Lecture-3

Modern Periodic Table

Book Ref.

Introduction to Modern Inorganic Chemistry

By S. Z. Haider

IUPAC Periodic Table of the Elements

1												13	14	15	16	17	18
1 H hydrogen 1.008 [1.0078, 1.0082]	2		Key: atomic number Symbol name conventional atomic weight standard atomic weight														2 He helium 4.0026
3 Li lithium 6.94 [6.938, 6.997]	4 Be beryllium 9.0122											5 B boron 10.81 [10.805, 10.821]	6 C carbon 12.011 [12.009, 12.012]	7 N nitrogen 14.007 [14.006, 14.008]	8 O oxygen 15.999 [15.999, 16.000]	9 F fluorine 18.998	10 Ne neon 20.180
11 Na sodium 22.990	12 Mg magnesium 24.305 [24.304, 24.307]	3	4	5	6	7	8	9	10	11	12	13 Al aluminium 26.982	14 Si silicon 28.085 [28.084, 28.086]	15 P phosphorus 30.974	16 S sulfur 32.06 [32.059, 32.076]	17 Cl chlorine 35.45 [35.446, 35.457]	18 Ar argon 39.95 [39.792, 39.963]
19 K potassium 39.098	20 Ca calcium 40.078(4)	21 Sc scandium 44.956	22 Ti titanium 47.867	23 V vanadium 50.942	24 Cr chromium 51.996	25 Mn manganese 54.938	26 Fe iron 55.845(2)	27 Co cobalt 58.933	28 Ni nickel 58.693	29 Cu copper 63.546(3)	30 Zn zinc 65.38(2)	31 Ga gallium 69.723	32 Ge germanium 72.630(8)	33 As arsenic 74.922	34 Se selenium 78.971(8)	35 Br bromine 79.904 [79.901, 79.907]	36 Kr krypton 83.798(2)
37 Rb rubidium 85.468	38 Sr strontium 87.62	39 Y yttrium 88.906	40 Zr zirconium 91.224(2)	41 Nb niobium 92.906	42 Mo molybdenum 95.95	43 Tc technetium	44 Ru ruthenium 101.07(2)	45 Rh rhodium 102.91	46 Pd palladium 106.42	47 Ag silver 107.87	48 Cd cadmium 112.41	49 In indium 114.82	50 Sn tin 118.71	51 Sb antimony 121.76	52 Te tellurium 127.60(3)	53 I iodine 126.90	54 Xe xenon 131.29
55 Cs caesium 132.91	56 Ba barium 137.33	57-71 lanthanoids	72 Hf hafnium 178.49(2)	73 Ta tantalum 180.95	74 W tungsten 183.84	75 Re rhenium 186.21	76 Os osmium 190.23(3)	77 Ir iridium 192.22	78 Pt platinum 195.08	79 Au gold 196.97	80 Hg mercury 200.59	81 Tl thallium 204.38 [204.38, 204.39]	82 Pb lead 207.2	83 Bi bismuth 208.98	84 Po polonium	85 At astatine	86 Rn radon
87 Fr francium	88 Ra radium	89-103 actinoids	104 Rf rutherfordium	105 Db dubnium	106 Sg seaborgium	107 Bh bohrium	108 Hs hassium	109 Mt meitnerium	110 Ds darmstadtium	111 Rg roentgenium	112 Cn copernicium	113 Nh nihonium	114 Fl flerovium	115 Mc moscovium	116 Lv livermorium	117 Ts tennessine	118 Og oganesson

57 La lanthanum 138.91	58 Ce cerium 140.12	59 Pr praseodymium 140.91	60 Nd neodymium 144.24	61 Pm promethium	62 Sm samarium 150.36(2)	63 Eu europium 151.96	64 Gd gadolinium 157.25(3)	65 Tb terbium 158.93	66 Dy dysprosium 162.50	67 Ho holmium 164.93	68 Er erbium 167.26	69 Tm thulium 168.93	70 Yb ytterbium 173.05	71 Lu lutetium 174.97
89 Ac actinium	90 Th thorium 232.04	91 Pa protactinium 231.04	92 U uranium 238.03	93 Np neptunium	94 Pu plutonium	95 Am americium	96 Cm curium	97 Bk berkelium	98 Cf californium	99 Es einsteinium	100 Fm fermium	101 Md mendelevium	102 No nobelium	103 Lr lawrencium

INTERNATIONAL UNION OF PURE AND APPLIED CHEMISTRY

For notes and updates to this table, see www.iupac.org. This version is dated 1 December 2018.

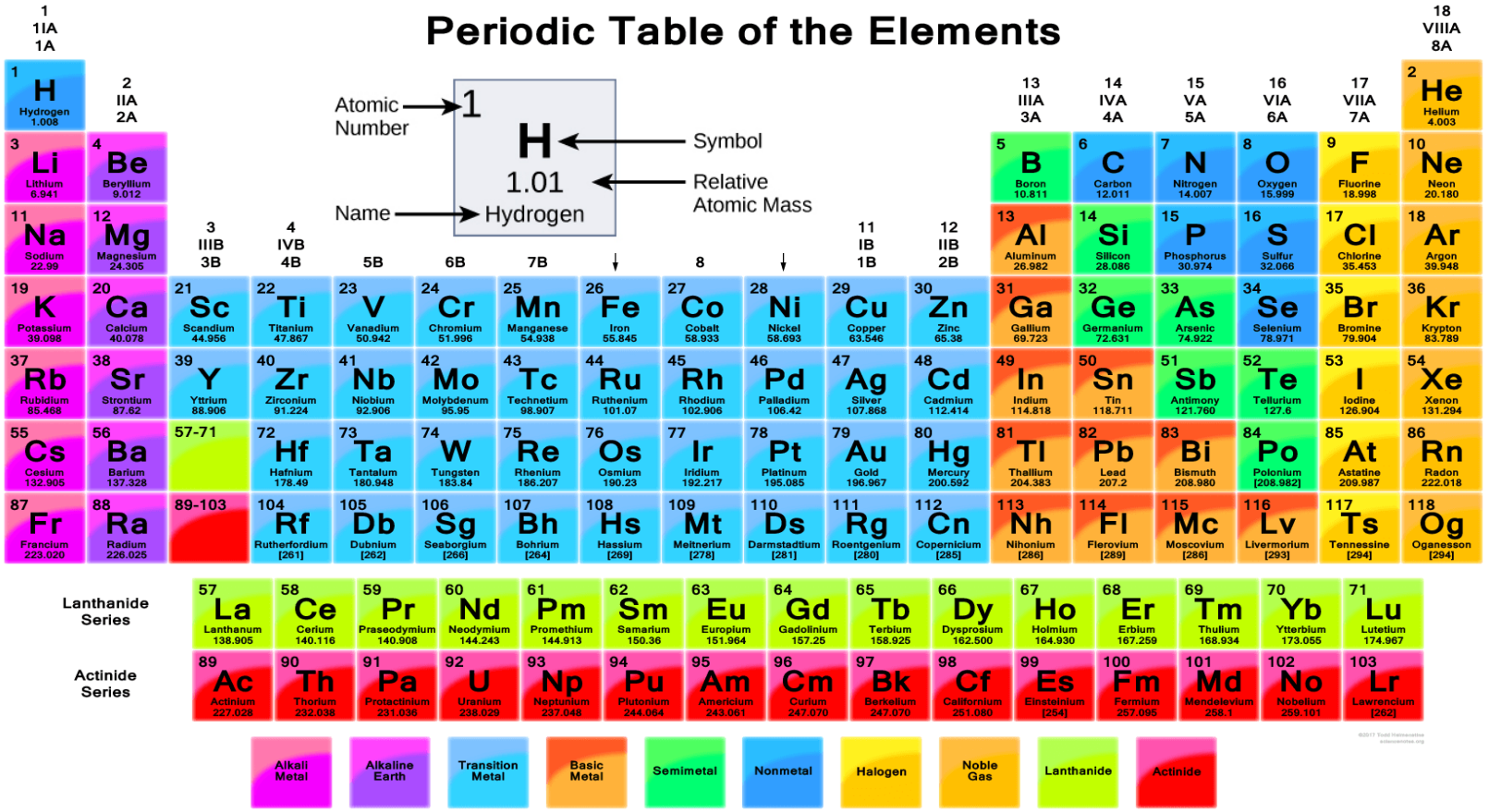
United Nations Educational, Scientific and Cultural Organization

2019 IYPT International Year of the Periodic Table of Chemical Elements

IUPAC

What is Periodic Table?

- A tabular arrangement of elements in rows and columns, highlighting the regular repetition of properties of the elements, is called a **periodic table.**


Periodic Table of the Elements
Atomic Number
Symbol
Relative Atomic Mass
Name
1
H
1.01
Hydrogen
Lanthanide Series
Actinide Series
Alkali Metal
Alkaline Earth
Transition Metal
Basic Metal
Semimetal
Nonmetal
Halogen
Noble Gas
Lanthanide
Actinide

Development of the Periodic Table

- In 1869 the Russian chemist Dmitri Mendeleev (1834–1907) and the German chemist J. Lothar Meyer (1830–1895), working independently, made similar discoveries.
- They found that when they arranged the elements in order of atomic mass, they could place them in horizontal rows, one row under the other, so that the elements in each vertical column have similar properties.
- Eventually, more accurate determinations of atomic masses revealed discrepancies in this ordering of the elements.

Development of the Periodic Table…

- When the elements in the periodic table are ordered by atomic number, such discrepancies vanish.
- In 1913, the British physicist Henry Moseley measured the wavelengths of certain X rays emitted by elements. His measurements showed that these wavelengths were related to the atomic numbers of the elements.
- In modern version of the periodic table, each entry lists the atomic number, atomic symbol, and atomic mass of an element.

Law of Periodicity

- Modern Statement of the Law of Periodicity (Moseley): 'The modern periodic law states that the properties of the elements repeat after certain regular intervals when these elements are arranged in order of their increasing atomic numbers'
- The **cause of periodicity** in properties is the repetition of similar outer electronic configuration after certain regular intervals. Since the nucleus is situated at the center of an atom and is shielded by electrons in the outermost level, therefore, the atomic mass has little effect on the chemical properties of the elements. Electrons are exposed to the environment. Hence, they can interact with other atoms. As a result, the physical and chemical properties of the elements depend upon their atomic numbers rather than the atomic masses.

Main Features of Modern Periodic Table

- Modern periodic table is based upon the electronic configuration of the elements. It consists of 18 vertical columns (Groups) and 7 horizontal rows (Periods).
- **Groups**: Elements that have similar chemical properties are grouped in columns called groups. All the members of a Group have the same valence configuration but different principal quantum numbers. These groups are numbered from 1 to 18.
- The groups are also divided into two sub- groups: A and B. These are IA(1), IIA(2), IIIB(3), IVB(4), VB(5), VIB(6), VIIB(7), VIIIB(8,9,10), IB(11), IIB(12), IIIA(13), IVA(14), VA(15), VIA(16), VIIA(17) and VIIIA (0,18).

Main Features…

- **Group 1** is called alkali metals. They are highly reactive and have a +1 charge. **Group 2** is called alkaline earth metals. They have +2 charge. **Transition metals** are in the middle, they have groups from 3 to 12. The **inner transition** metals are at the bottom- as lanthanides and actinides. **Group 17** is called halogens. They are also highly reactive and have a -1 charge. **Group 18** or zero is called the Noble Gases/ Inert Gases.
- Hydrogen occupies a unique position at the top of the periodic table. It does not fit naturally into any Group. It has a single positive charge, like the alkali metals, but at room temperature, it is a gas that doesn't act like a metal.

v·t·e	Groups in the periodic table																	[hide]
IUPAC group	1	2	3[a]	[a]	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Mendeleev (I–VIII)	I	II	III		IV	V	VI	VII	VIII			I	II	III	IV	V	VI	VII	[b]
CAS (US, A-B-A)	IA	IIA	IIIB		IVB	VB	VIB	VIIB	VIIIB			IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
old IUPAC (Europe, A-B)	IA	IIA	IIIA		IVA	VA	VIA	VIIA	VIII			IB	IIB	IIIB	IVB	VB	VIB	VIIB	0
Trivial name	Alkali metals	Alkaline earth metals[r]										Coinage metals	Volatile metals	Icosagens	Crystallogens	Pnictogens[r]	Chalcogens[r]	Halogens[r]	Noble gases[r]
Name by element[r]	Lithium group	Beryllium group	Scandium group		Titanium group	Vanadium group	Chromium group	Manganese group	Iron group	Cobalt group	Nickel group	Copper group	Zinc group	Boron group	Carbon group	Nitrogen group	Oxygen group	Fluorine group	Helium *or* Neon group
Period 1	H[h]																		He
Period 2	Li	Be												B	C	N	O	F	Ne
Period 3	Na	Mg												Al	Si	P	S	Cl	Ar
Period 4	K	Ca	Sc		Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Period 5	Rb	Sr	Y		Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Period 6	Cs	Ba	La	Ce–Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Period 7	Fr	Ra	Ac	Th–Lr	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og

[a] Group 3 has scandium (Sc) and yttrium (Y). For the rest of the group, sources differ as either being (1) lutetium (Lu) and lawrencium (Lr), *or* (2) lanthanum (La) and actinium (Ac), *or* (3) the whole set of 15+15 lanthanides and actinides. IUPAC has initiated a project to standardize the definition as either (1) **Sc, Y, Lu and Lr**, or (2) **Sc, Y, La and Ac**.[20]

[b] Group 18, the noble gases, were not discovered at the time of Mendeleev's original table. Later (1902), Mendeleev accepted the evidence for their existence, and they could be placed in a new "group 0", consistently and without breaking the periodic table principle.

[r] Group name as recommended by IUPAC.

[h] Hydrogen (H), while placed in group 1, is not considered to be part of the alkali metals.

Main Features…

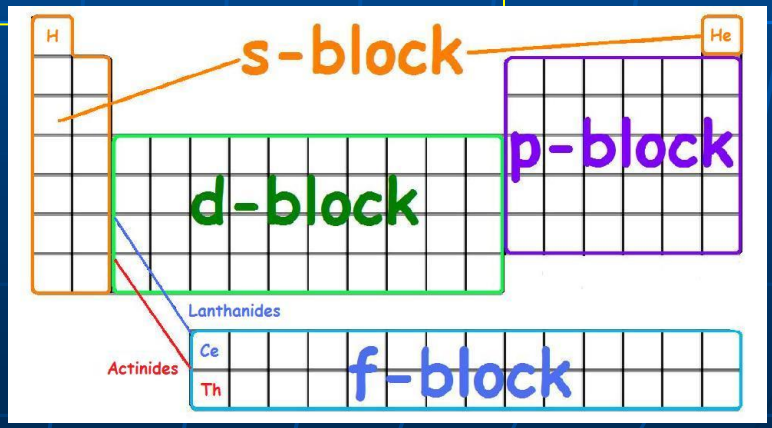
- The elements in group VIIIB consist of three groups (8, 9 & 10) of elements at the middle of the periodic table. They contain triads, which are metals with very similar properties, usually found together.
- **Periods**: The period number of an element signifies the highest unexcited energy level for an electron in that element. The period number equals the principal quantum number of the valence shell.
- The first period consists of only two elements – Hydrogen and Helium. The 2^{nd} and 3^{rd} period consists of 8 elements each.

Main Features…

- On the other hand, the 4^{th} and 5^{th} consists of 18 elements each while the 6^{th} and 7^{th} period consists of 32 elements each.
- A separate panel at the bottom consists of 15 elements of the 6^{th} period called the **lanthanides** and 15 elements of the 7^{th} period called the **actinides**.
- Elements 113, 115, 117 and 118, the most recent discoveries, were officially confirmed by the International Union of Pure and Applied Chemistry (IUPAC) in 2016. Their proposed names, nihonium (Nh), moscovium (Mc), tennessine (Ts) and oganesson (Og) respectively.
- **Lanthanoids (La-Lu)** and **actinoids (Ac-Lr)** are collective names also recommended by IUPAC**.**

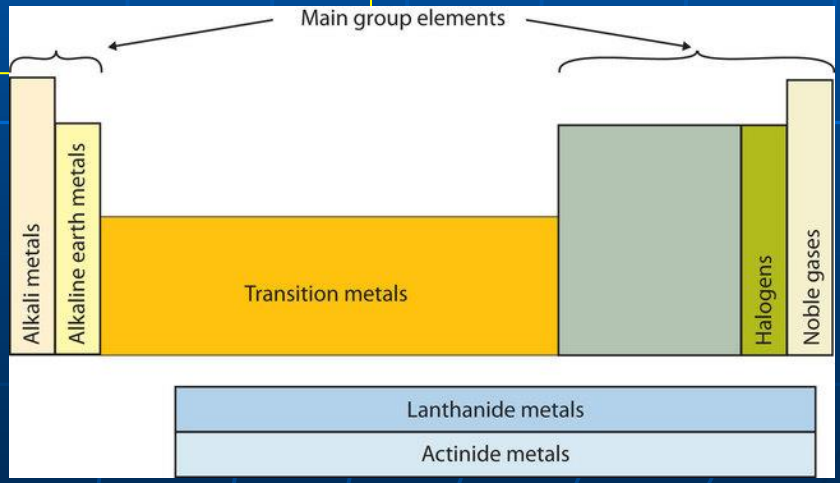
Classification of the **elements** into **BLOCKS**

- The **s-block** elements have valence configuration s^1 or s^2.
- The **p-block** elements have valence configuration s^2p^1 to s^2p^6.
- The **d-block** elements have valence configurations in which d-subshells are being filled.
- The **f-block** elements have valence configurations in which f-subshells are being filled.



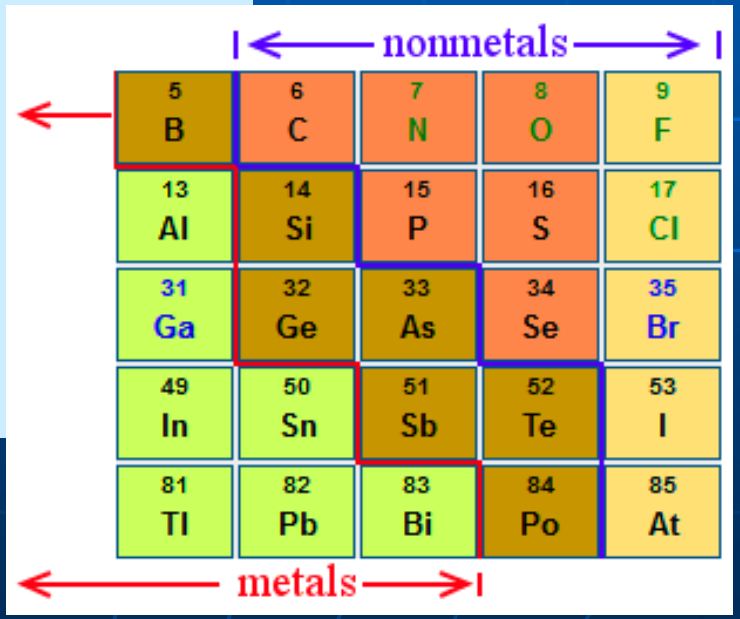
Classification of elements depending on electronic configuration:

- The **Inert Gases** (elements of '0' group)
- The **Representative Elements** ('s' and 'p' block elements)
- The **Transition Elements** ('d' block elements)
- The **Inner Transition Elements** ('f' block elements)



Classification of elements into metals, nonmetals & metalloids

- Elements are classified according to their properties into three major categories :
- (1) ***metals***,
- *(2)* ***nonmetals***, and
- *(3)* ***metalloids***.



What are the Metals?

- Most elements are metals.
- they are divided into groups:
- *(1) alkali metals*,
- *(2) alkaline earth metals*, and
- *(3) transition metals*.
- The transition metals can be divided into smaller groups, such as the *lanthanides* and *actinides*.

Properties of Metals

- Metals share some common properties:
- They are lustrous (shiny),
- malleable (can be hammered into sheets) and
- ductile (can be drawn into wire), and
- are good conductors of heat and electricity.
- Except for mercury, the metallic elements are solids at room temperature (about 20^0C).
- These properties result from the ability to easily move the electrons in the outer shells of metal atoms.

Alkali Metals

- Group 1 is called alkali metals. They are highly reactive and have a +1 charge. They are lithium (Li), sodium (Na), potassium (K), rubidium (Rb), cesium (Cs) and francium (Fr).
- Alkali metals are common in nature and daily life. Sodium chloride is table salt; lithium compounds are used in greases, in batteries, and as drugs to treat patients who exhibit manic-depressive or bipolar behavior. Lithium, rubidium, and cesium are relatively rare in nature, and francium is so unstable and highly radioactive that it exists in only trace amounts, sodium and potassium are the seventh and eighth most abundant elements in Earth's crust, respectively.

Alkaline Earth Metals

- Group 2 is called alkaline earth metals. They have +2 charge. Their atoms are smaller than those of the alkali metals. They are beryllium (Be), magnesium (Mg), calcium (Ca), strontium (Sr), barium (Ba) and radium (Ra).
- Beryllium, strontium, and barium are rare, and radium is unstable and highly radioactive. In contrast, calcium and magnesium are the fifth and sixth most abundant elements on Earth, respectively; they are found in huge deposits of limestone and other minerals.

Transition Metals

- The transition elements are located in Groups 3 to 12.
- Iron and gold are examples of transition metals.
- These elements are very hard, with high melting points and boiling points.
- The transition metals are good electrical conductors and are very malleable.
- They show positive oxidation states of +2 and +3 generally and contain two incomplete energy levels (‘s’ & ‘d’ orbitals).

Transition Metals…

- They are effective catalytic agents and generally form coloured and complex compounds.
- The transition metals include most of the elements, so they can be categorized into smaller groups.
- The lanthanides (rare earths) and actinides (trans-uranium) are classes of transition elements.
- Another way to group transition metals is into **triads**, *which are metals with very similar properties, usually found together*.

Metal Triads

- These are transition metals with very similar properties, usually found together.
- The iron triad consists of iron, cobalt, and nickel.
- Just under iron, cobalt, and nickel is the palladium triad of ruthenium, rhodium, and palladium,
- while under them is the platinum triad of osmium, iridium, and platinum.

Lanthanides

- The lanthanides are silvery metals that tarnish easily.
- They are relatively soft metals, with high melting and boiling points.
- The lanthanides react to form many different compounds.
- These elements are used in lamps, magnets, lasers, and to improve the properties of other metals.

Actinides

- The actinides are in the row below the lanthanides.
- Their atomic numbers follow actinium.
- All of the actinides are radioactive, with positively charged ions.
- They are reactive metals that form compounds with most nonmetals.
- The actinides are used in medicines and nuclear devices.

Lanthanides & Actinides

- These elements have three incomplete outer levels (‘s’, ‘d’ & ‘f’ orbitals) and their properties are similar to as in the case of transition elements.

Nonmetals

- A **nonmetal** is an element that does not exhibit the characteristics of a metal.
- Most of the nonmetals are gases (for example, chlorine and oxygen) or solids (for example, phosphorus and sulfur).
- The solid nonmetals are usually hard, lack metallic luster, brittle substances.
- Bromine is the only liquid nonmetal.
- The halogens and the noble gases are two groups of nonmetals.

Metalloids or Semimetals

- M**etalloids,** or **semimetals** (B, Si, Ge, As, Sb, Te, Bi, Po), are elements having both metallic and nonmetallic properties.
- These elements, such as silicon (Si) and germanium (Ge), are usually good semiconductors—elements that, when pure, are poor conductors of electricity at room temperature but become moderately good conductors at higher temperatures.

Elements recognized as metalloids

Periods → / Groups ↓	13	14	15	16	17
2	B Boron	C Carbon	N Nitrogen	O Oxygen	F Fluorine
3	Al Aluminium	Si Silicon	P Phosphorus	S Sulfur	Cl Chlorine
4	Ga Gallium	Ge Germanium	As Arsenic	Se Selenium	Br Bromine
5	In Indium	Sn Tin	Sb Antimony	Te Tellurium	I Iodine
6	Tl Thallium	Pb Lead	Bi Bismuth	Po Polonium	At Astatine

Commonly recognized (93%): B, Si, Ge, As, Sb, Te

Irregularly recognized (44%): Po, At

Less commonly recognized (24%): Se

Rarely recognized (9%): C, Al

Arbitrary metal-nonmetal dividing line: between Be and B, Al and Si, Ge and As, Sb and Te, Po and At

Halogens

- Halogens are in Group 17, form ions with a -1 charge. These are highly reactive. They are fluorine (F), chlorine (Cl), bromine (Br), iodine (I) and astatine (At).
- All the halogens react readily with metals to form salts, such as sodium chloride and calcium chloride (used in some areas as road salt).
- Compounds containing fluoride ions are added to toothpaste and the water supply to prevent dental cavities. Fluorine is also found in Teflon coatings on kitchen utensils.

Halogens…

- Chlorofluorocarbon (CFC) propellants and refrigerants are believed to lead to the depletion of Earth's ozone layer and contain both fluorine and chlorine.
- Bromine and iodine are less abundant than chlorine, and astatine is so radioactive that it exists in only negligible amounts in nature. These elements are also found in bleaches and disinfectants.

Noble Gases

- The noble gases are helium (He), neon (Ne), argon (Ar), krypton (Kr), xenon (Xe) and radon (Rn).
- Because the noble gases are composed of only single atoms, they are called monatomic.
- At room temperature and pressure, they are unreactive gases. Because of their lack of reactivity, for many years they were called inert gases or rare gases.
- However, the first chemical compounds containing the noble gases were prepared in 1962.

Noble Gases…

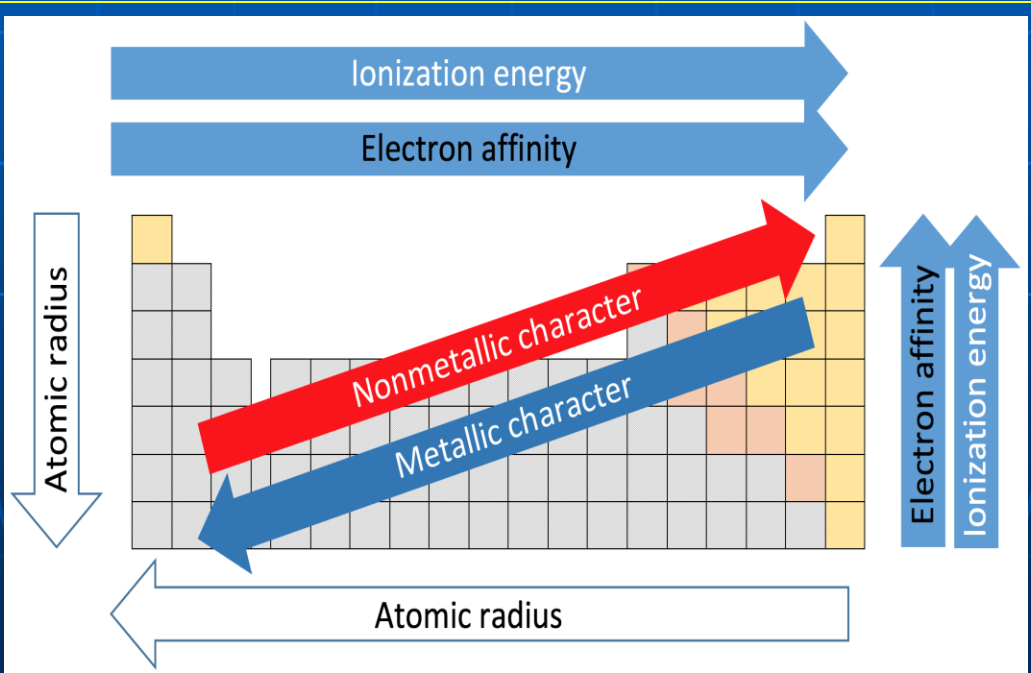
- Although the noble gases are relatively minor constituents of the atmosphere, natural gas contains substantial amounts of helium.
- Because of its low reactivity, argon is often used as an unreactive (inert) atmosphere for welding and in light bulbs. The red light emitted by neon in a gas discharge tube is used in neon lights.
- The noble gases are not reactive.
- Inactivity of the noble gases is due to- (a) complete pairing of all electrons present, (b) absence of any molecular orbital, (c) stable energy state, (d) very high ionization potential and (e) negligible electron affinities.

Periodic trends

- The periodic table helps predict some properties of the elements compared to each other. For example-
- Atom size decreases as you move from left to right across the table and increases as you move down a column.
- Energy required to remove an electron from an atom increases as you move from left to right and decreases as you move down a column.
- The ability to form a chemical bond increases as you move from left to right and decreases as you move down a column.

Periodic trends…

- In general, electron affinity value decreases with the increasing atomic radius because the electrostatic force of attraction decreases between the electron being added and the atomic nucleus. This is due to an increase in the distance between them.



Some Definitions

- The **electronegativity** is a measure of the tendency of an atom to attract a bonding pair of electrons towards itself.
- The **electron affinity** of an atom or molecule is defined as the amount of energy released or spent when an electron is added to a neutral atom or molecule in the gaseous state to form a negative ion ($X + e^- \rightarrow X^-$).
- The **ionization energy** is the energy required to remove an electron from a gaseous atom or ion ($X + \text{energy} \rightarrow X^- + e^-$).

Usefulness & Limitations of the periodic table

Usefulness are- (1) Classification of the elements, (2) Prediction of undiscovered elements, (3) Correction of atomic weight, (4) Periodic table in industrial research etc.,

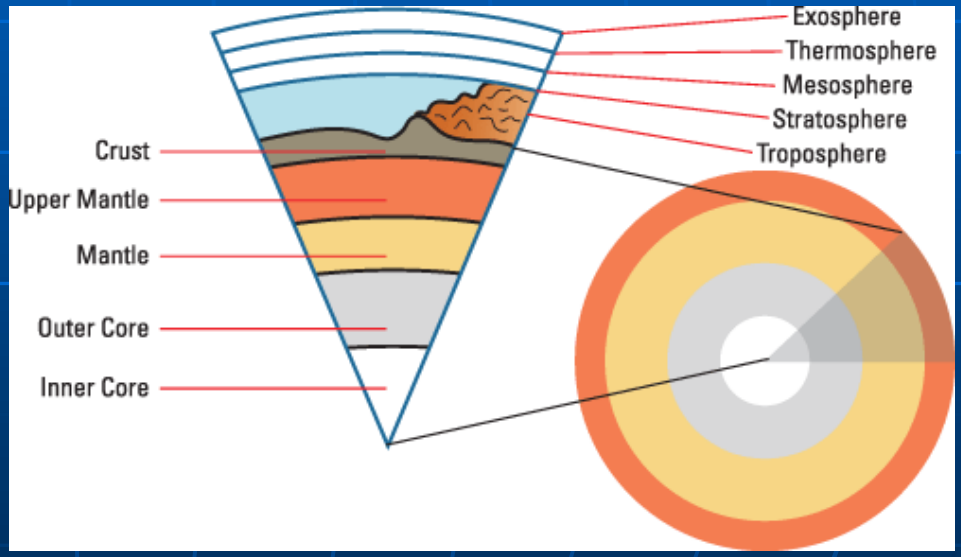
Limitations are- (1) Position of hydrogen, (2) The position of Lanthanides and Actinides, (3) Properties which are not periodic functions, (4) Diagonal relationship etc.

Naturally Occurring and Synthetic Elements

- Of the 118 known elements, 94 are found in appreciable quantities in nature. Between hydrogen (H, 1) and uranium (U, 92), only technetium (Tc, 43) and promethium (Pm, 61) are prepared artificially.
- All trans-uranium elements, those following uranium in the periodic table are synthetic.
- Elements are produced artificially in a variety of nuclear transmutation reactions by neutrons or charged particles, including heavy ions.

Distribution of elements on Earth and in Living Systems

- Earth's interior can be divided into- crust, mantle and core.
- Earth's crust extends from the surface to a depth of about 40 km.
- Scientists have been able only to study the crust.



Elements in Human Body

- The essential trace elements in the human body which make up about 0.1 % of body mass are iron (Fe), copper (Cu), zinc (Zn), iodine (I), and cobalt (Co).
- These elements are necessary for biological functions such as growth, transport of oxygen for metabolism, and defense against disease.
- Too much or too little of these elements in our body over an extended period of time can lead to serious illness, retardation, or even death.

Elements on Earth

- The majority of elements are naturally occuring.
- Of the 94 elements that are found in nature, 12 make up 99.7% of Earth's crust by mass.
- They are (in decreasing order of natural abundance) oxygen (O), silicon (Si), aluminum (Al), iron (Fe), calcium (Ca). magnesium (Mg), sodium (Na), potassium (K), titanium (Ti), hydrogen (H), phosphorus (P), and manganese (Mn).
- Core consisting mostly of iron at the centre of Earth. Surrounding the core is a layer called mantle, which consists of hot fluid containing iron, carbon, silicon, and sulfur.

Possible Questions

1. Describe the modern periodic table by highlighting the main features or write down the main features of modern periodic table

2. Write short notes on

a) Transition metals b) Halogens c) Noble gas

3. Classify metals and describe one of them with properties, uses and examples.

4. What are non-metals? Discuss one type of non metals with their properties and uses.

5. Sate the law of periodicity? Classify the elements depending on their electronic structure

6. Discuss halogens and noble gases with examples and uses.

7. What is periodic table? Explain the periodic trend of atomic radius with reason.

Abundance of Elements

Natural Abundance of the Elements	
Element	**Percent by Mass** (g/100g of sample)
Oxygen	45.5
Silicon	27.2
Aluminum	8.3
Iron	6.2
Calcium	4.7
Magnesium	2.8
All others	5.3

Abundance of the Elements in the Human Body	
Element	**Percent by Mass** (g/100g of sample)
Oxygen	65
Carbon	18
Hydrogen	10
Nitrogen	3
Calcium	1.6
Phosphorus	1.2
All others	1.2

Next Class
Quiz-3 &
Organic Chemistry
& Chemical
Reactions

Thank you