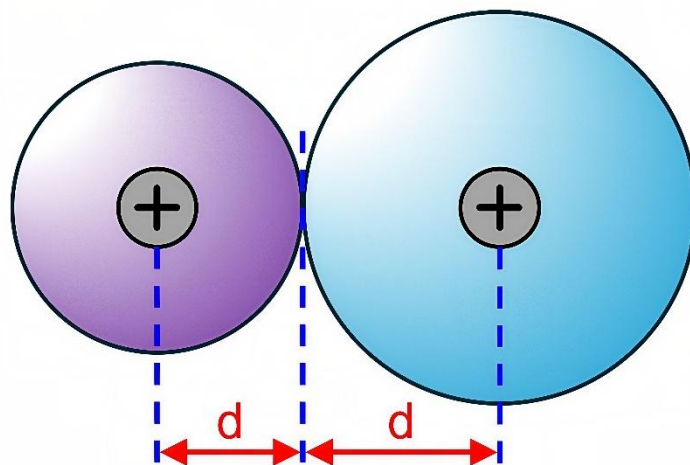
- metallic radius (M_r) = $d \div 2$

e.g. for Mg $d = 360 \text{ pm}$, $360 \div 2 = 180 \text{ pm}$

- The metallic radius is half the distance between the nuclei of two adjacent, bonded metal atoms in a metallic crystal lattice. It is a measure of the size of an atom in a metallic solid. This value is calculated by taking the internuclear distance between two neighbouring metal atoms and dividing it by two.

Periodic Table of the Chemical Elements

Periodic Trends – Atomic Radius



- ionic radii (I_r)

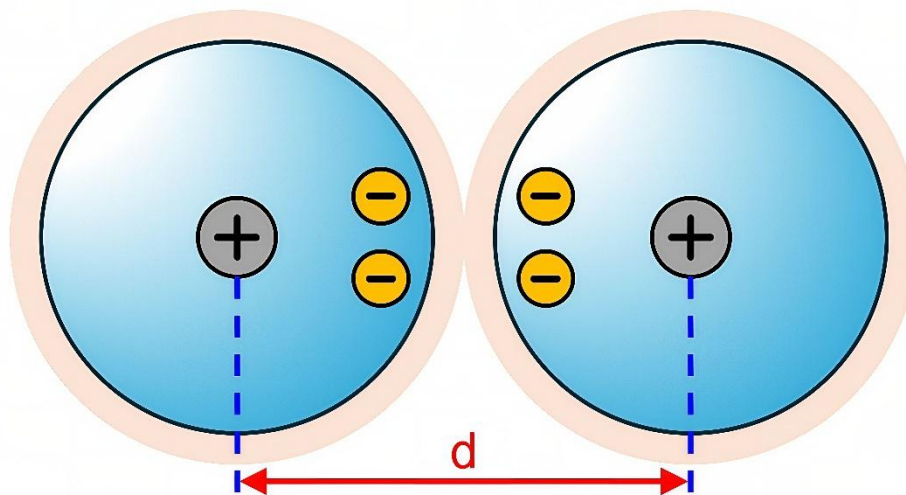
e.g. (I_r) for Na^+ = 102 pm

e.g. (I_r) for Cl^- = 181 pm

- Ionic radius is the measure of an ion's size, defined as the distance from the nucleus to the outermost electrons in an ionic crystal lattice. It is typically measured in picometers ($1 \text{ pm} = 1 \times 10^{-12} \text{ m}$). When a neutral atom forms a cation by losing electrons, its radius becomes smaller; conversely, when it forms an anion by gaining electrons, its radius becomes larger.

Periodic Table of the Chemical Elements

Periodic Trends – Atomic Radius

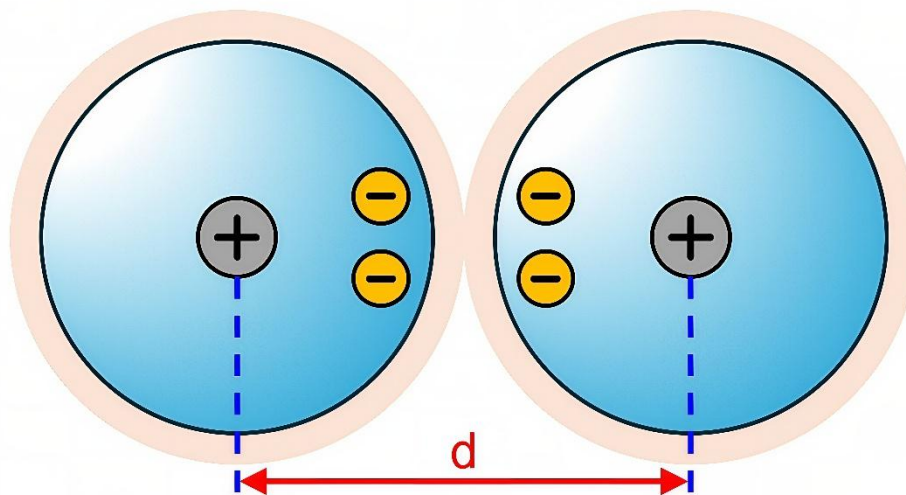


- Van der Waals radius (VdW_r) = $d \div 2$
e.g. for He $d = 280 \text{ pm}$, $280 \div 2 = 140 \text{ pm}$

- Within the same period, noble gases have the *smallest theoretical atomic radius*. This is because atomic radius (based on the size of the electron cloud of an isolated atom) decreases across the period as the effective nuclear charge increases. Noble gases have the highest effective nuclear charge in the period, so their electrons are attracted more strongly to the nucleus, resulting in a smaller atomic radius.

Periodic Table of the Chemical Elements

Periodic Trends – Atomic Radius

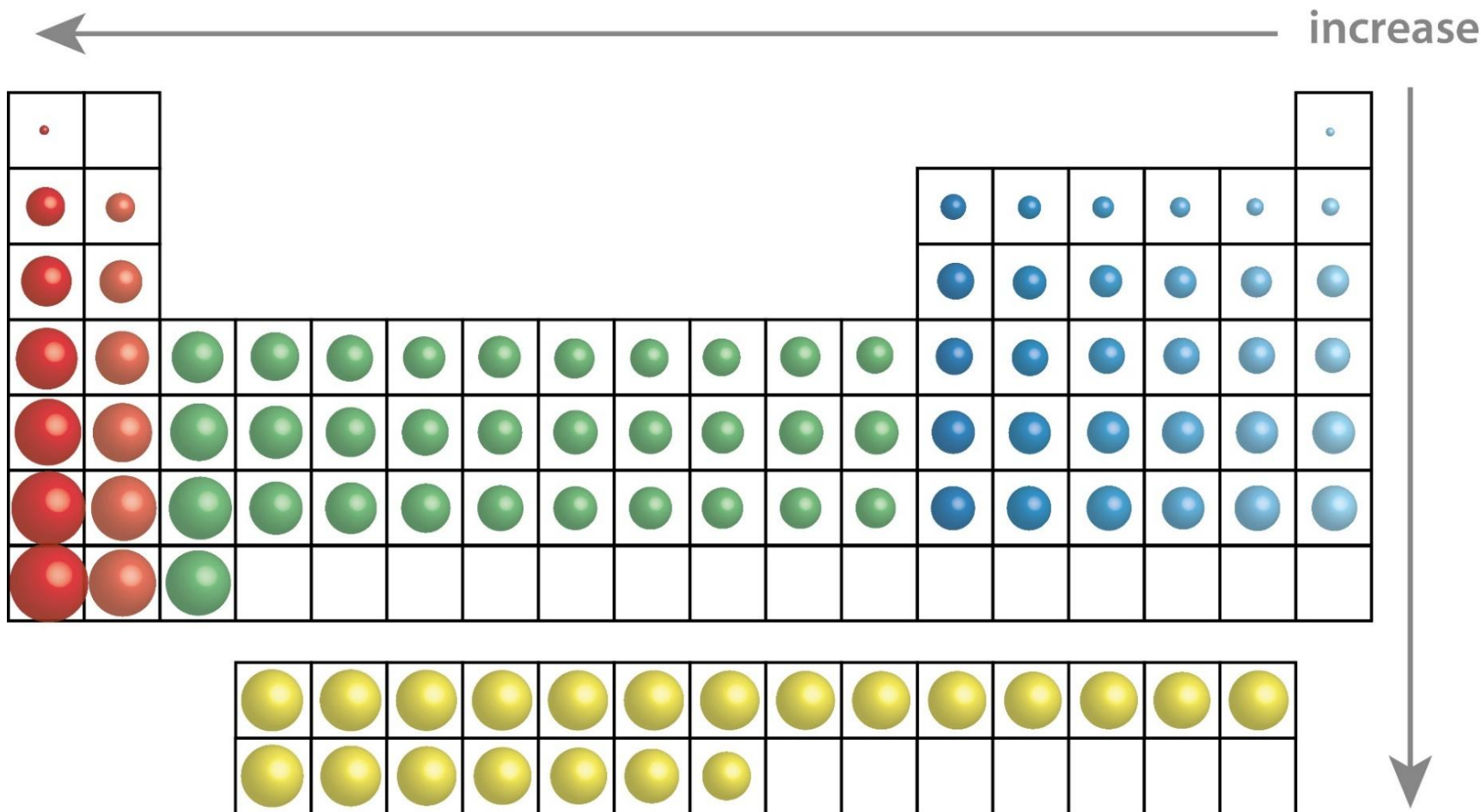


- Van der Waals radius (VdW_r) = $d \div 2$
e.g. for He $d = 280 \text{ pm}$, $280 \div 2 = 140 \text{ pm}$

- However, when using *van der Waals radius*, noble gases appear to have the *largest radius* in the Period. This is because noble gas atoms are monatomic and do not form covalent bonds. Their measured radius is based on van der Waals interactions, which arise from weak intermolecular forces between *separate atoms*. Since these atoms do not share electrons, the distance between two nuclei in a noble gas solid is relatively large – the atoms can only approach until electron-electron repulsion prevents them from getting any closer.

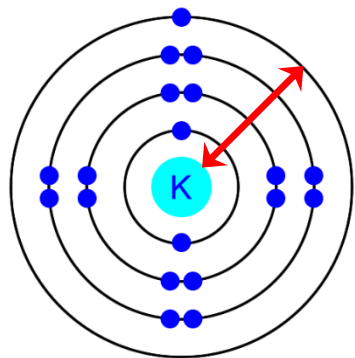
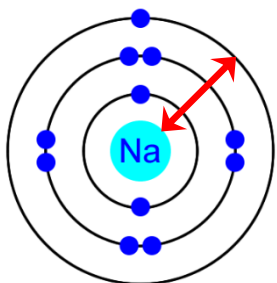
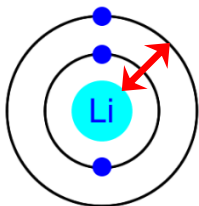
Periodic Table of the Chemical Elements

Periodic Trends – Atomic Radius



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.

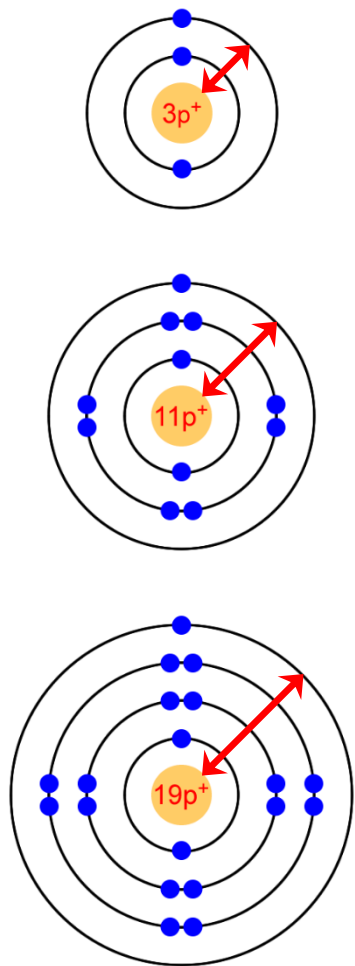
$$Z_{\text{eff}} (\text{Na}) = 11 - 10 = +1$$

$$Z_{\text{eff}} (\text{K}) = 19 - 18 = +1$$



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.

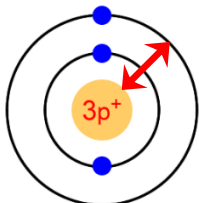
$$Z_{\text{eff}} (\text{Na}) = 11 - 10 = +1$$

$$Z_{\text{eff}} (\text{K}) = 19 - 18 = +1$$

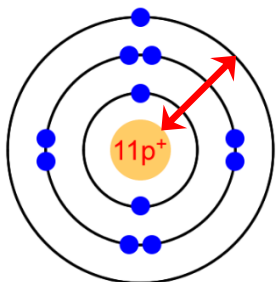


Periodic Table of the Chemical Elements

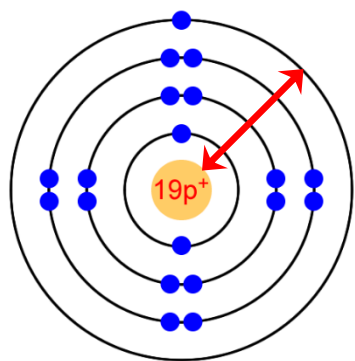
Periodic Trends – Atomic Radius



- 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.

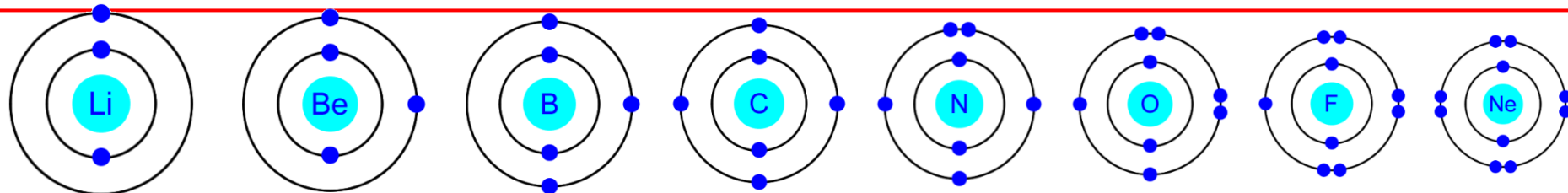


- Moving down a Group, atomic radius increases due to the *addition of a new electron shell* to the atom.



Periodic Table of the Chemical Elements

Periodic Trends – Atomic Radius

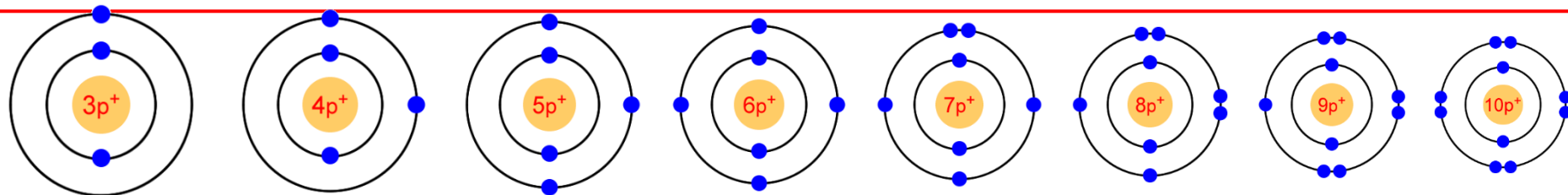


- Atomic radii *decrease* from the left-hand-side to the right-hand-side of any Period of the Periodic Table.
- The number of protons in the nucleus of an atom (nuclear charge) *increases* across a Period.
- The number of electron shells *remains constant* across a Period and therefore the number of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

$$Z_{\text{eff}} (\text{Li}) = 3 - 2 = +1$$

$$Z_{\text{eff}} (\text{Ne}) = 10 - 2 = +8$$

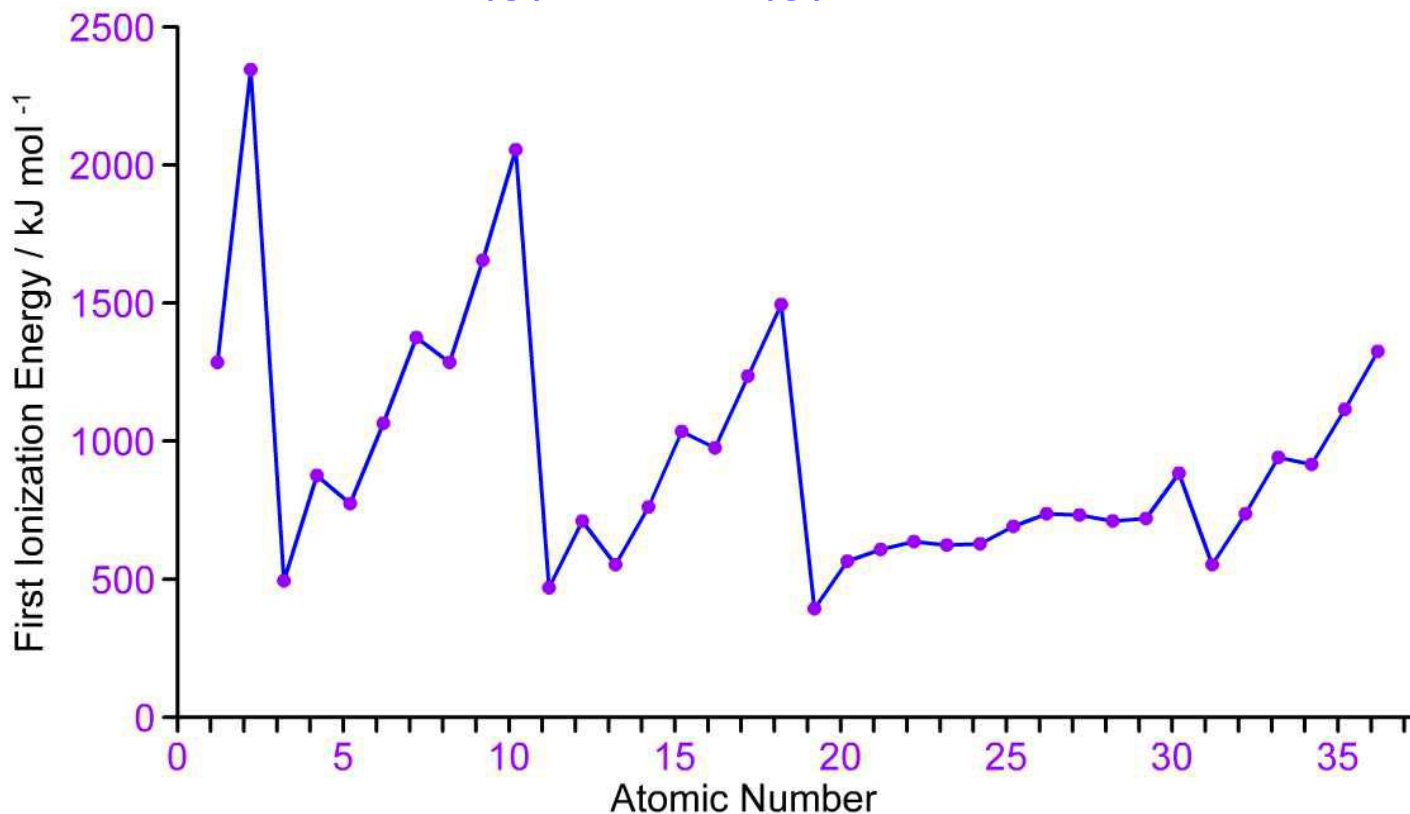
- An increase in effective nuclear charge means that there is an *increase in the electrostatic force of attraction* between the positively charged protons in the nucleus and negatively charged electrons in the valence shell of the atom, causing a steady *decrease in atomic radius across a Period*.



Periodic Table of the Chemical Elements

Periodic Trends – First Ionization Energy

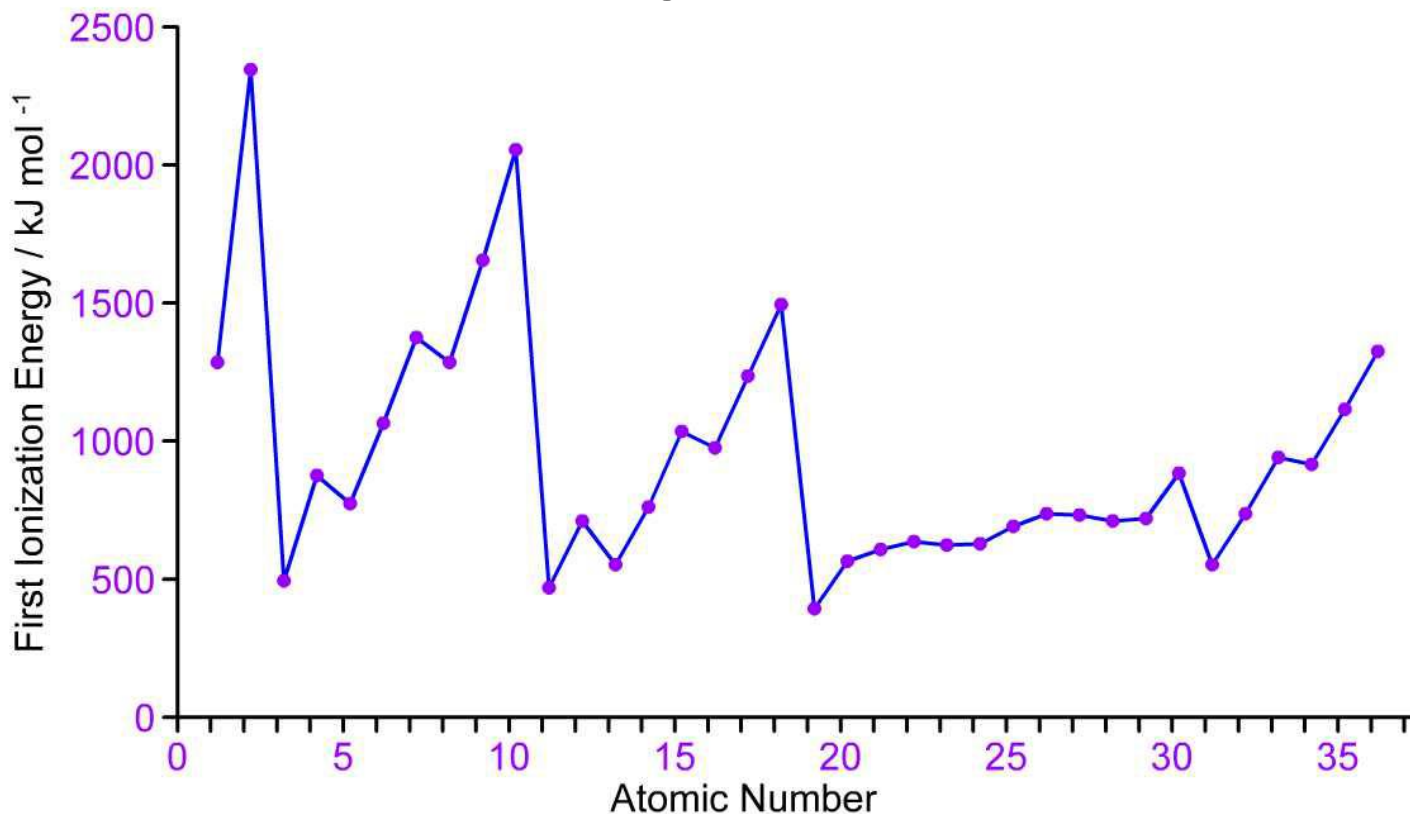
- First ionization energy is the energy required to convert 1 mole (6×10^{23}) of gaseous atoms into one mole (6×10^{23}) of unipositive ($1+$) gaseous ions.



Periodic Table of the Chemical Elements

Periodic Trends – First Ionization Energy

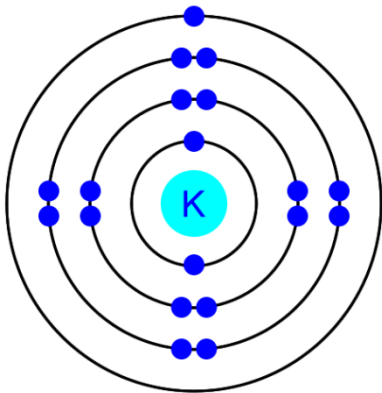
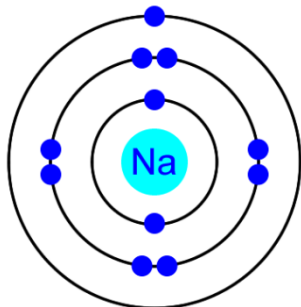
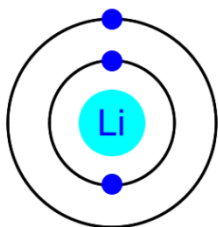
- Essentially, first ionization energy gives an indication of the amount of energy that is required to remove a single electron from the valence shell of a single atom.



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.

$$Z_{\text{eff}} (\text{Li}) = 3 - 2 = +1$$

$$Z_{\text{eff}} (\text{Na}) = 11 - 10 = +1$$

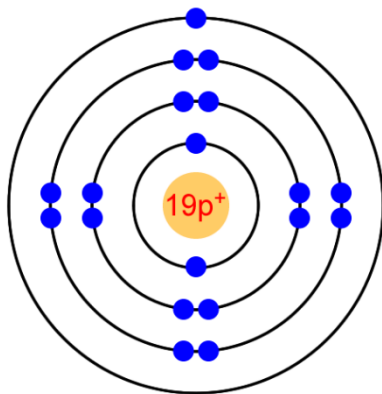
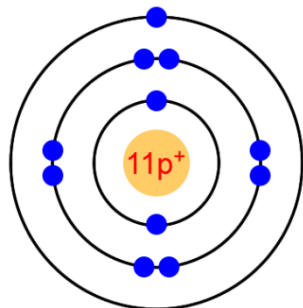
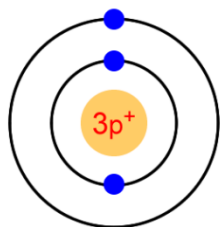
$$Z_{\text{eff}} (\text{K}) = 19 - 18 = +1$$



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.

$$Z_{\text{eff}} (\text{Li}) = 3 - 2 = +1$$

$$Z_{\text{eff}} (\text{Na}) = 11 - 10 = +1$$

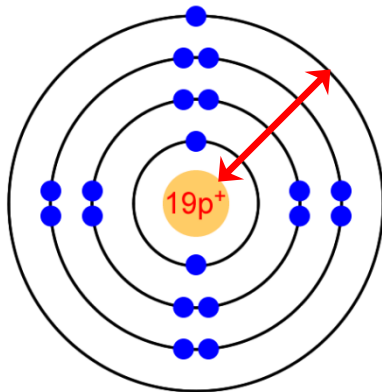
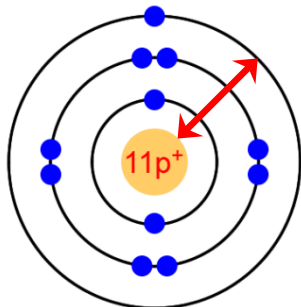
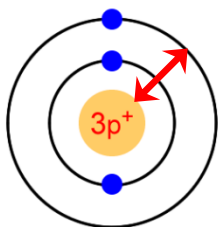
$$Z_{\text{eff}} (\text{K}) = 19 - 18 = +1$$



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).

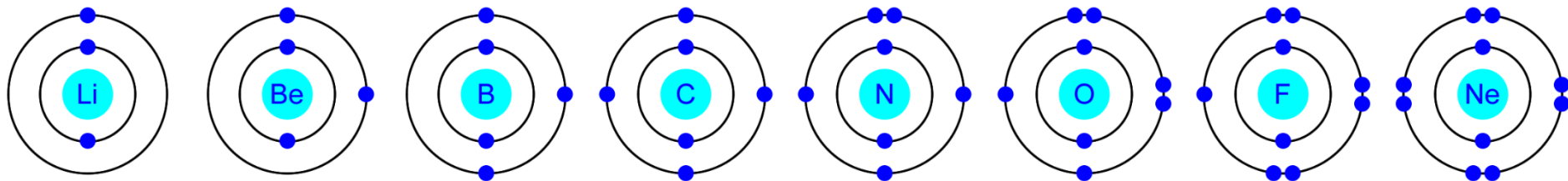
- Less energy is required to remove an electron from the valence shell of the atom, therefore *first ionization energy decreases down a Group*.



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*.

$$Z_{\text{eff}}(\text{Li}) = 3 - 2 = +1$$

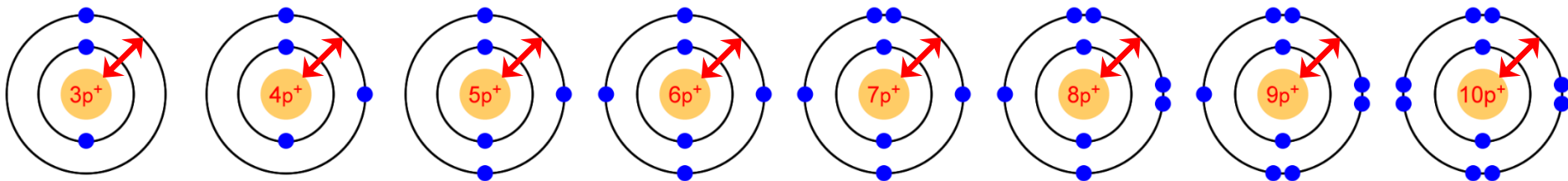
$$Z_{\text{eff}}(\text{Ne}) = 10 - 2 = +8$$



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*.

$$Z_{\text{eff}} (\text{Li}) = 3 - 2 = +1$$

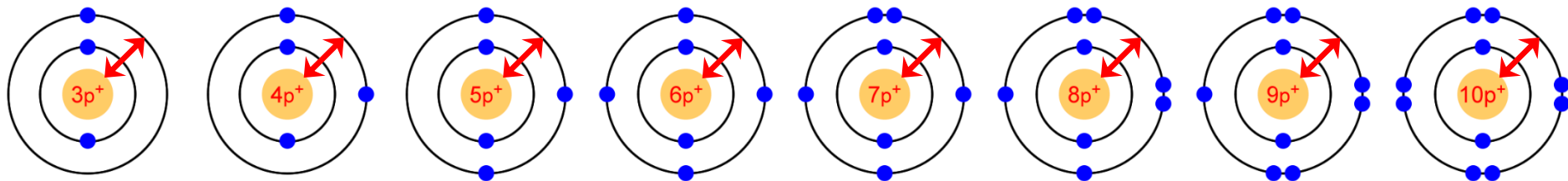
$$Z_{\text{eff}} (\text{Ne}) = 10 - 2 = +8$$



Periodic Table of the Chemical Elements

Periodic Trends – First Ionization Energy

- First ionization energy *increases across a Period*.



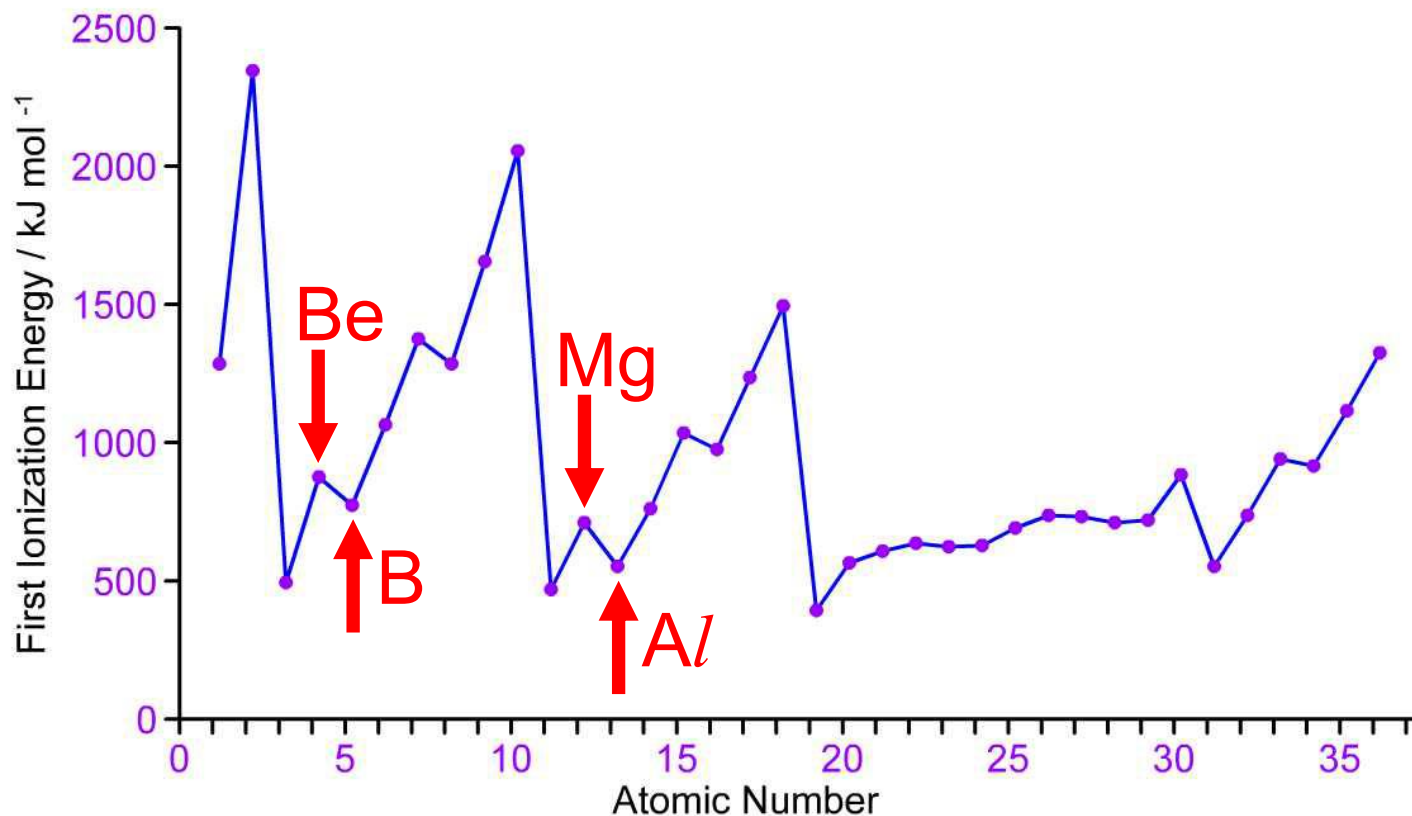
- An increase in effective nuclear charge means that there is an *increase in the electrostatic force of attraction* between the positively charged protons in the nucleus and negatively charged electron(s) in the valence shell of the atom – which are the electrons that are lost during ionization.
- Moving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

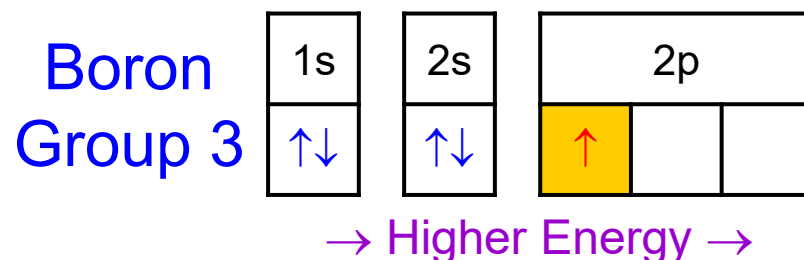
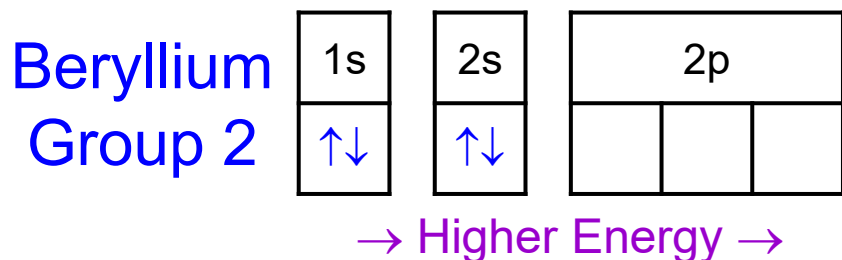
- First ionization energy *decreases* slightly between *Group 2* and *Group 13* elements.



Periodic Table of the Chemical Elements

Periodic Trends – First Ionization Energy

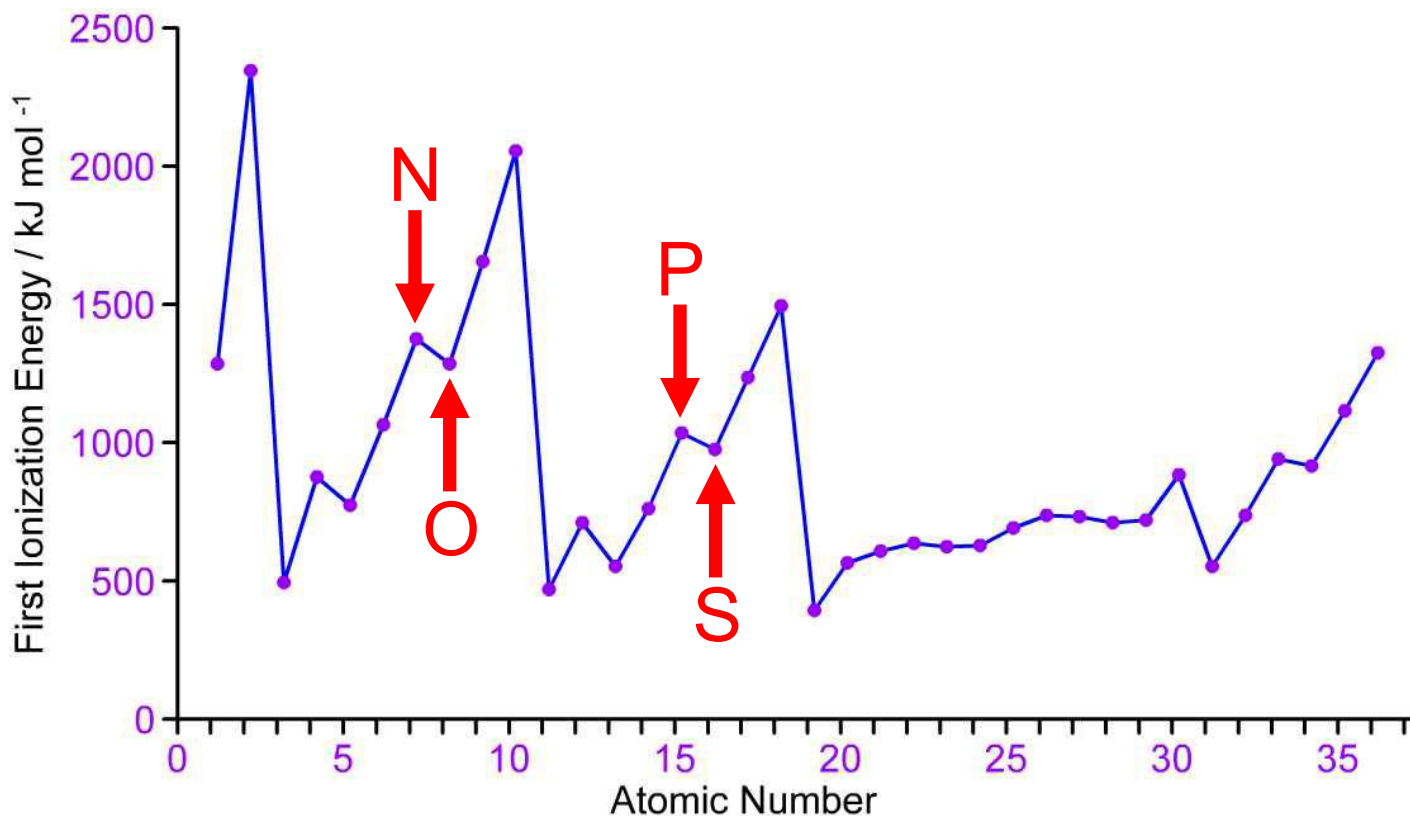
- First ionization energy *decreases* slightly between *Group 2 and Group 13* elements.
- Moving from Group 2 to Group 13, the additional electron enters a *p*-orbital of the same principle quantum shell.
- An electron in a *p*-orbital is *higher in energy* than an electron in the *s*-orbital of the 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.



Periodic Table of the Chemical Elements

Periodic Trends – First Ionization Energy

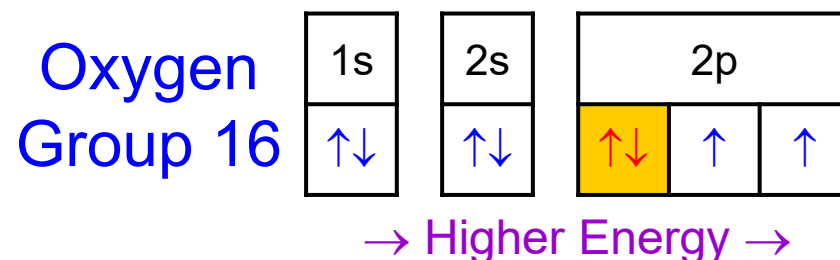
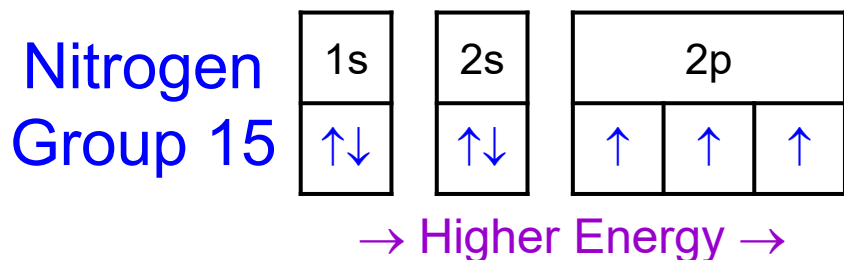
- First ionization energy *decreases* slightly between *Group 15* and *Group 16* elements.



Periodic Table of the Chemical Elements

Periodic Trends – First Ionization Energy

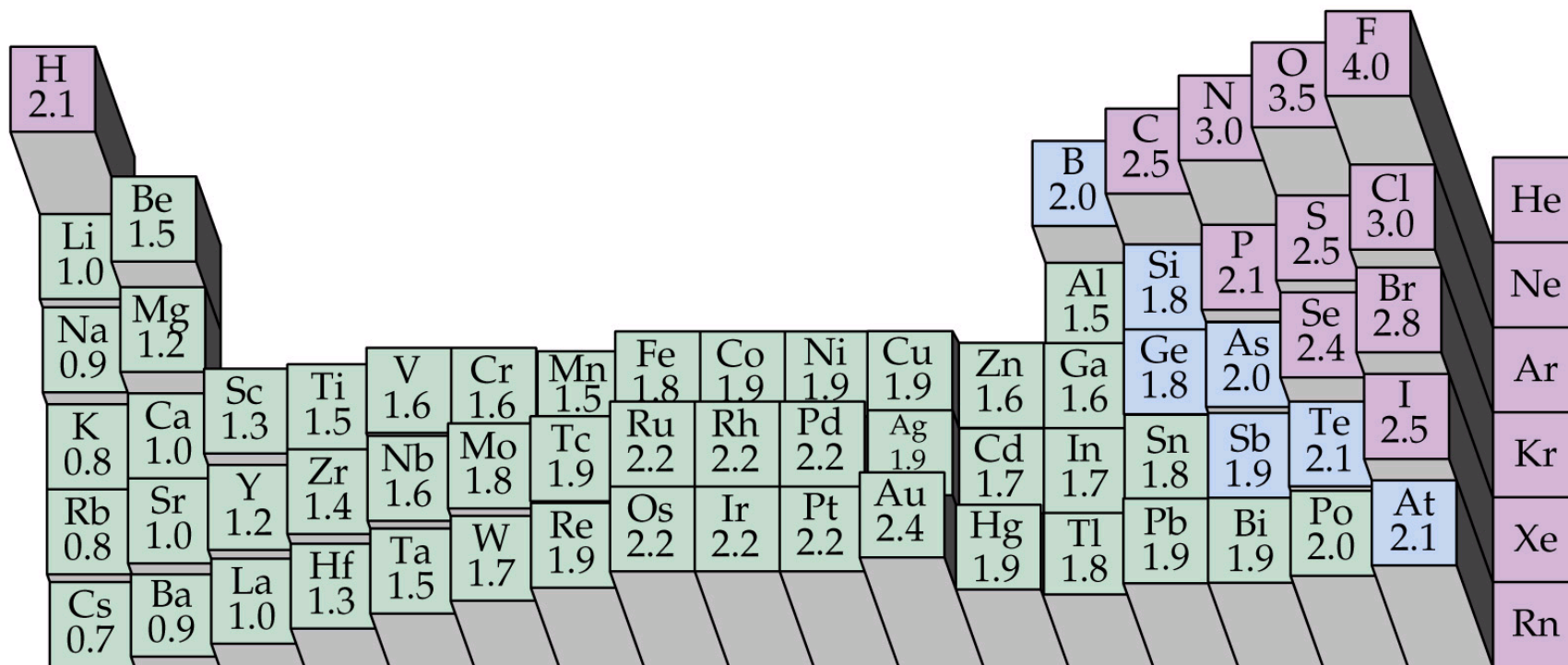
- First ionization energy *decreases* slightly between *Group 15* and *Group 16* elements.
- Moving from Group 15 to Group 16, the additional electron must spin pair with an existing electron in one of the atom's *p*-orbitals.
- An *electrostatic force of repulsion* between the two spin paired electrons 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.

Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity

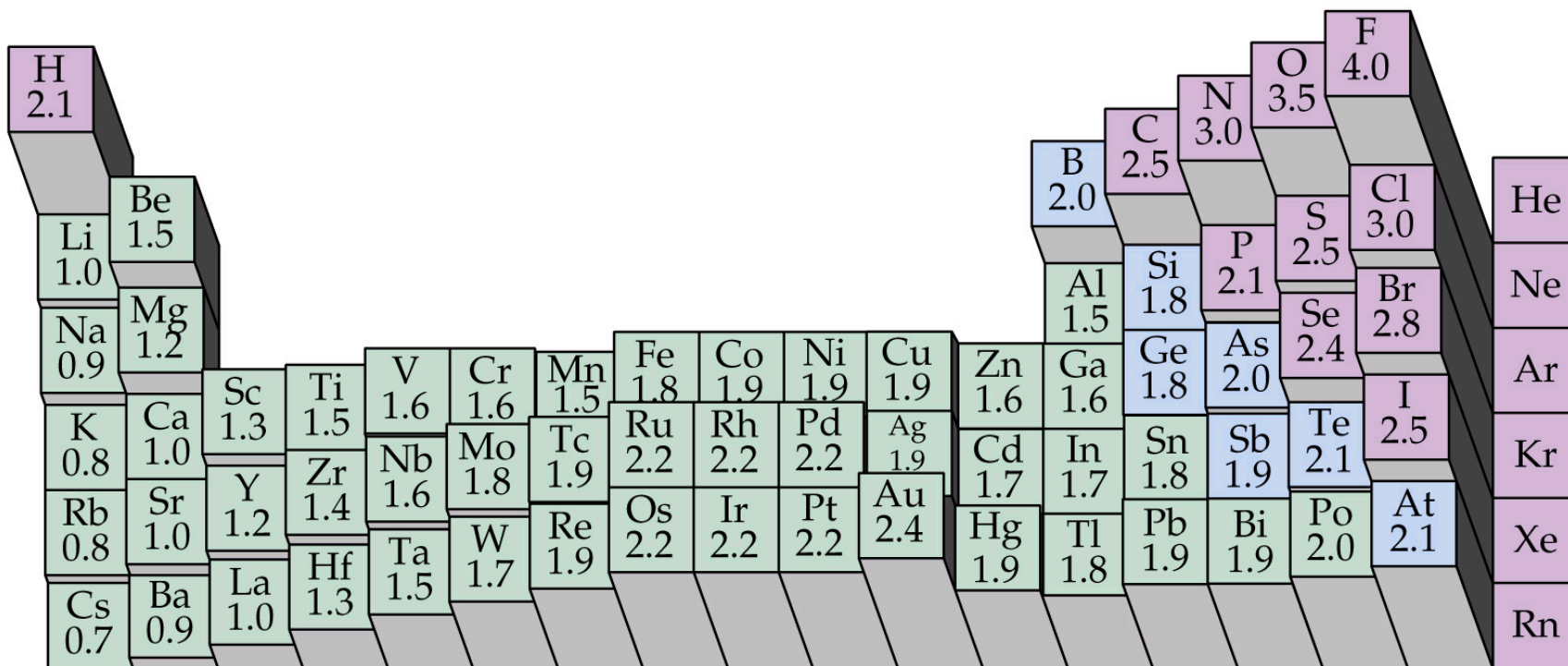
- Definition of *Electronegativity*
- Electronegativity is a measure of the relative tendency of an atom to attract a *shared pair* or *bonding pair of electrons*.
- Electronegativity values of the chemical elements are given on a scale of 0 to 4, with 4 being the most electronegative (Pauling scale).
- 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

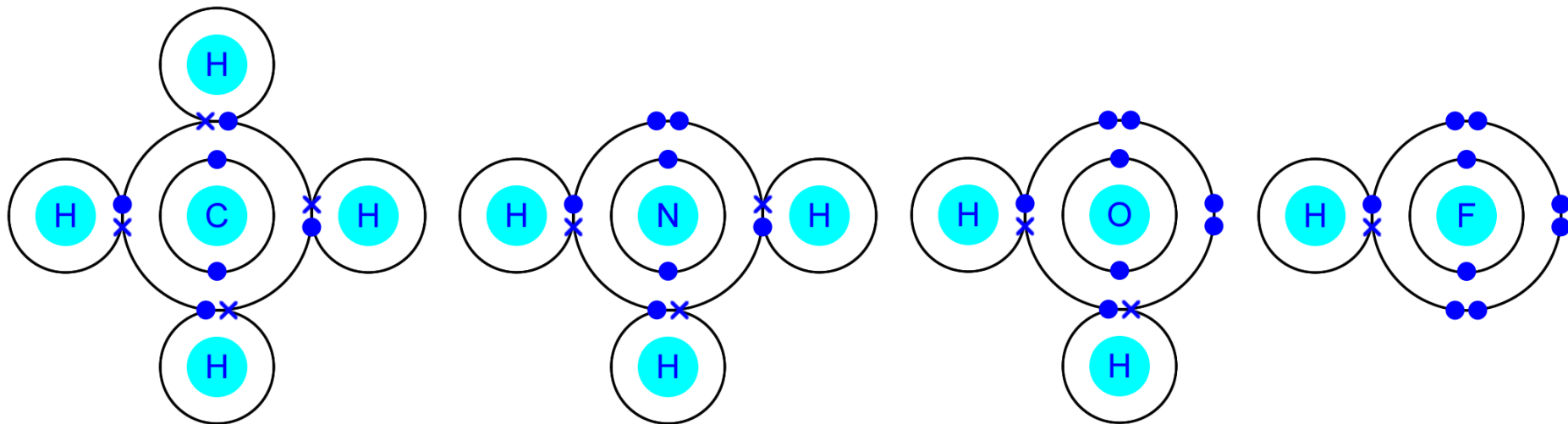
Periodic Trends – Electronegativity

- 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

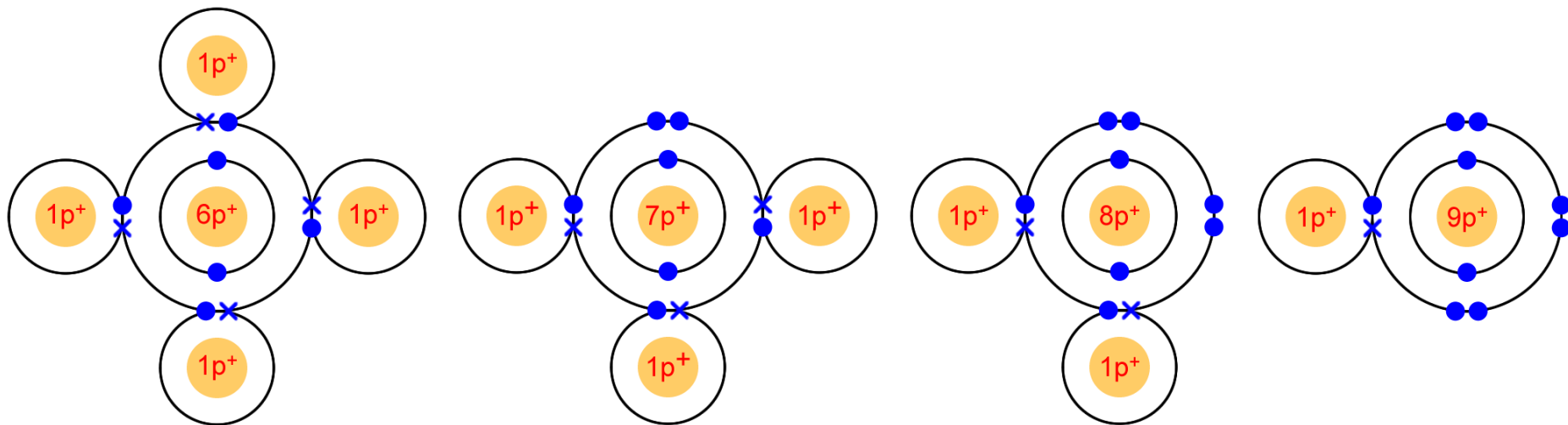


- The increasing effective nuclear charge will exert a *stronger electrostatic force of attraction* on a shared pair of electrons in the valence shell of the atom.
- As a consequence, electronegativity values *increase while moving across a Period* from the left-hand-side to the right-hand side.



Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity

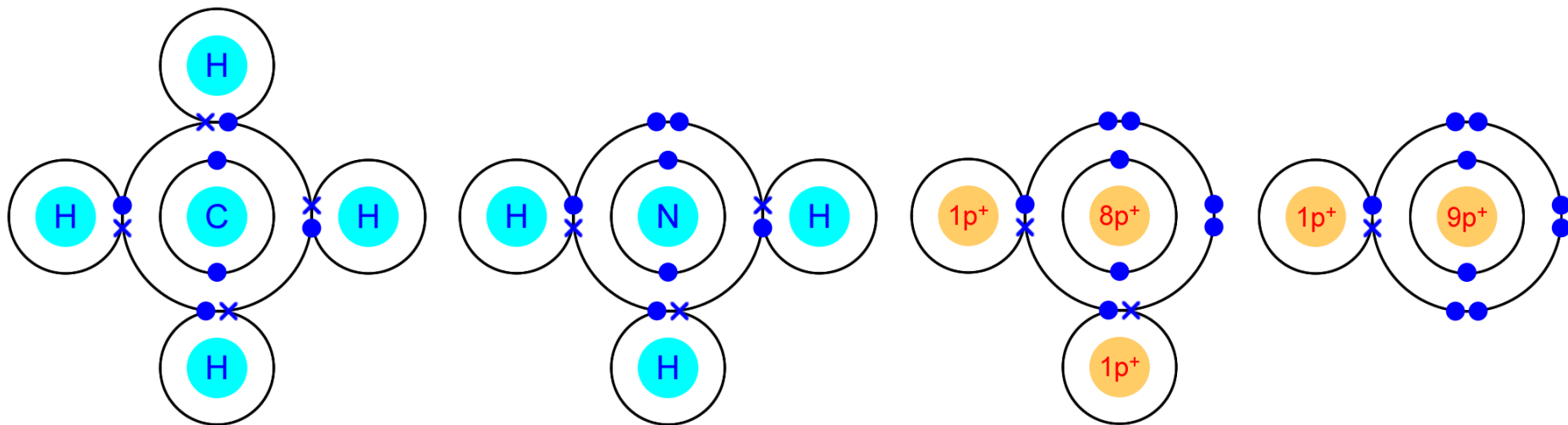


- The increasing effective nuclear charge will exert a *stronger electrostatic force of attraction* on a shared pair of electrons in the valence shell of the atom.
- As a consequence, electronegativity values *increase while moving across a Period* from the left-hand-side to the right-hand side.



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).

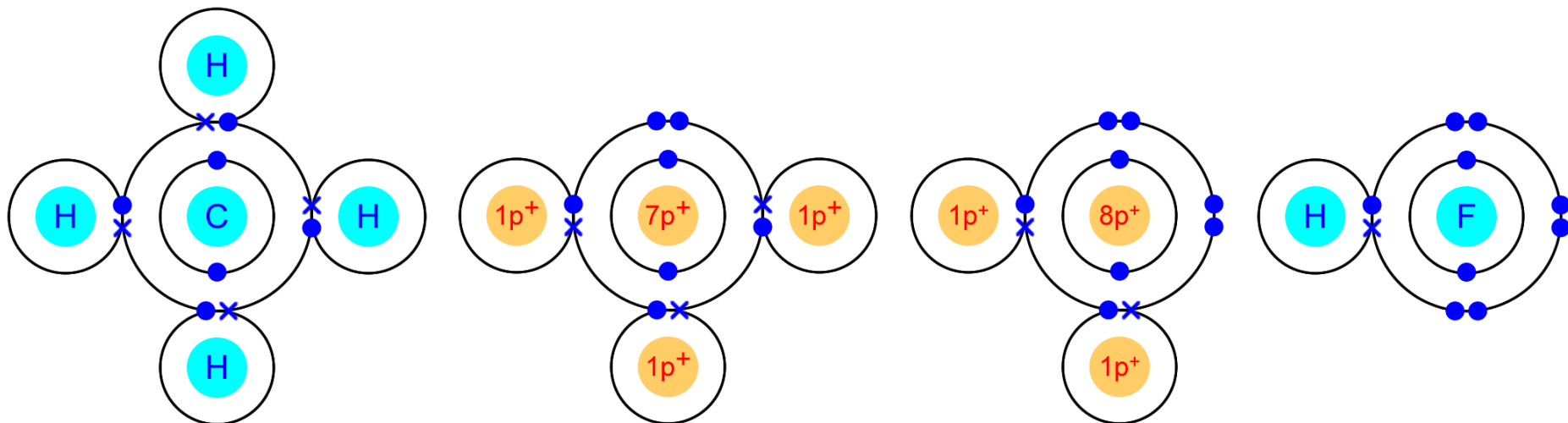
$$Z_{\text{eff}} (\text{F}) = 9 - 2 = 7$$

$$Z_{\text{eff}} (\text{O}) = 8 - 2 = 6$$



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).

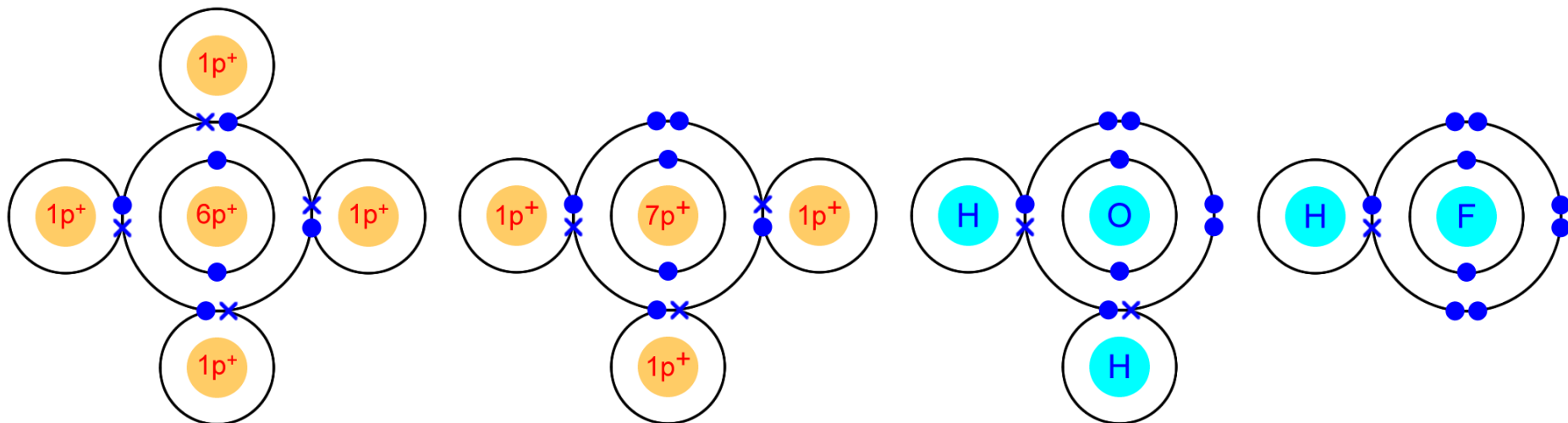
$$Z_{\text{eff}} (\text{O}) = 8 - 2 = 6$$

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



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.

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



Periodic Table of the Chemical Elements

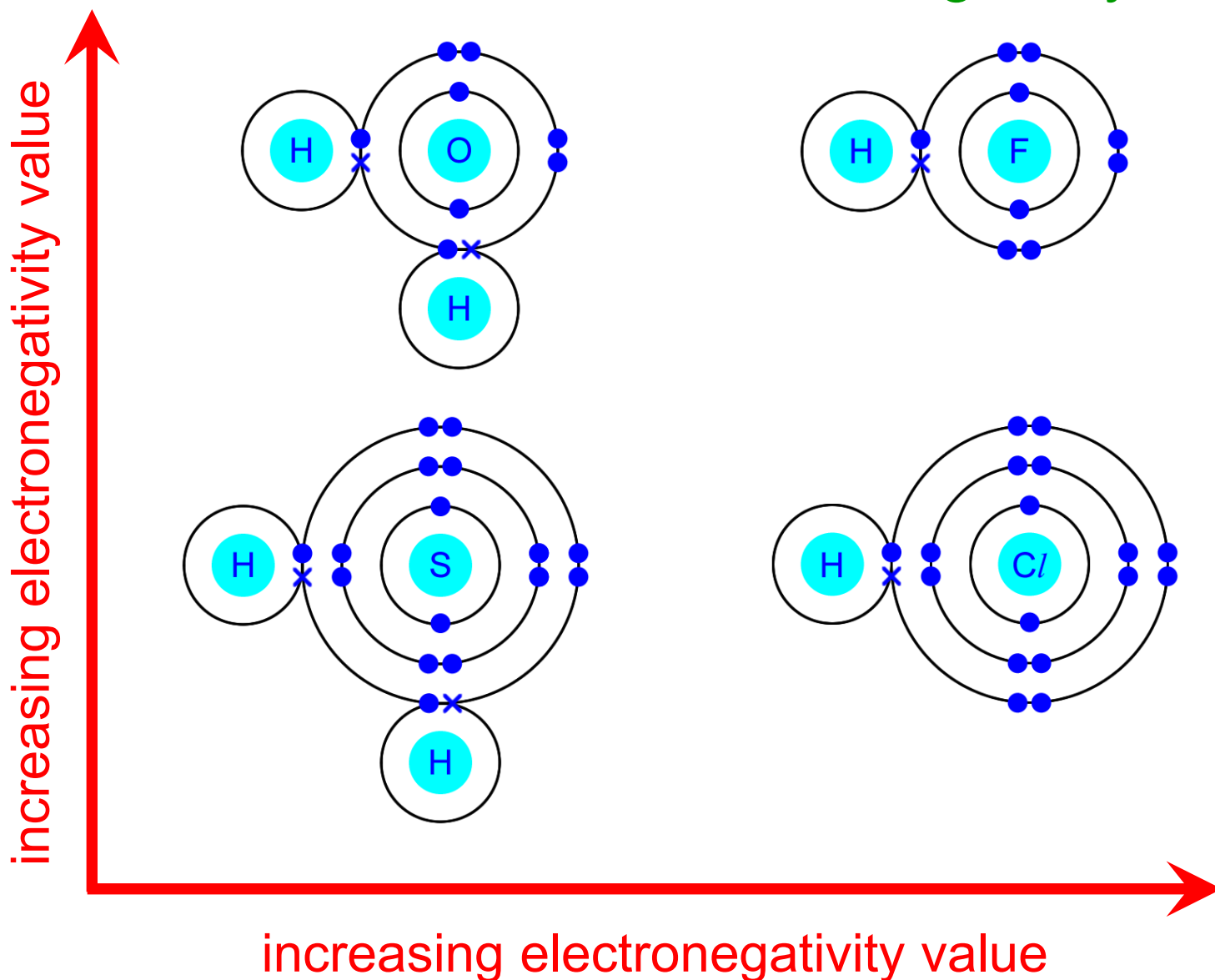
Periodic Trends – Electronegativity

- 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 down 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.



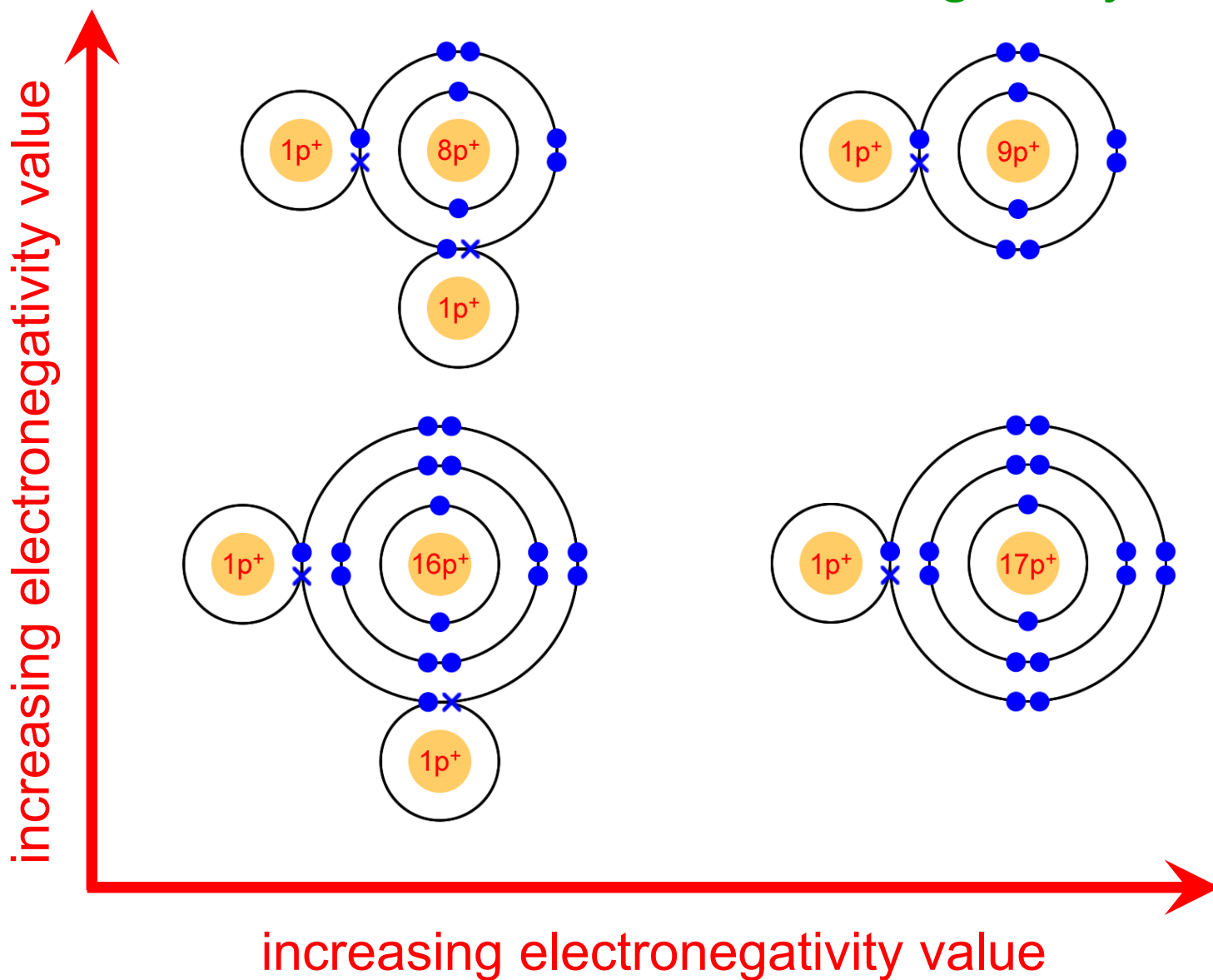
Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity



Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity



Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity

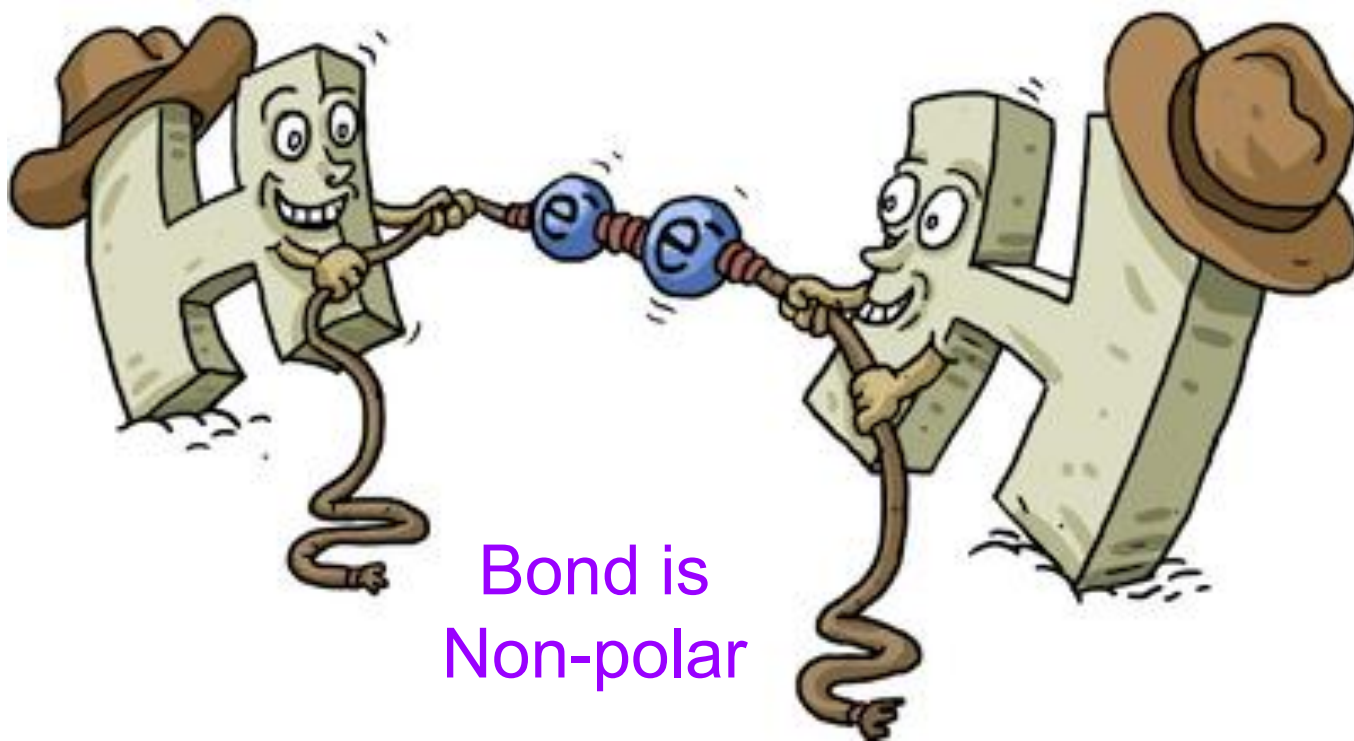
- When two atoms of different elements are held together by a covalent bond, if the difference in electronegativity values of the two elements is greater than ~ 0.5 , then the covalent bond will be *polar*.
 - The atom of the element with the *greater* electronegativity value, because it is pulling the negatively charged bonding pair of electrons *towards* it, will gain a *slight negative charge*, written as δ^- (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 δ^+ (delta positive).

Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity

Hydrogen = 2.1

Hydrogen = 2.1



Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity

Chlorine = 3.0

Hydrogen = 2.1

δ^-



δ^+

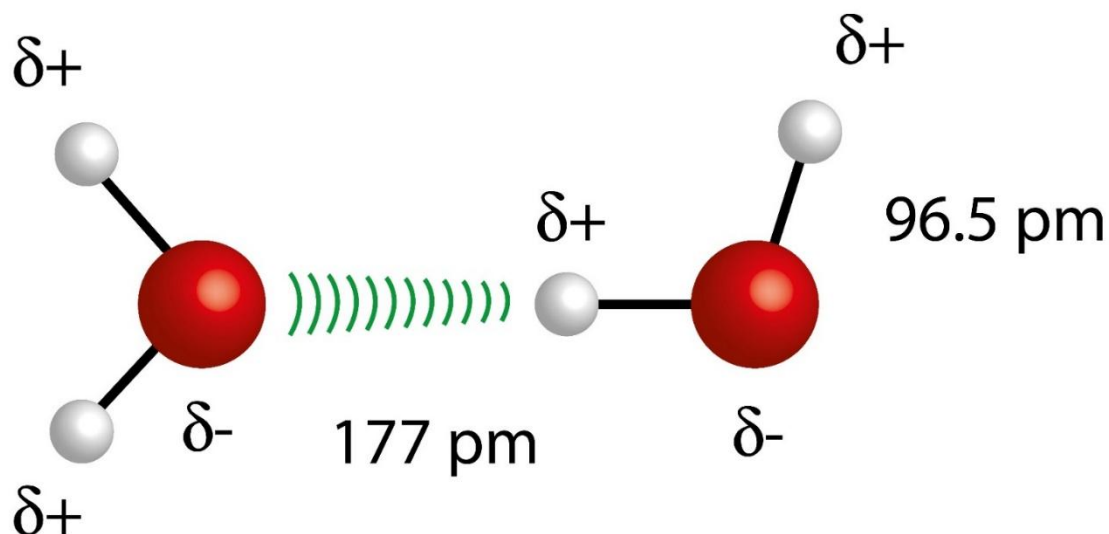
Bond is Polar



Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity

- Hydrogen Bonding Between Water Molecules



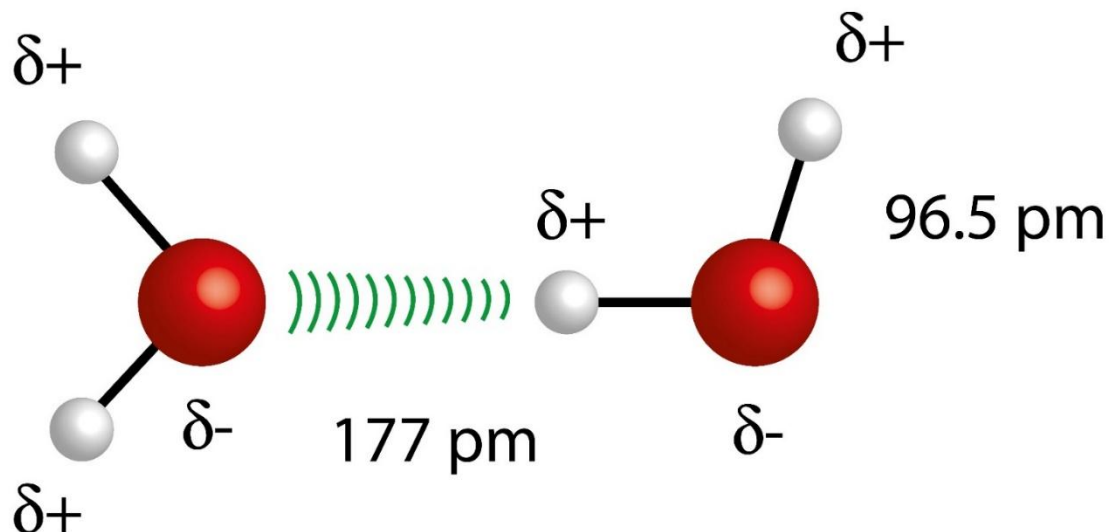
- The bond between oxygen (electronegativity value = 3.5) and hydrogen (electronegativity value = 2.1) in water is *polar*.



Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity

- Hydrogen Bonding Between Water Molecules



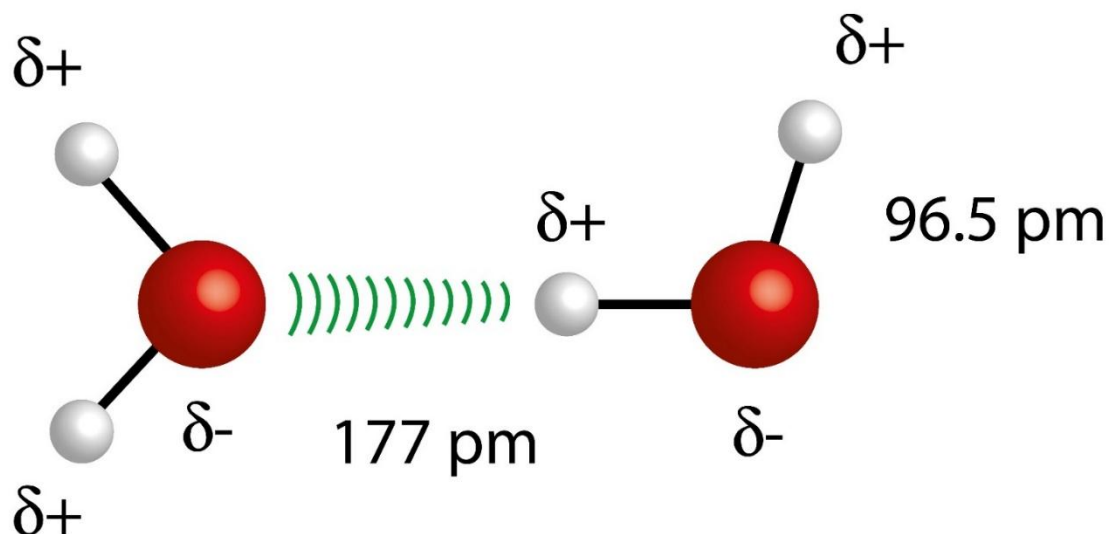
- The oxygen atom attracts the bonding pair of electrons towards itself, away from the hydrogen atom.



Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity

- Hydrogen Bonding Between Water Molecules



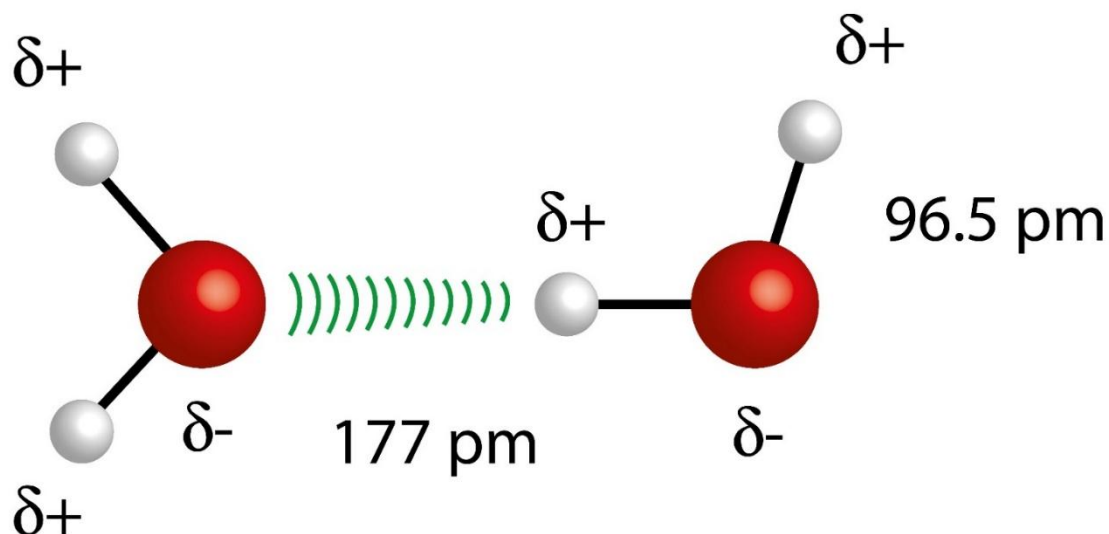
- The oxygen atom gains a slight negative charge written δ^- (delta negative) while the hydrogen atom gains a slight positive charge, written δ^+ (delta positive).



Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity

- Hydrogen Bonding Between Water Molecules

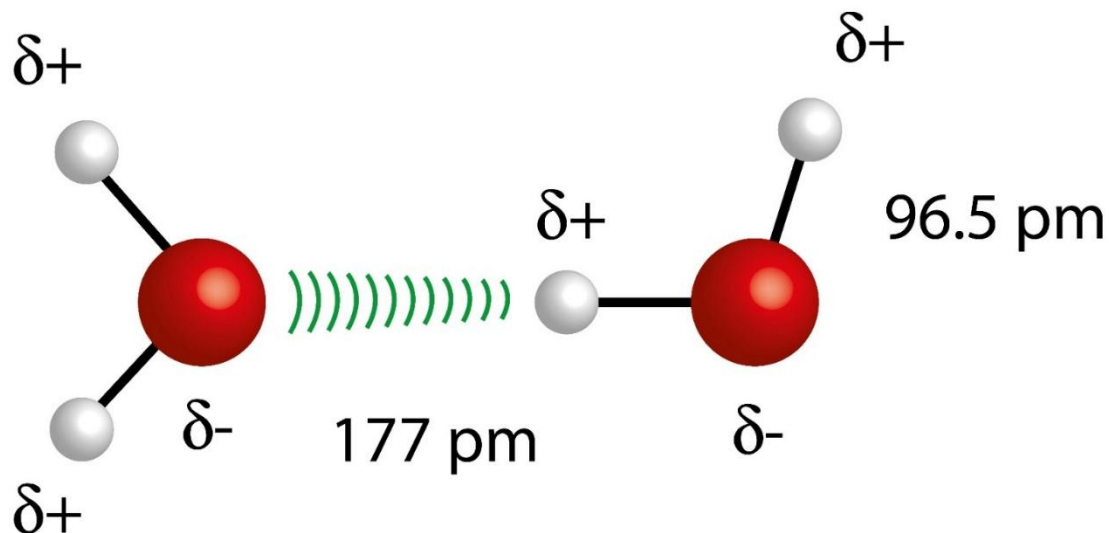


- A weak electrostatic force of attraction between the δ^+ hydrogen atom of one water molecule and a lone pair of electrons on the δ^- oxygen atom of another water molecule creates an intermolecular force of attraction between the two water molecules.

Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity

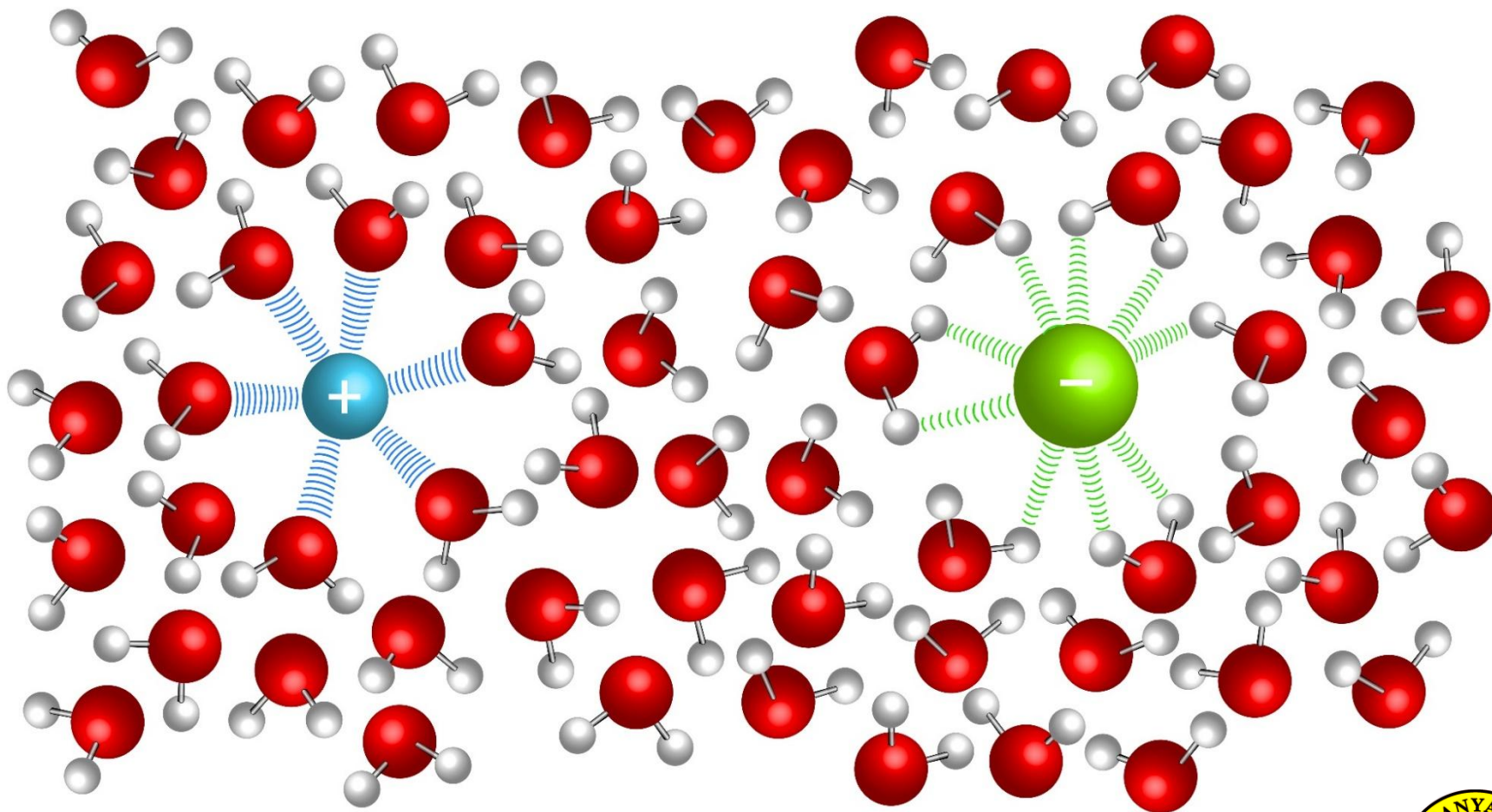
- Hydrogen Bonding Between Water Molecules



- This special intermolecular force of attraction is called a *hydrogen bond*. It is stronger than 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



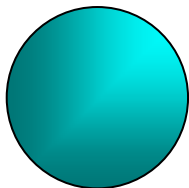
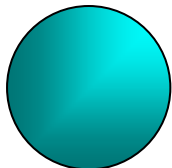
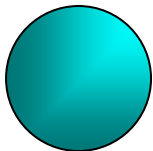
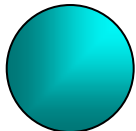
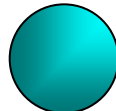


Periodic Table of the Chemical Elements

Periodic Trends – Electronegativity

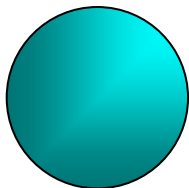
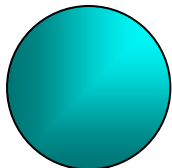
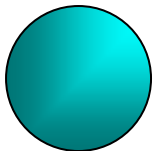
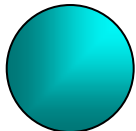
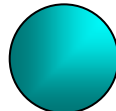


- Ionic compounds dissolve in polar solvents such as water.
- The $\delta+$ *hydrogen atoms* of the water molecules are attracted towards the *negative anions* in the ionic lattice.
- The $\delta-$ *oxygen atoms* of the water molecules are attracted towards the *positive cations* in the ionic lattice.



Periodic Table of the Chemical Elements

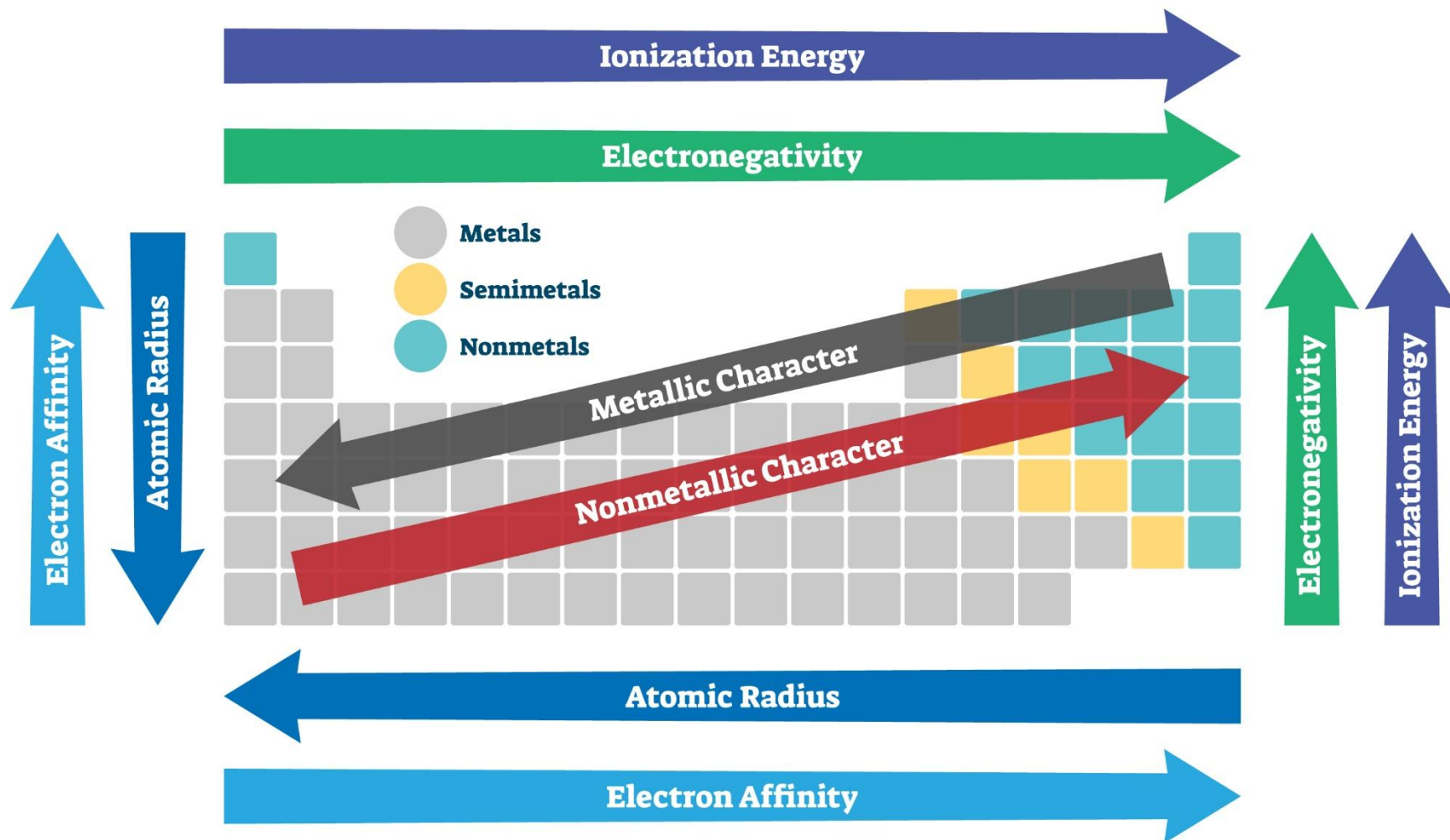
Elements of Third Period	Na Group 1	Mg Group 2	Al Group 13	Si Group 14	P Group 15	S Group 16	Cl Group 17
Atomic Number	11	12	13	14	15	16	17
Atomic Radius / nm	0.157 	0.136 	0.125 	0.117 	0.110 	0.104 	0.099 
Electronegativity Value	0.9	1.2	1.5	1.8	2.1	2.5	3.0
First Ionization Energy / kJ mol ⁻¹	494	736	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	<ul style="list-style-type: none"> • 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

PERIODIC TABLE TRENDS



Periodic Table of the Chemical Elements



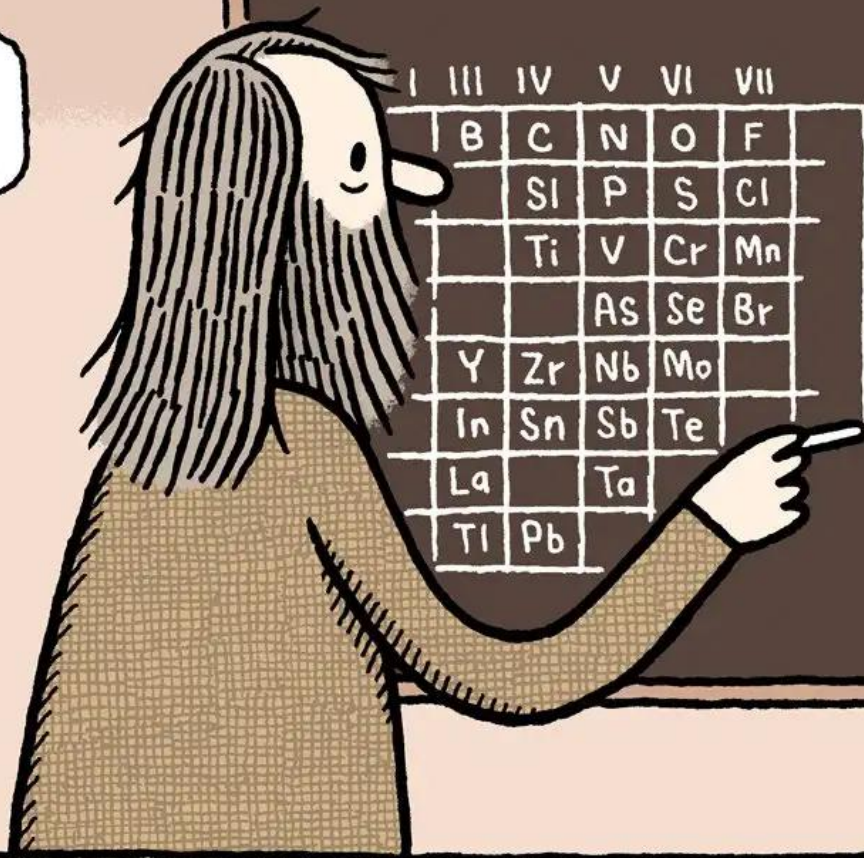
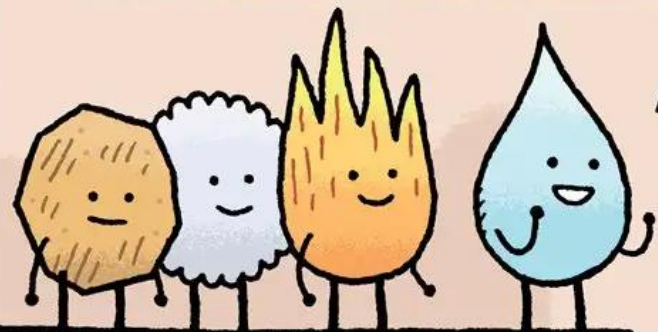
Presentation on
The Periodic Table of Chemical Elements
By Dr. Chris Slatter
christopher_john_slatter@nygh.edu.sg

Nanyang Girls' High School
2 Linden Drive
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>

LOOK! HE'S ADDING AN EIGHTH COLUMN. THAT MUST BE FOR US!



EARTH, AIR, FIRE AND WATER WAIT EXCITEDLY TO SEE HOW THEY'LL FIT INTO DMITRI MENDELEEV'S TABLE OF ELEMENTS.

TOM GAULD for NEW SCIENTIST