INORGANIC CHEMISTRY

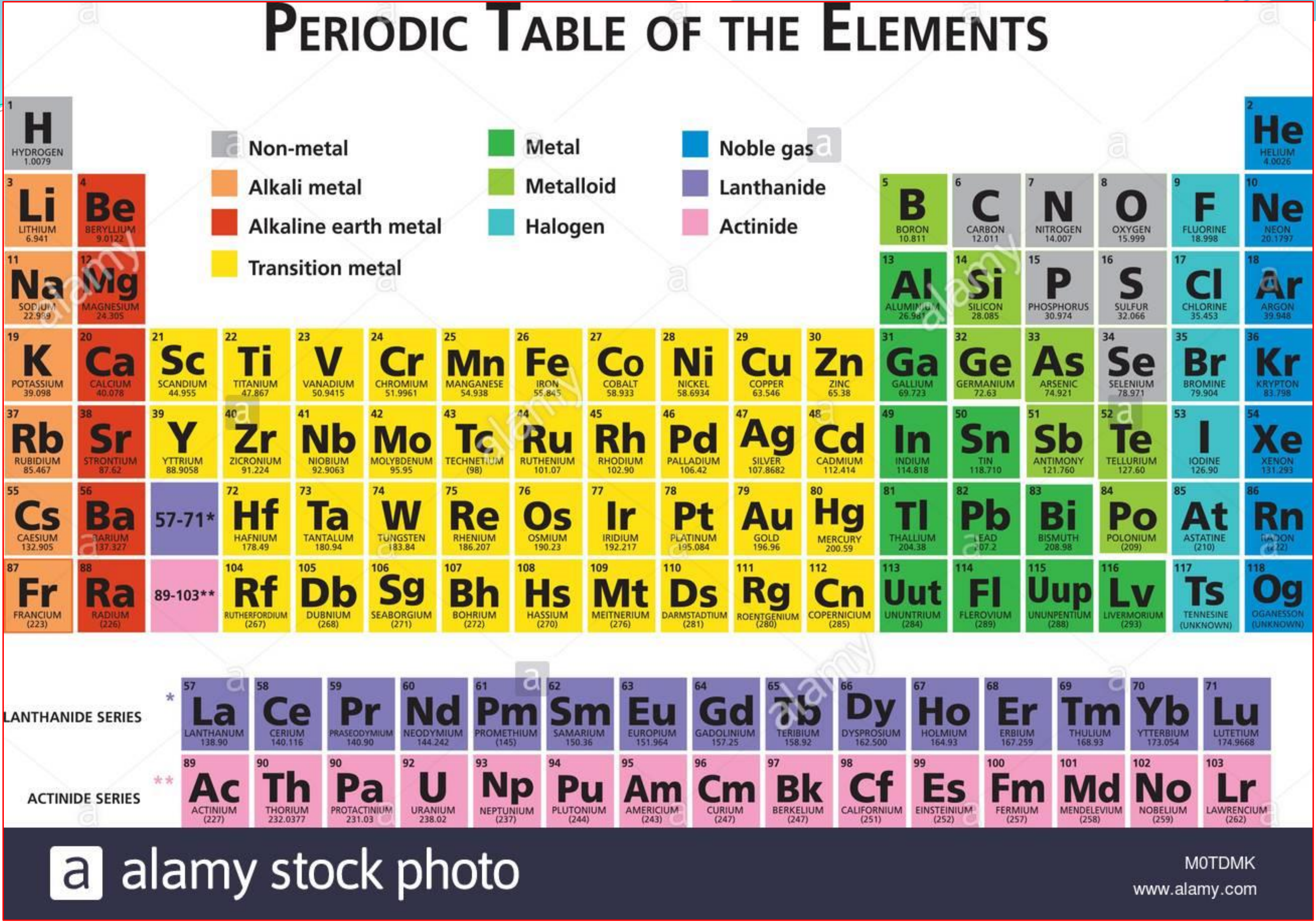
CHAPTER- The d-Block Elements

ONLINE LECTURE

NO. 11

DATE:- 30, SEPTEMBER 2020

TIME: (10.00A.M.)



PERIODIC TABLE OF THE ELEMENTS

- Non-metal
- Alkali metal
- Alkaline earth metal
- Transition metal
- Metal
- Metalloid
- Halogen
- Noble gas
- Lanthanide
- Actinide

1 H HYDROGEN 1.0079																	2 He HELIUM 4.0026
3 Li LITHIUM 6.941	4 Be BERYLLIUM 9.0122											5 B BORON 10.811	6 C CARBON 12.011	7 N NITROGEN 14.007	8 O OXYGEN 15.999	9 F FLUORINE 18.998	10 Ne NEON 20.1797
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55 Cs CAESIUM 132.905	56 Ba BARIUM 137.327	57-71*	72 Hf HAFNIUM 178.49	73 Ta TANTALUM 180.94	74 W TUNGSTEN 183.84	75 Re RHENIUM 186.207	76 Os OSMIUM 190.23	77 Ir IRIDIUM 192.217	78 Pt PLATINUM 195.084	79 Au GOLD 196.96	80 Hg MERCURY 200.59	81 Tl THALLIUM 204.38	82 Pb LEAD 207.2	83 Bi BISMUTH 208.98	84 Po POLONIUM (209)	85 At ASTATINE (210)	86 Rn RADON (222)
87 Fr FRANCIUM (223)	88 Ra RADIUM (226)	89-103**	104 Rf RUTHERFORDIUM (267)	105 Db DUBNIUM (268)	106 Sg SEABORGIUM (271)	107 Bh BOHRIUM (272)	108 Hs HASSIUM (270)	109 Mt MEITNERIUM (276)	110 Ds DARMSTADTIUM (281)	111 Rg ROENTGENIUM (280)	112 Cn COPERNICIUM (285)	113 Uut UNUNTRIUM (284)	114 Fl FLEROVIUM (289)	115 Uup UNUNPENTIUM (288)	116 Lv LIVERMORIUM (293)	117 Ts TENNESINE (UNKNOWN)	118 Og OGANESSON (UNKNOWN)

LANTHANIDE SERIES *	57 La LANTHANUM 138.90	58 Ce CERIUM 140.116	59 Pr PRASEODYMIUM 140.90	60 Nd NEODYMIUM 144.242	61 Pm PROMETHIUM (145)	62 Sm SAMARIUM 150.36	63 Eu EUROPIUM 151.964	64 Gd GADOLINIUM 157.25	65 Tb TERIBIUM 158.92	66 Dy DYSPROSIUM 162.500	67 Ho HOLMIUM 164.93	68 Er ERBIUM 167.259	69 Tm THULIUM 168.93	70 Yb YTTERBIUM 173.054	71 Lu LUTETIUM 174.9668
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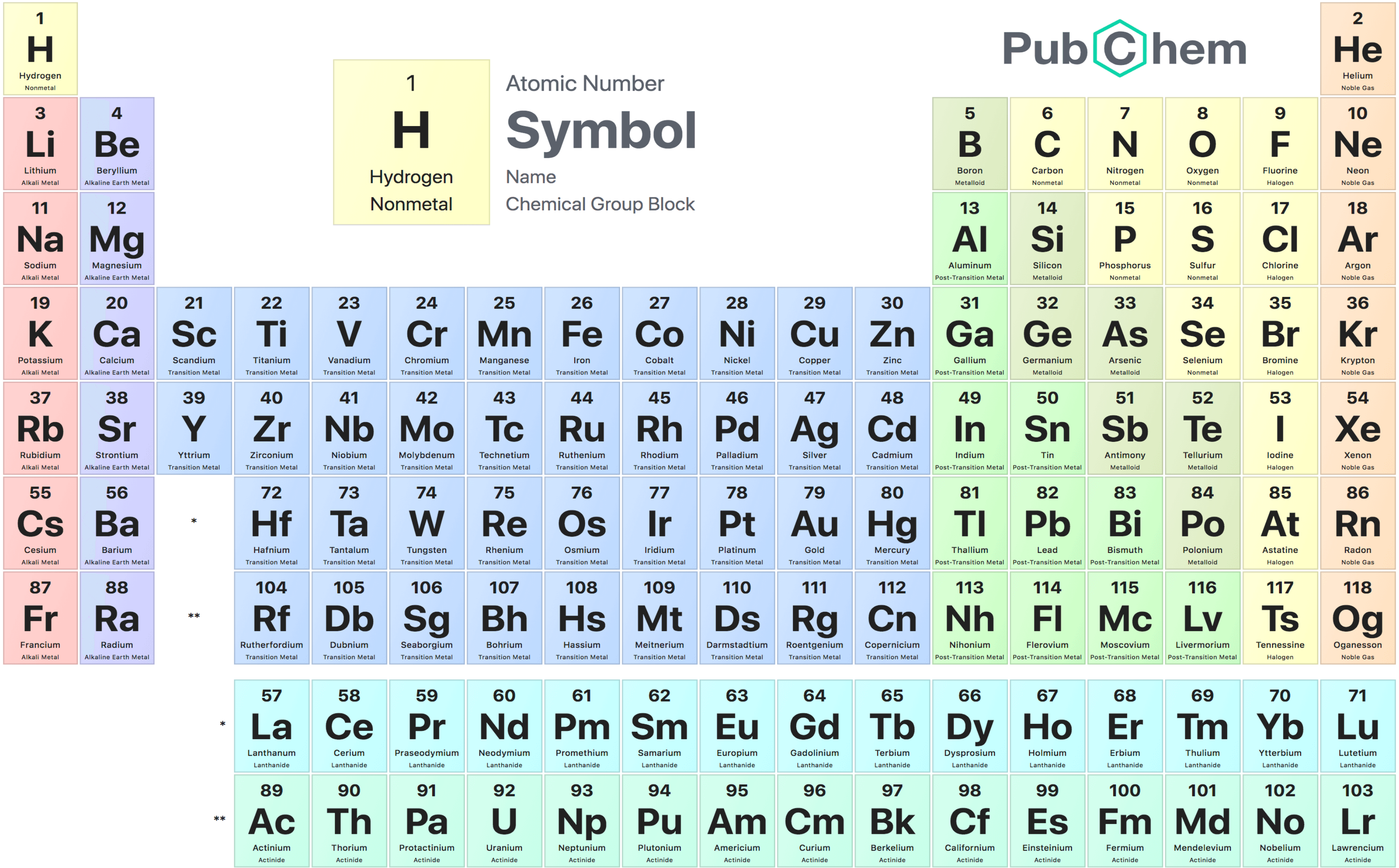


PubChem

1
H
Hydrogen
Nonmetal

Atomic Number
Symbol
Name
Chemical Group Block

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

3) Molar volume and Densities: - The molar volumes of transition elements are much lower than those of the S-block elements. This is because, in a transition series, as the atomic number increases, the extra electrons are added in inner d-orbitals and extra protons are added in the nucleus. The extra nuclear charge attracts all the electrons more strongly, which decreases the atomic volume.

Density is defined as mass per unit volume (g/cm^3). The density increases with decrease in atomic volume. The densities of transition elements are quite high. Most of these elements have densities greater than 5 g/cm^3. The exceptions are Sc, Ti and Y with density 3.01, 4.51 and 4.47 g/cm^3 respectively.

4) Melting points and boiling points: - The melting point and boiling points of the transition elements are generally very high (Above 900^0c). This is because of the close packed structure in these elements. The melting points of d-block elements are much higher than those of S-block elements. But the melting points of Zn (420^0c), Cd (321^0c) and Hg (-39^0c) are much lower than other d-block elements. These are notable exceptions. These elements are moderately volatile. This is due to the following reasons:

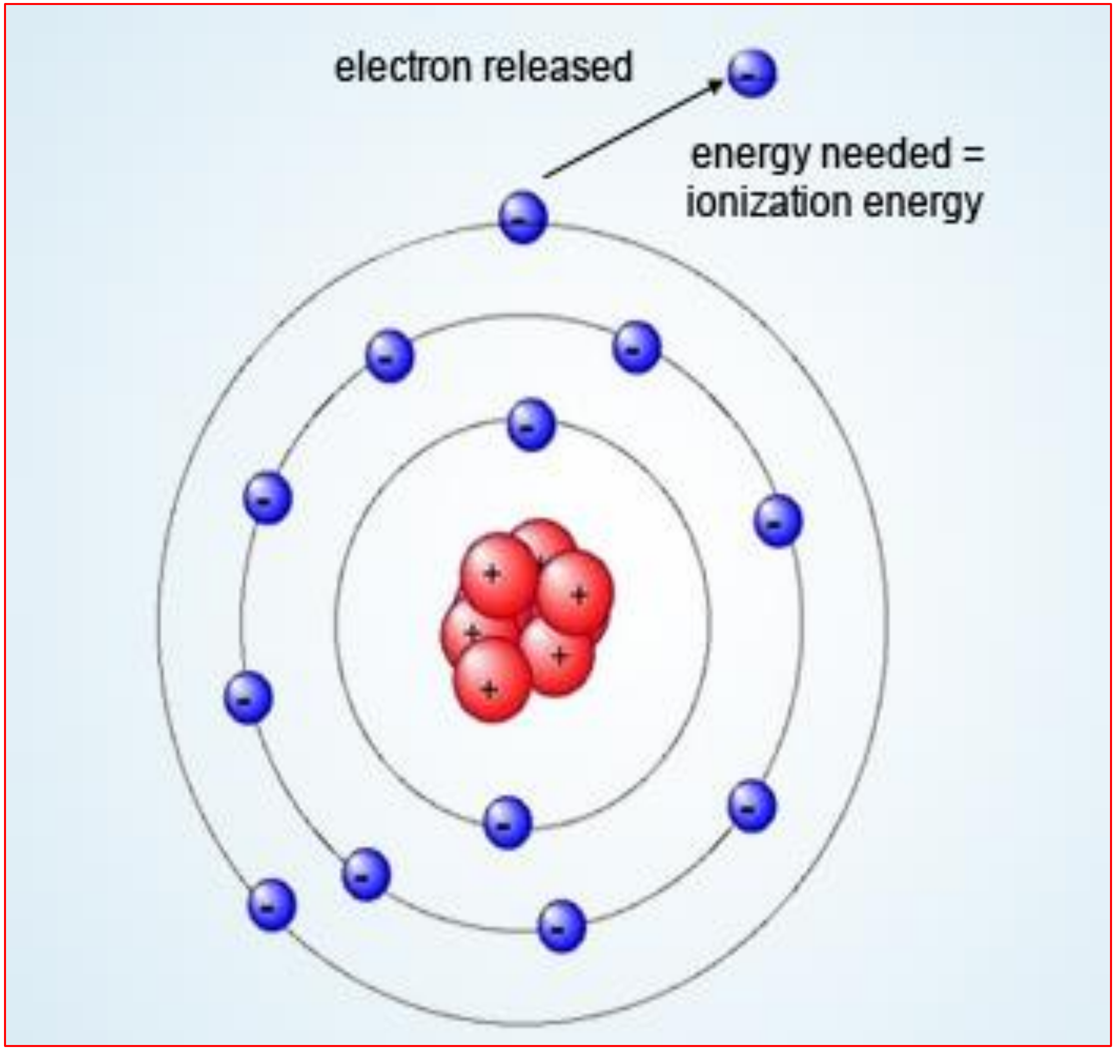
i) These elements are non-transition elements.

ii) They have completely filled sets of d-orbitals.

iii) The covalent bonding cannot take place amongst the atoms of these elements. Due to vacant d-orbitals in other d-block elements, the covalent bonding takes place. The melting and boiling points of other d-block elements are high due to covalent bonding.

5) Ionisation energies: - The energy required to remove an electron from the last orbit of an atom is called as ionization energy. The energy is usually expressed in KJ/mole. When this energy is expressed in electron volt, then it is known as ionization potential. The I.P. values of d-block elements are intermediate between those of S-block and P-block elements.

The ionization energy increases slowly on moving along the transition series from left to right. This is due to slow decrease in atomic size and increase in nuclear charge from left to right. The I. P. value of Zn is much higher due to the special stability of completely filled 3d subshell. Similarly, the I. P. values of Cr and Cu are much higher than those of their neighbours. This is due to the special stability of half filled (d^5) subshell for Cr and fully filled (d^{10}) subshell for Cu ions.


electron released
energy needed =
ionization energy

INORGANIC CHEMISTRY

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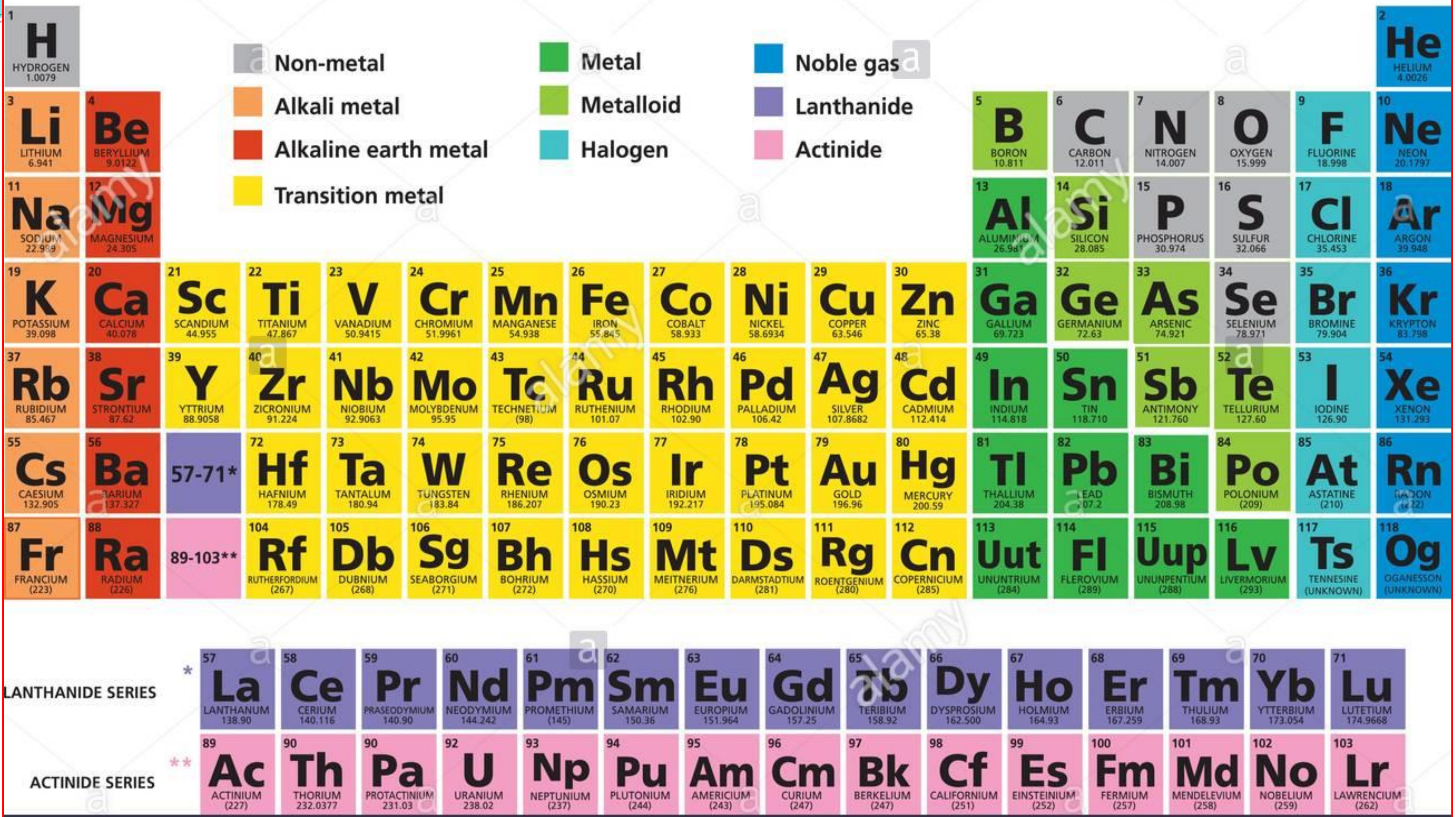
NO. 12

DATE:- 9, OCTOBER 2020

TIME: (9.00A.M.)

PERIODIC TABLE OF THE ELEMENTS



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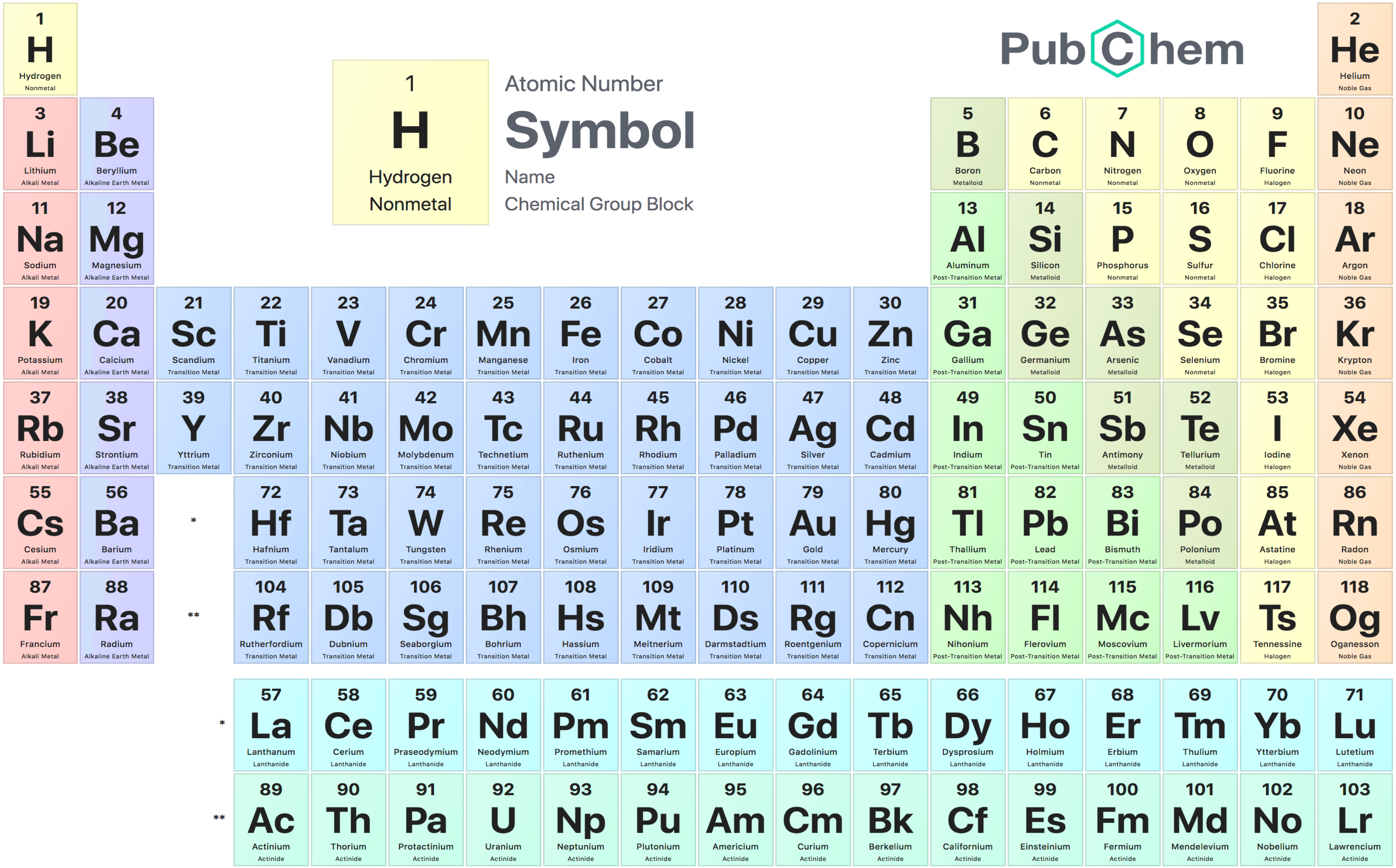

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Nonmetal

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6) Reactivity: - Many of d-block elements are sufficiently reactive. They react with mineral acids (HCl, HNO_3, H_2SO_4) and liberate hydrogen (H_2) gas.

$Fe + 2HCl \rightarrow FeCl_2 + H_2(g)$

Few of these elements possess noble character. The Pt and gold are noble metals. In general, the d-block elements are less reactive. The reactivity of the elements goes on decreasing across a series.

The factors which reduce the reactivity of d-block elements are:

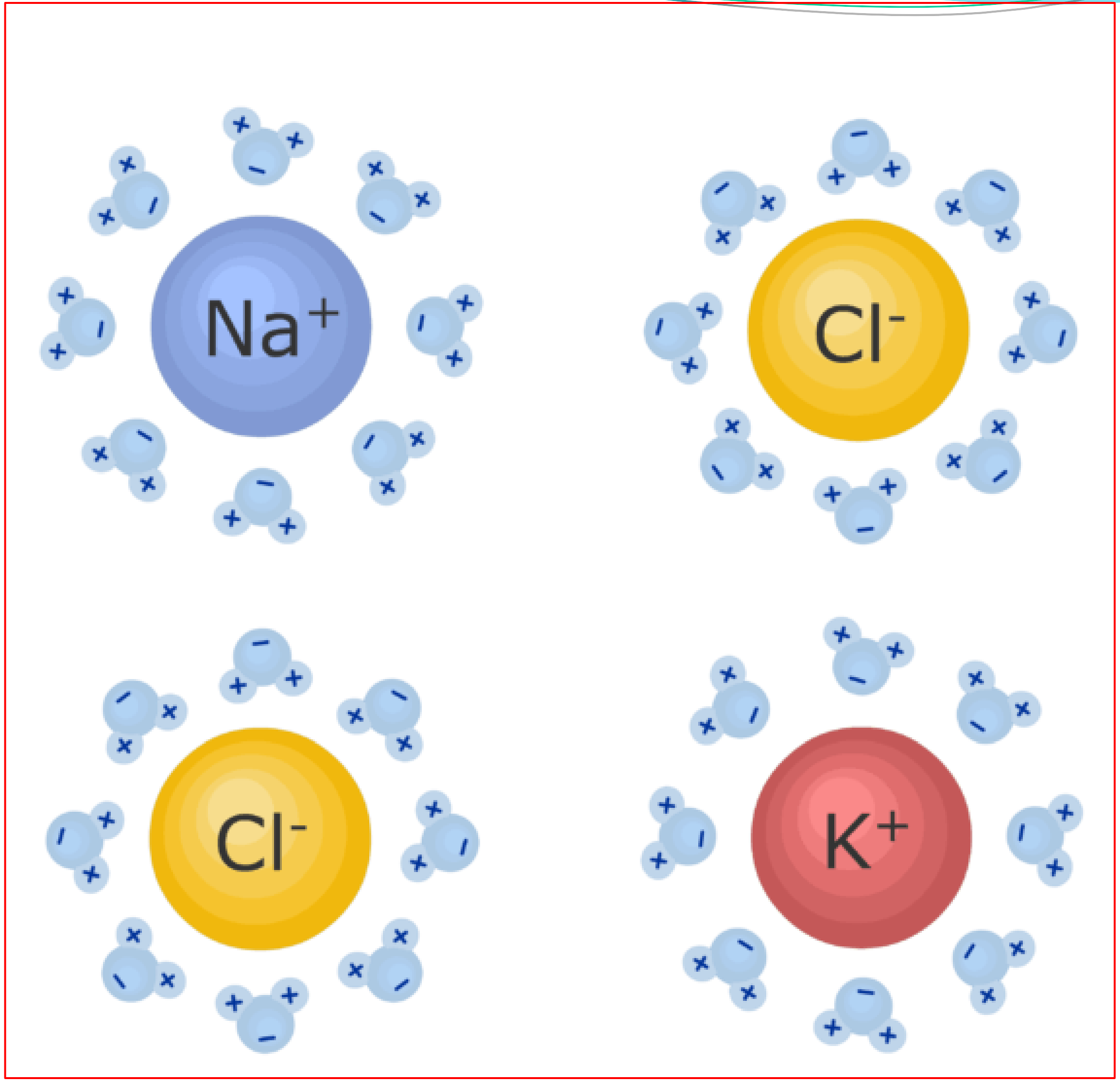
a) They have comparatively small atoms.

b) They have very high ionization energies.

c) They have high melting points.

d) They have high heats of sublimation due to covalent bonding. They require large amount of energy to change them from solid to vapour state.

e) They have low heats of hydration of their ions.


Na+
Cl-
Cl-
K+

INORGANIC CHEMISTRY

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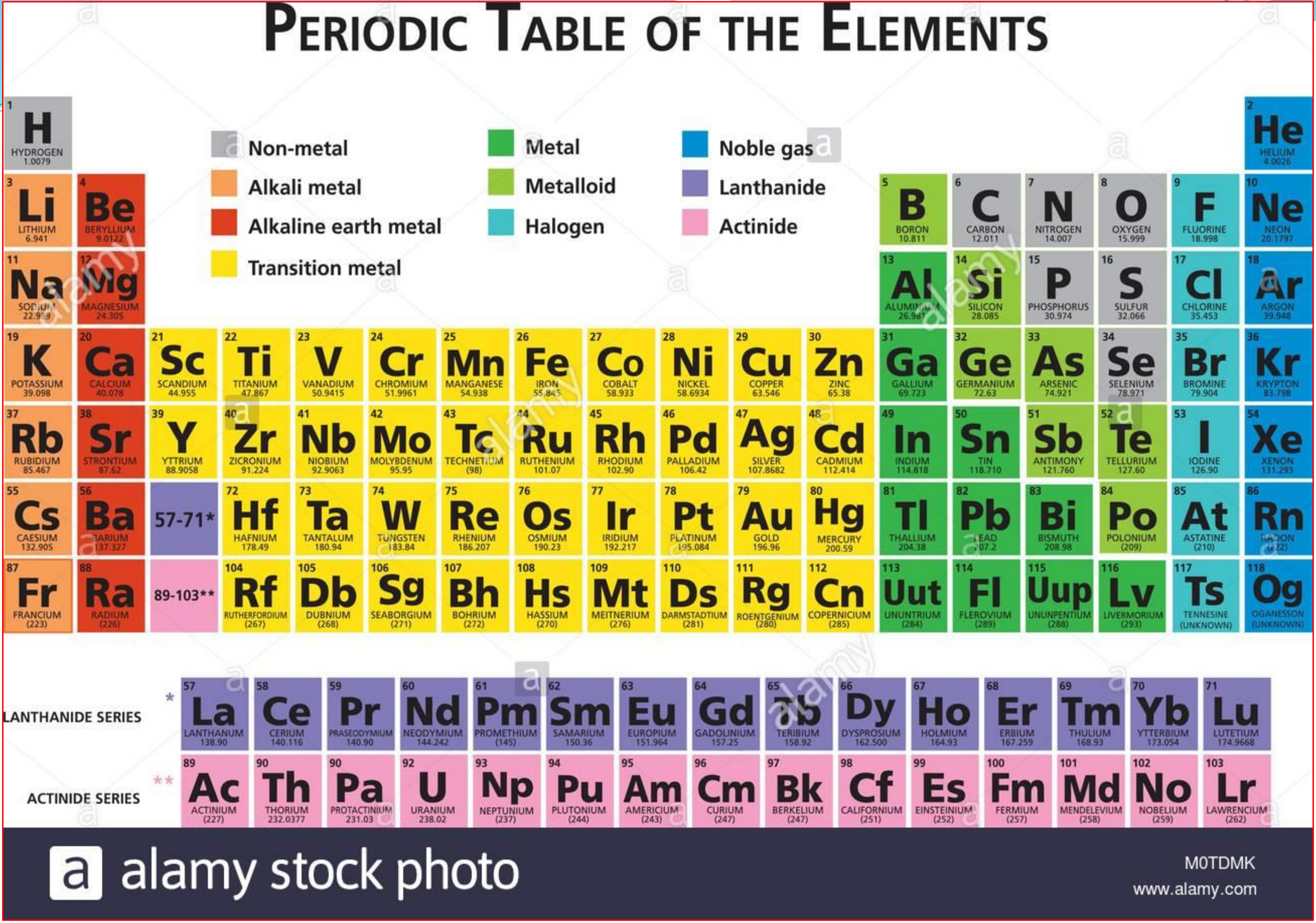
ONLINE LECTURE

NO. 13

DATE:- 14, OCTOBER 2020

TIME: (10.00A.M.)



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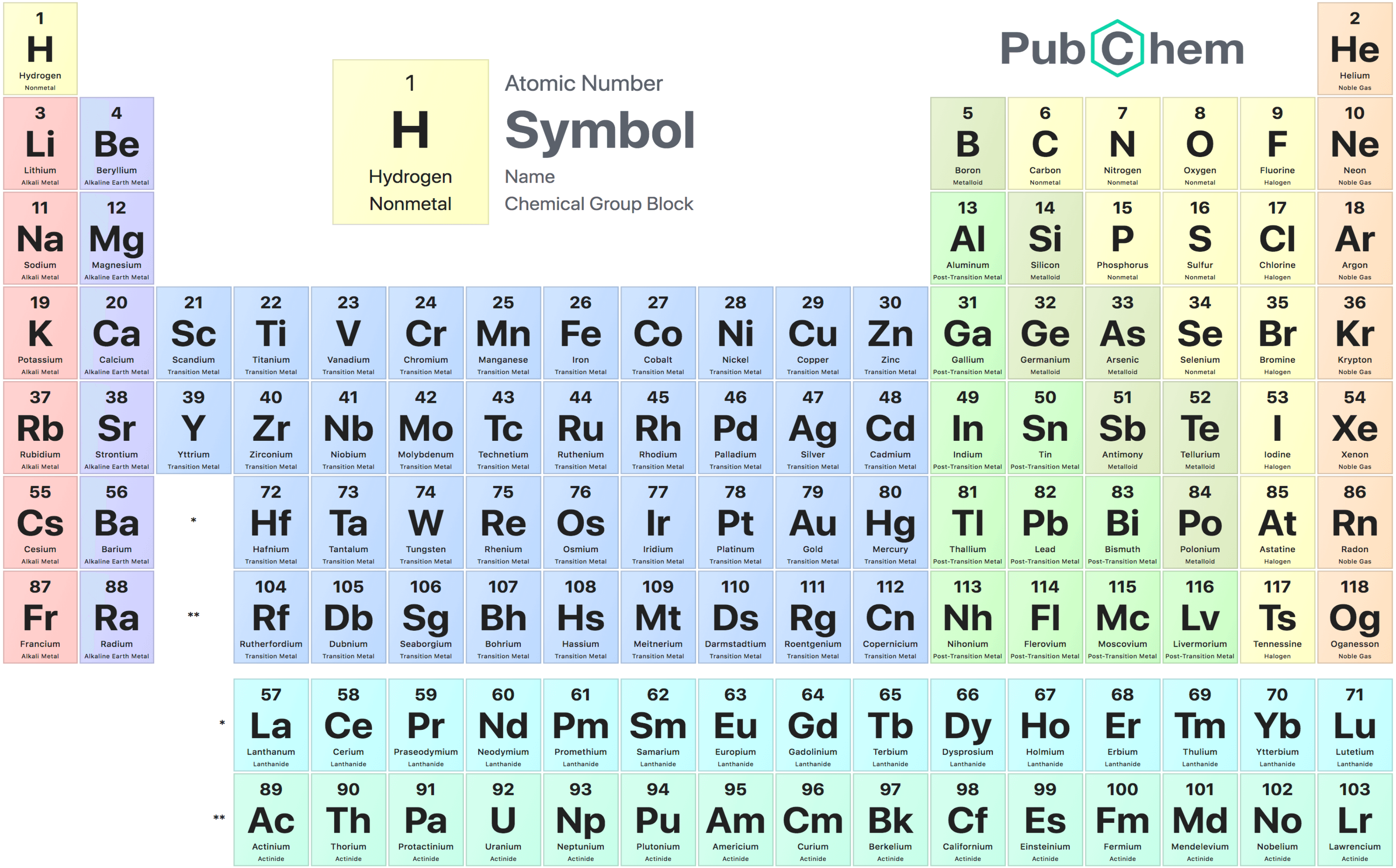
PERIODIC TABLE OF ELEMENTS



PubChem

1 H Hydrogen Nonmetal	
Atomic Number	
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1) Find the oxidation state of Mn in KMnO4

K = +1, Mn = x, O = -2

(+1)+x +(-2) × 4 = 0

1 +x -8 =0

x-7 = 0

x = +7

Therefore, oxidation state of Mn is +7.

2) Find oxidation state of Carbon in CO_3^{-2}

C = x, O = -2

x +(-2) × 3 =-2

x -6 = -2

x = -2+6

x = +4.

3)Find oxidation state of N in $NH4^{+}$

N = x, H = +1

x + (+1) ×4 = +1

x +4 = +1

x = 1-4

x = -3

7) Oxidation states: - "The oxidation state of an element is the charge (positive or negative) which the element posses in the compound". The transition elements show variable oxidation states. This is because, the energy difference between the (n-1) d and nS-orbitals is very small and electrons from both energy levels can be used for bonding. i.e. The oxidation states of transition elements are related to electronic configurations.

Elements	Electronic confg^n.	Oxidation states
Scandium	$3d^1\ 4S^2$	+2, +3
Titanium	$3d^2\ 4S^2$	+2, +3, +4
Vanadium	3d3 $4S^2$	+2, +3, +4, +5
Chromium	$3d^5\ 4S^1$	+1, +2, +3, +4, +5, +6
Manganese	3d5 $4S^2$	+2, +3, +4, +5, +6, +7
Iron	$3d^6\ 4S^2$	+2, +3, +4, +5, +6
Cobalt	$3d^7\ 4S^2$	+2, +3, +4
Nickel	$3d^8\ 4S^2$	+2, +3, +4
Copper	$3d^{10}\ 4S^1$	+1, +2
Zinc	$3d^{10}\ 4S^2$	+2

Scandium shows +2 oxid.^{n} state by using its two 4S electrons. It shows +3 oxid.^{n} state also by using its two 4S electrons and one d-electron. Thus, Sc shows +2 and +3 oxid.^{n} states. Similarly, Cr has only one S-electron and five d-electrons. It can show +1state by using only one S-electron in chemical bonding. In addition, it can show +2, +3, +4, +5 and +6 states when it uses one, two, three, four or all the five of its d-orbitals as well. Hence, up to Mn, the minimum oxidation state is given by the number of electrons in outer S-subshell and the maximum oxidation state is given by the 'sum' of the outer S and d-electrons. Up to Mn, the 3d subshell is no more than half filled.

In the next elements, Fe ($3d^6\ 4S^2$), Co ($3d^7\ 4S^2$), Ni ($3d^8\ 4S^2$), Cu ($3d^{10}\ 4S^1$) and Zn ($3d^{10}\ 4S^2$) the number of 3d electrons are more than five. The minimum oxidation state is still equal to the number of the outer S-electrons. However, the maximum oxidation state is not related at all with the electronic configuration.

INORGANIC CHEMISTRY

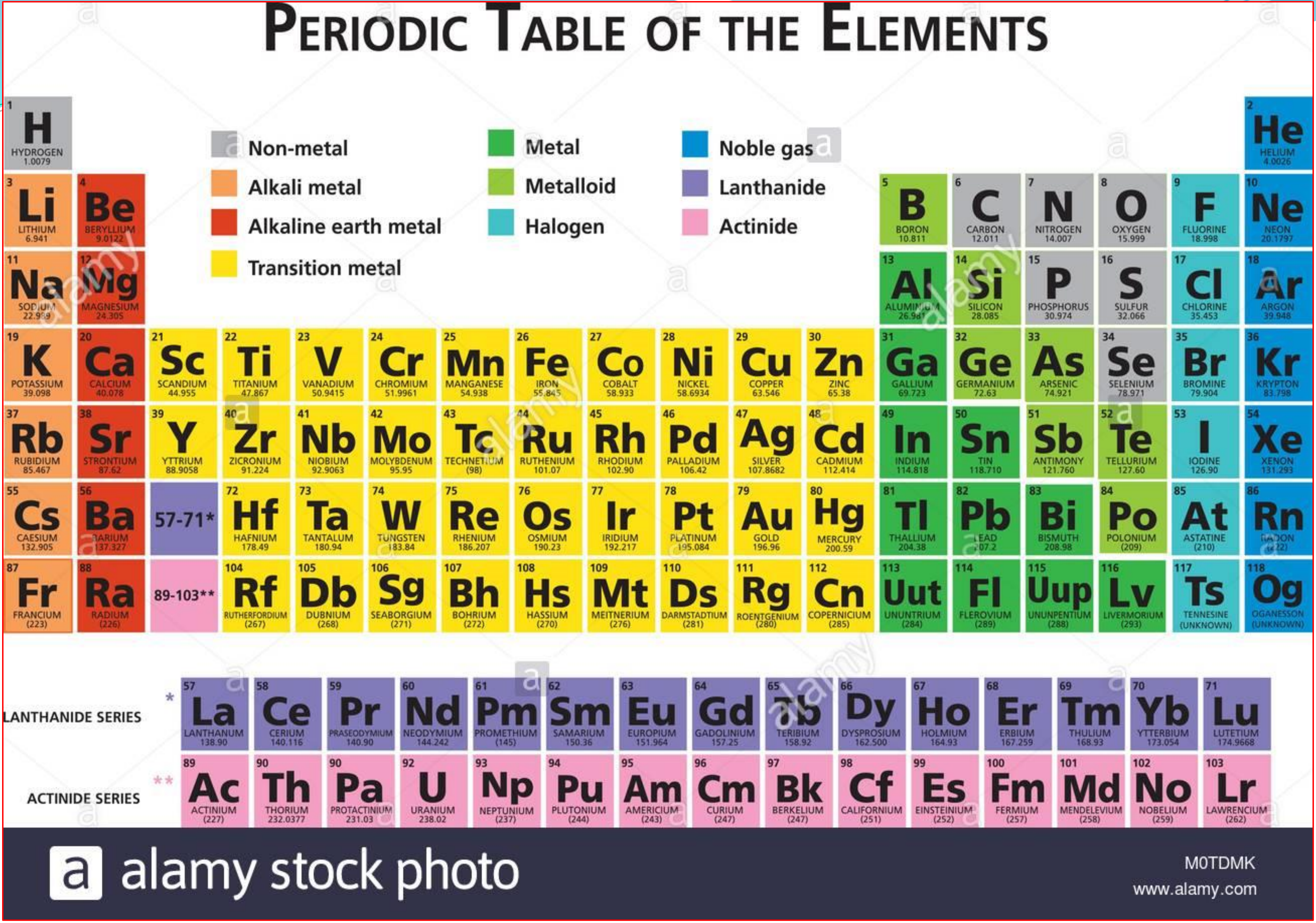
CHAPTER- The d-Block Elements

ONLINE LECTURE

NO. 14

DATE:- 16, OCTOBER 2020

TIME: (9.00A.M.)



PERIODIC TABLE OF THE ELEMENTS

- Non-metal
- Alkali metal
- Alkaline earth metal
- Transition metal
- Metal
- Metalloid
- Halogen
- Noble gas
- Lanthanide
- Actinide

1 H HYDROGEN 1.0079																	2 He HELIUM 4.0026
3 Li LITHIUM 6.941	4 Be BERYLLIUM 9.0122											5 B BORON 10.811	6 C CARBON 12.011	7 N NITROGEN 14.007	8 O OXYGEN 15.999	9 F FLUORINE 18.998	10 Ne NEON 20.1797
11 Na SODIUM 22.989	12 Mg MAGNESIUM 24.305											13 Al ALUMINIUM 26.981	14 Si SILICON 28.085	15 P PHOSPHORUS 30.974	16 S SULFUR 32.066	17 Cl CHLORINE 35.453	18 Ar ARGON 39.948
19 K POTASSIUM 39.098	20 Ca CALCIUM 40.078	21 Sc SCANDIUM 44.955	22 Ti TITANIUM 47.867	23 V VANADIUM 50.9415	24 Cr CHROMIUM 51.9961	25 Mn MANGANESE 54.938	26 Fe IRON 55.845	27 Co COBALT 58.933	28 Ni NICKEL 58.6934	29 Cu COPPER 63.546	30 Zn ZINC 65.38	31 Ga GALLIUM 69.723	32 Ge GERMANIUM 72.63	33 As ARSENIC 74.921	34 Se SELENIUM 78.971	35 Br BROMINE 79.904	36 Kr KRYPTON 83.798
37 Rb RUBIDIUM 85.467	38 Sr STRONTIUM 87.62	39 Y YTTRIUM 88.9058	40 Zr ZICRONIUM 91.224	41 Nb NIOBIUM 92.9063	42 Mo MOLYBDENUM 95.95	43 Tc TECHNETIUM (98)	44 Ru RUTHENIUM 101.07	45 Rh RHODIUM 102.90	46 Pd PALLADIUM 106.42	47 Ag SILVER 107.8682	48 Cd CADMIUM 112.414	49 In INDIUM 114.818	50 Sn TIN 118.710	51 Sb ANTIMONY 121.760	52 Te TELLURIUM 127.60	53 I IODINE 126.90	54 Xe XENON 131.293
55 Cs CAESIUM 132.905	56 Ba BARIUM 137.327	57-71*	72 Hf HAFNIUM 178.49	73 Ta TANTALUM 180.94	74 W TUNGSTEN 183.84	75 Re RHENIUM 186.207	76 Os OSMIUM 190.23	77 Ir IRIDIUM 192.217	78 Pt PLATINUM 195.084	79 Au GOLD 196.96	80 Hg MERCURY 200.59	81 Tl THALLIUM 204.38	82 Pb LEAD 207.2	83 Bi BISMUTH 208.98	84 Po POLONIUM (209)	85 At ASTATINE (210)	86 Rn RADON (222)
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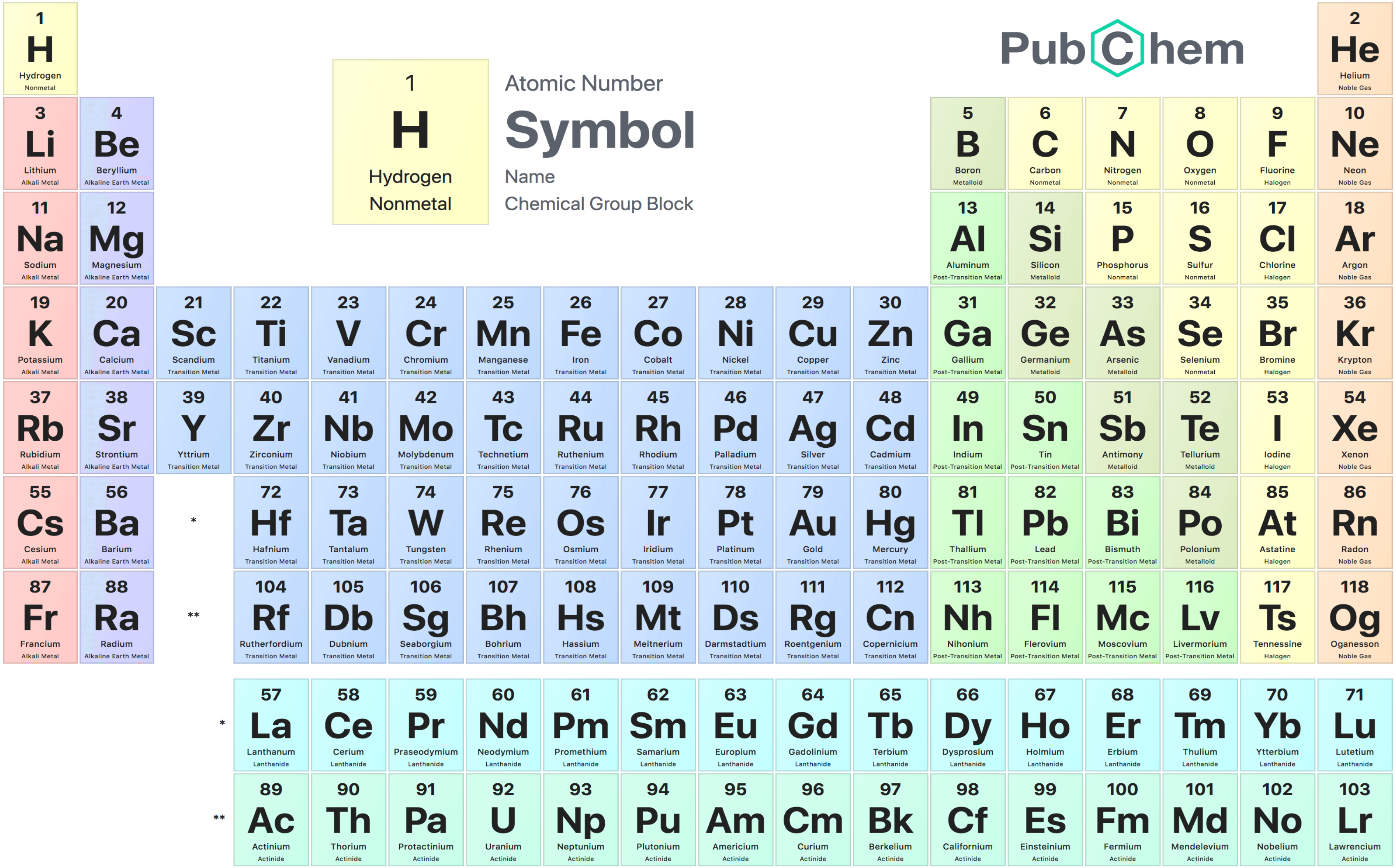

PubChem

1 **H** Hydrogen Nonmetal	Atomic Number **Symbol** Name Chemical Group Block

1 **H** Hydrogen Nonmetal																	2 **He** Helium Noble Gas
3 **Li** Lithium Alkali Metal	4 **Be** Beryllium Alkaline Earth Metal											5 **B** Boron Metalloid	6 **C** Carbon Nonmetal	7 **N** Nitrogen Nonmetal	8 **O** Oxygen Nonmetal	9 **F** Fluorine Halogen	10 **Ne** Neon Noble Gas
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37 **Rb** Rubidium Alkali Metal	38 **Sr** Strontium Alkaline Earth Metal	39 **Y** Yttrium Transition Metal	40 **Zr** Zirconium Transition Metal	41 **Nb** Niobium Transition Metal	42 **Mo** Molybdenum Transition Metal	43 **Tc** Technetium Transition Metal	44 **Ru** Ruthenium Transition Metal	45 **Rh** Rhodium Transition Metal	46 **Pd** Palladium Transition Metal	47 **Ag** Silver Transition Metal	48 **Cd** Cadmium Transition Metal	49 **In** Indium Post-Transition Metal	50 **Sn** Tin Post-Transition Metal	51 **Sb** Antimony Metalloid	52 **Te** Tellurium Metalloid	53 **I** Iodine Halogen	54 **Xe** Xenon Noble Gas
55 **Cs** Cesium Alkali Metal	56 **Ba** Barium Alkaline Earth Metal	*	72 **Hf** Hafnium Transition Metal	73 **Ta** Tantalum Transition Metal	74 **W** Tungsten Transition Metal	75 **Re** Rhenium Transition Metal	76 **Os** Osmium Transition Metal	77 **Ir** Iridium Transition Metal	78 **Pt** Platinum Transition Metal	79 **Au** Gold Transition Metal	80 **Hg** Mercury Transition Metal	81 **Tl** Thallium Post-Transition Metal	82 **Pb** Lead Post-Transition Metal	83 **Bi** Bismuth Post-Transition Metal	84 **Po** Polonium Metalloid	85 **At** Astatine Halogen	86 **Rn** Radon Noble Gas
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8) Reducing properties: - Except Copper, all the first transition series elements have higher values of standard oxidation potential than that of standard hydrogen electrode (SHE). Hence, these metals except Copper can lose electrons and get easily oxidized to their ions in aqueous solutions.

$$M \rightarrow M^{+2}(aq.) + 2e^{-}$$

Therefore, they are good reducing agents. Because, a reducing agent always losses electrons and undergoes oxidation. But, they are less powerful reducing agents than alkali or alkaline earth metals. This is because,

i) Their atomic sizes are small.

ii) They have high ionization energies.

iii) They have low heats of hydration of their ions.

iv) They have high heats of vapourisation.

Copper has a negative oxidation potential. This means that, copper is not able to displace H^+ ions from acid solutions. The reaction,

$$Cu + 2H^+ (aq.) \rightarrow Cu^{+2}(aq.) + H_2 (g)$$

does not take place. The tendency of Cu to change into Cu^{+2} ion, $Cu \rightarrow Cu^{+2}(aq.) +2e^-$ is extremely small. Hence, Copper is a poor reducing agent.

9) Standard electrode potentials: - Standard electrode potential is defined as the potential developed at the single electrode at 298K due to half cell reaction, when an electrode is dipped in its salt solution having unit activity.

The standard electrode potential of H_2 electrode is taken as zero. Except Copper, the standard oxidation potential of first transition series elements are much higher than that of SHE. Therefore, it is expected that, these metals, except Cu, evolve H_2 gas when reacted with acid solution.

$$M + 2H^+ (aq.) \rightarrow M^{+2}(aq.) + H_2 (g)$$

However, these metals react very slowly with acids. Some of these metals get protected from the attack of acids due to the formation of thin impervious layer of an inert oxide. e.g. Cr is so unreactive that it can be used as a protective non-oxidizing metal, because it gets coated with a non-reactive oxide Cr_2O_3.

INORGANIC CHEMISTRY

CHAPTER- The d-Block Elements

ONLINE LECTURE

NO. 15

DATE:- 21, OCTOBER 2020

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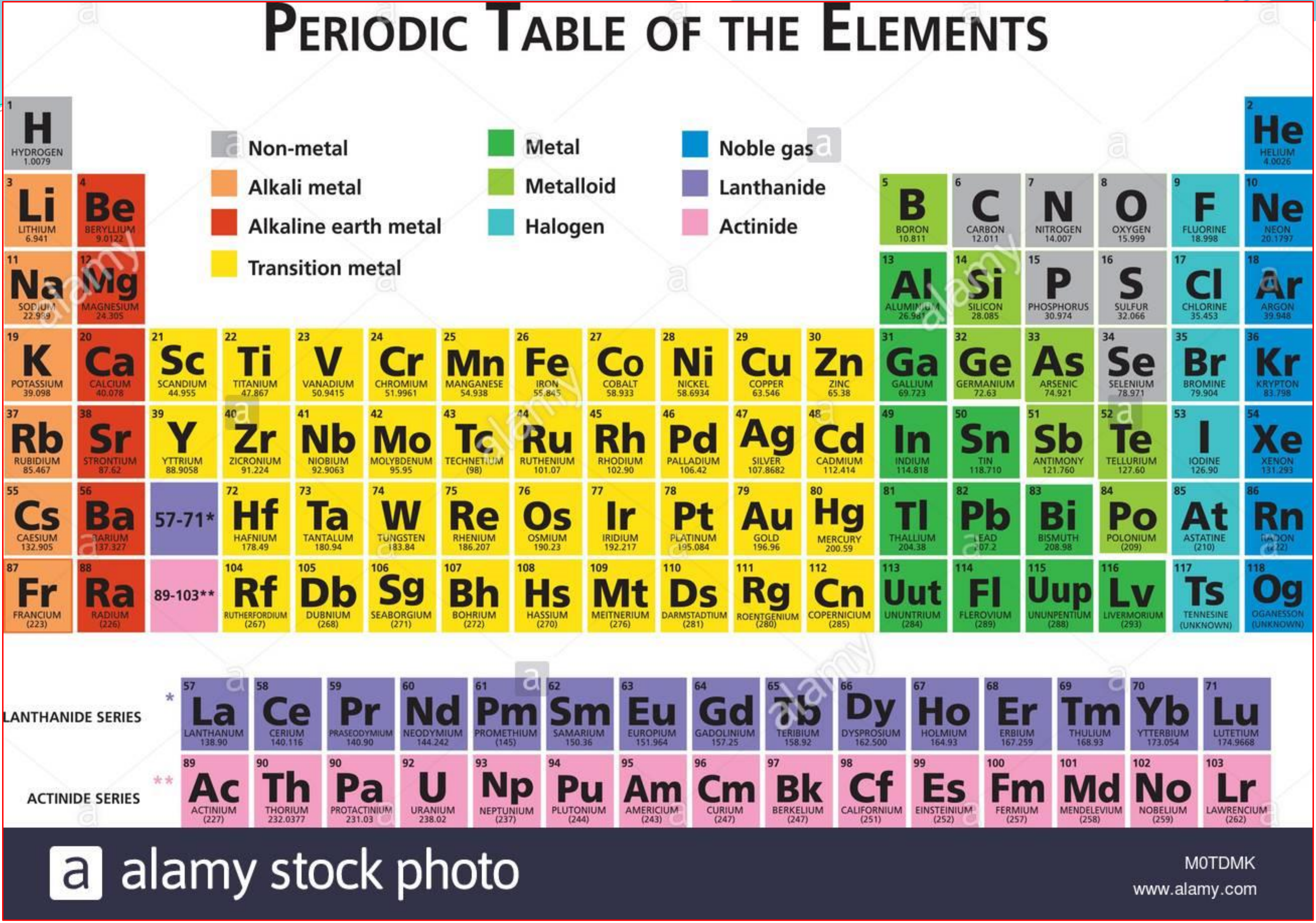

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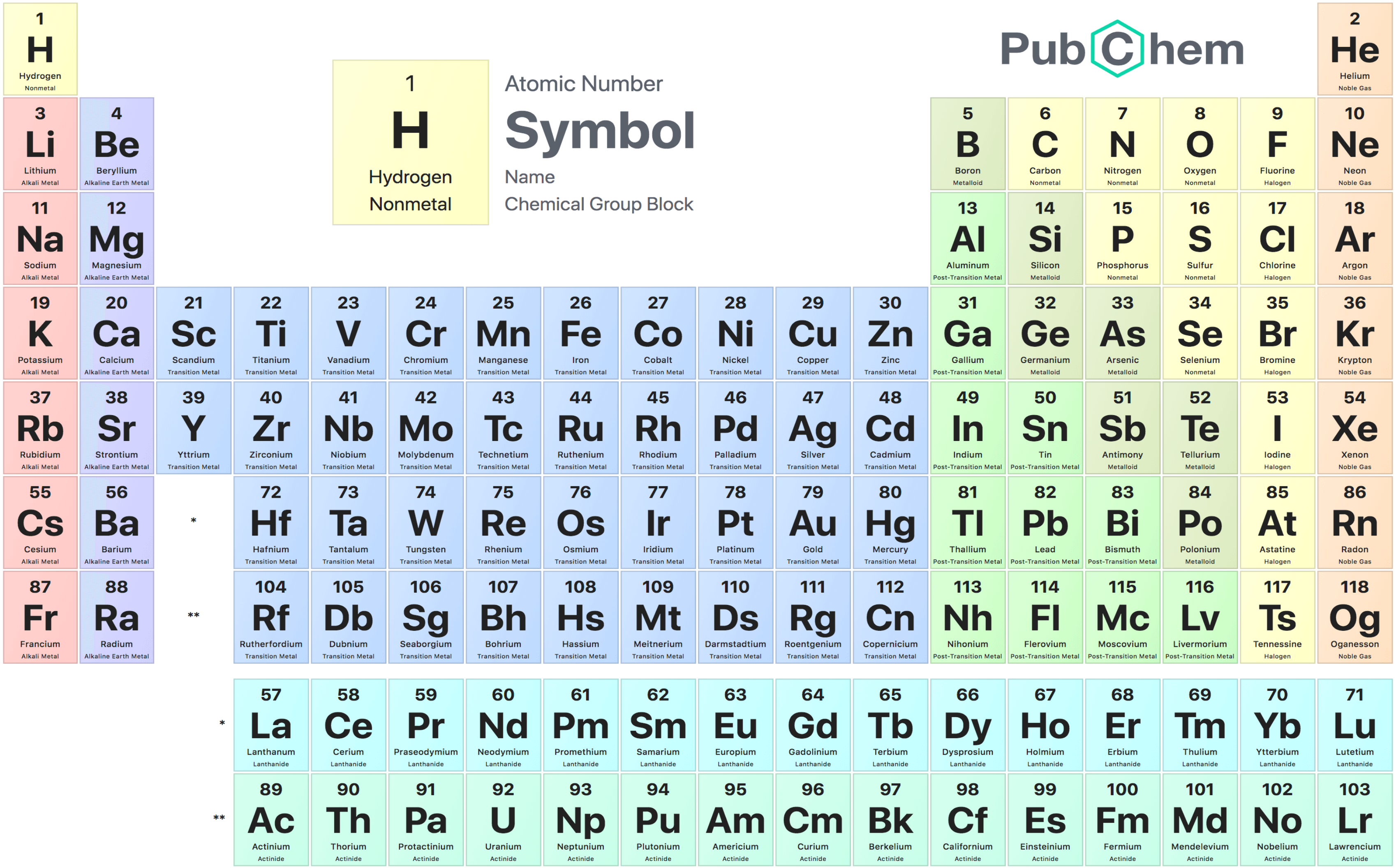

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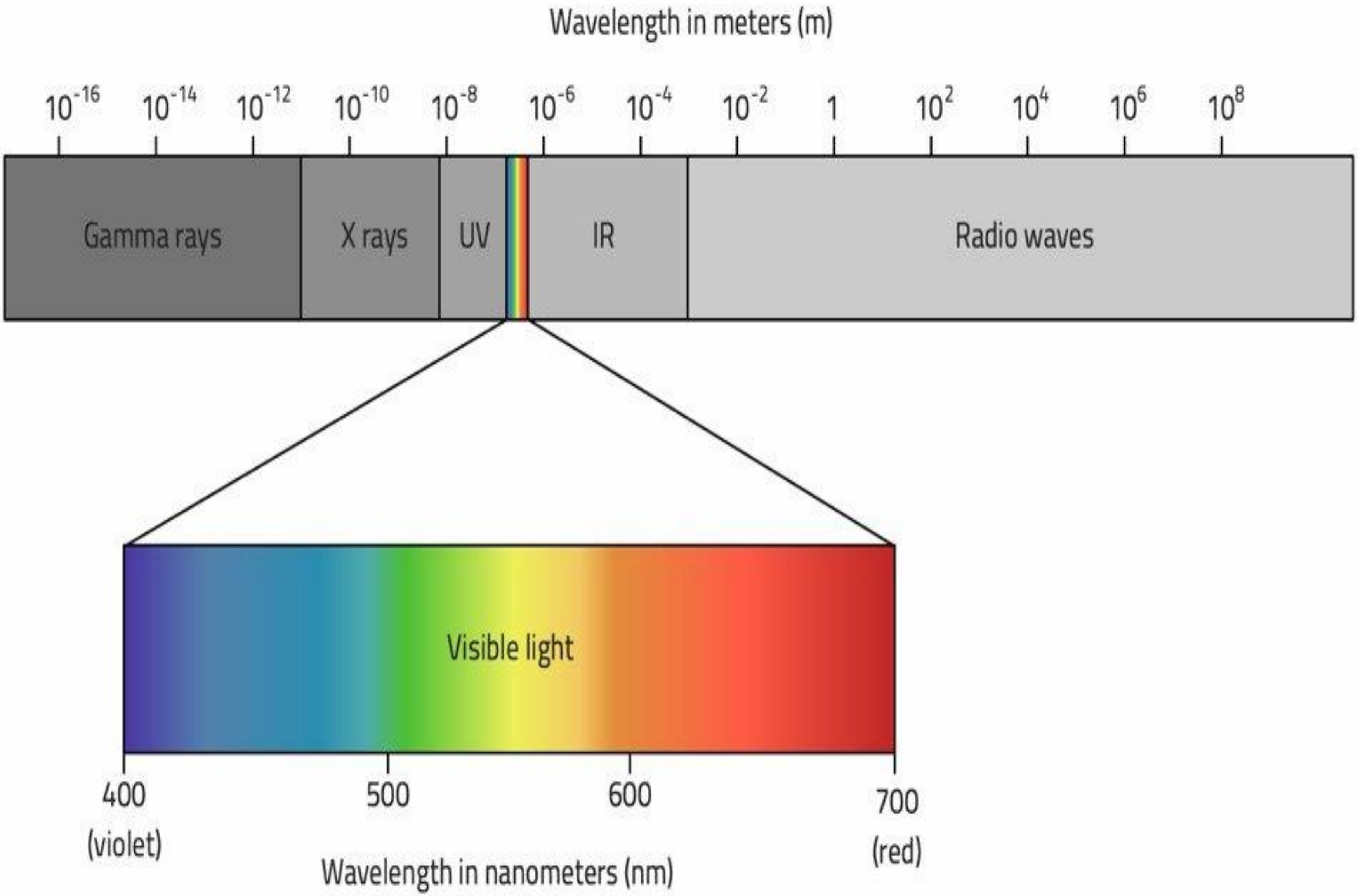
11 Na Sodium Alkali Metal	12 Mg Magnesium Alkaline Earth Metal											13 Al Aluminum Post-Transition Metal	14 Si Silicon Metalloid	15 P Phosphorus Nonmetal	16 S Sulfur Nonmetal	17 Cl Chlorine Halogen	18 Ar Argon Noble Gas
19 K Potassium Alkali Metal	20 Ca Calcium Alkaline Earth Metal	21 Sc Scandium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


Wavelength in meters (m)
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10^{-14}
10^{-12}
10^{-10}
10^{-8}
10^{-6}
10^{-4}
10^{-2}
1
10^{2}
10^{4}
10^{6}
10^{8}
Gamma rays
X rays
UV
IR
Radio waves
Visible light
400
(violet)
500
600
700
(red)
Wavelength in nanometers (nm)

10) Colour: - Compounds of transition metals are usually coloured. The colour is due to the presence of partly filled d-subshell and preferential absorption of energy of some visible light. The energies of d-orbitals of metal ions in their compounds are split into two sets of energy levels, due to crystal field effects. The colour of transition metal ions arises due to the excitation of electrons from the d-orbitals of lower energy (t_2g) to the d-orbitals of higher energy (eg).

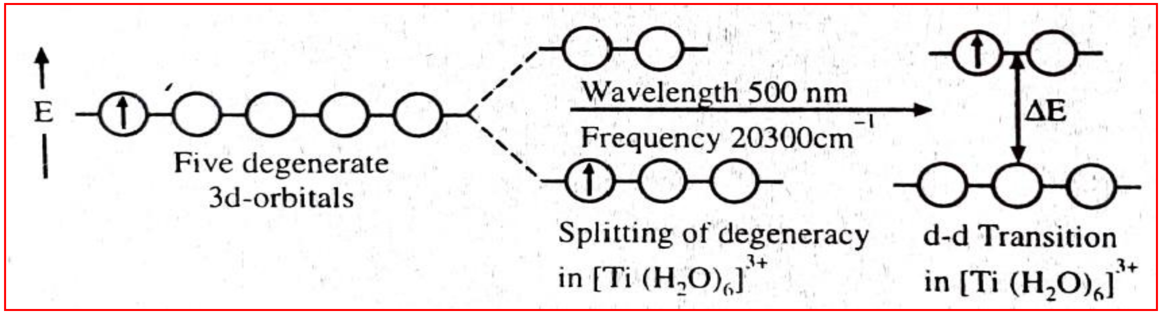
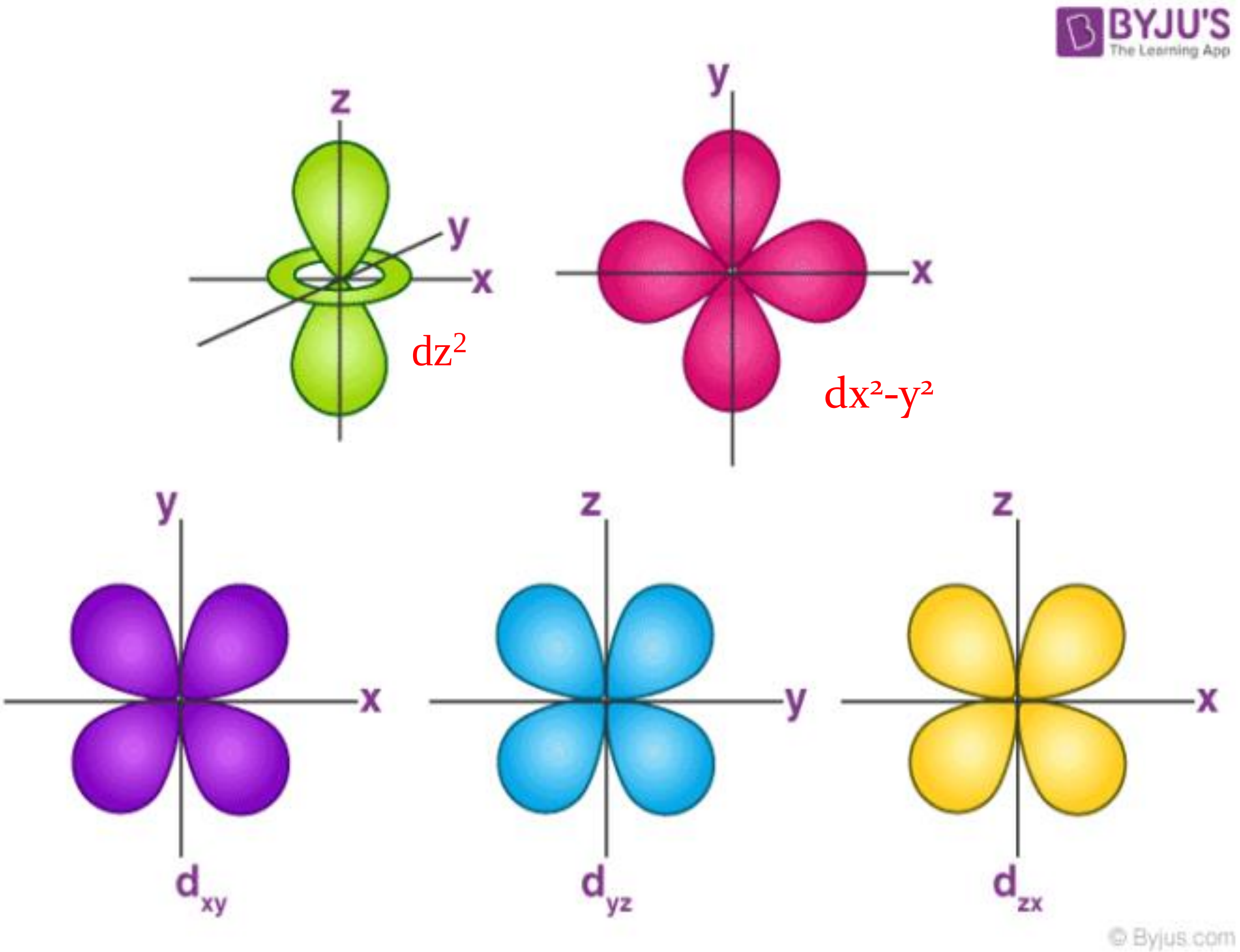


Figure 1: d-d transition in Ti^{+3} ion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The energy difference between these two levels is small. The light energy for such d-d electron transition is absorbed from visible region. The visible region consists of energy of seven colors (VIBGYOR). The colour of the substance is from the property of the substance to absorb light of certain wavelength of visible light.

For every type of absorbed energy from visible region there is a complementary colour that is transmitted or reflected. The colour of the substance is nothing but the colour of the transmitted light.

e.g. Cu^{+2}(aq.) ion absorbs radiations corresponding to red light and then it transmits radiations of wavelength of blue colour. Thus, Cu^{+2}(aq.) ion will appears blue.

a) Transition metal ions which have completely filled d-orbitals are colourless. Because, there are no vacant d-orbitals available for d-d transition. e.g. Zn^{+2} ($3d^{10}$), Cd^{+2}($4d^{10}$), Hg^{+2} ($5d^{10}$) ions are colourless.

Zn (30) → $1S^2, 2S^2, 2P^6, 3S^2, 3P^6,$ **$\underline{4S^2, 3d^{10}}$**

Cd(48) → $1S^2, 2S^2, 2P^6, 3S^2, 3P^6, 4S^2, 3d^{10}, 4p^6,$ **$\underline{5s^2, 4d^{10}}$**

Hg (80) ⟶ $1S^2, 2S^2, 2P^6, 3S^2, 3P^6, 4S^2, 3d^{10}, 4p^6, 5s^2, 4d^{10}, 5p^6, 4f^{14}$,**$\underline{6s^2, 5d^{10}}$**

b) Transition metal ions which have completely empty d-orbitals are also colourless. e.g. Sc^{+3} and Ti^{+4} ions are colourless.

Sc (21) → $1S^2, 2S^2, 2P^6, 3S^2, 3P^6,$ **$\underline{4S^2, 3d^1}$** **Sc^{+3}** $\rightarrow 4S^0 3d^0$

Ti (22) → $1S^2, 2S^2, 2P^6, 3S^2, 3P^6,$ **$\underline{4S^2, 3d^2}$** **Ti^{+4}** $\rightarrow 4S^0 3d^0$

c) The ions of S and P-block elements are colorless because excitation of electrons from lower S or P orbitals to higher S or P or d orbitals requires very high amount of energy from uv region. There is no absorption of light from the visible region. Hence, ions of S and P-block elements are colourless.