

PROF. DR. SELEN BİLGE KOÇAK

CHM0307 INORGANIC CHEMISTRY I

PERIODIC PROPERTIES OF ATOMS

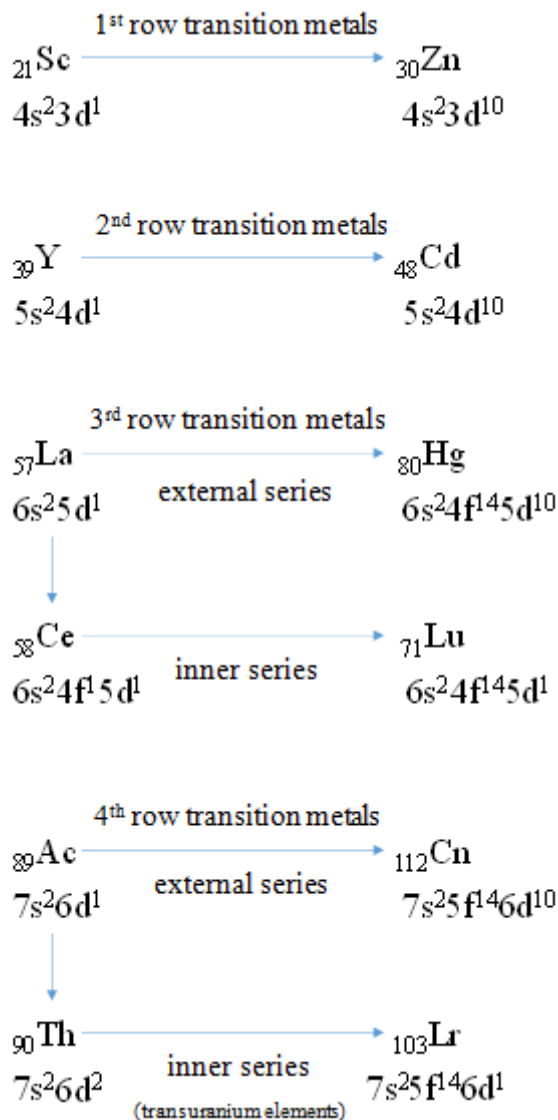
PERIODIC TABLE

Legend:

- Alkali Metal (Orange)
- Alkaline Earth Metal (Yellow)
- Transition Metal (Pink)
- Lanthanide (Light Orange)
- Actinide (Light Purple)
- Metal (Teal)
- Semimetal (Green)
- Non-metal (Light Green)
- Noble Gas (Light Blue)
- Solid (White)
- Liquid (Light Blue)
- Gas (Light Green)
- Synthetic (Light Purple)

The transition metals are metals between the 2A group and the 3A group. Transition metals are metals that correspond to the introduction of electrons into the *d* and *f* orbitals and are therefore examined separately as *d*-block metals and *f*-block metals. The main transition metals are between the IIA and IIIA groups in the periodic table and the 10 metals in the 3rd, 4th and 5th periods are called 1st, 2nd and 3rd row transition metals. The inner transition metals are called lanthanides (rare earth metals, monazite metals) and inner transition metals in the 7th period are called actinides. Actinides are radioactive metals while lanthanides are active metals. The transition metals are the most studied elements on the periodic table. Metals used in technology with more. Transition metals are metals used in technology. The first five groups of transition metals are examined separately according to vertical similarities. The horizontal trinity similarities in the groups after the fifth group are higher than the vertical similarities.

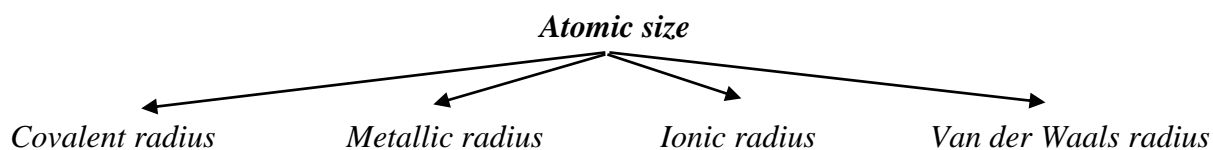
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$f^1 d^1$	f^3	f^4	f^5	f^6	f^7	$f^7 d^1$	f^9	f^{10}	f^{11}	f^{12}	f^{13}	f^{14}	$f^{14} d^1$
<i>Ce</i>	<i>Pr</i>	<i>Nd</i>	<i>Pm</i>	<i>Sm</i>	<i>Eu</i>	<i>Gd</i>	<i>Tb</i>	<i>Dy</i>	<i>Ho</i>	<i>Er</i>	<i>Tm</i>	<i>Yb</i>	<i>Lu</i>
<i>Th</i>	<i>Pa</i>	<i>U</i>	<i>Np</i>	<i>Pu</i>	<i>Am</i>	<i>Cm</i>	<i>Bk</i>	<i>Cf</i>	<i>Es</i>	<i>Fm</i>	<i>Md</i>	<i>No</i>	<i>Lr</i>
d^2	$f^2 d^1$	$f^3 d^1$	$f^4 d^1$	f^6	f^7	$f^7 d^1$	f^9	f^{10}	f^{11}	f^{12}	f^{13}	f^{14}	$f^{14} d^1$

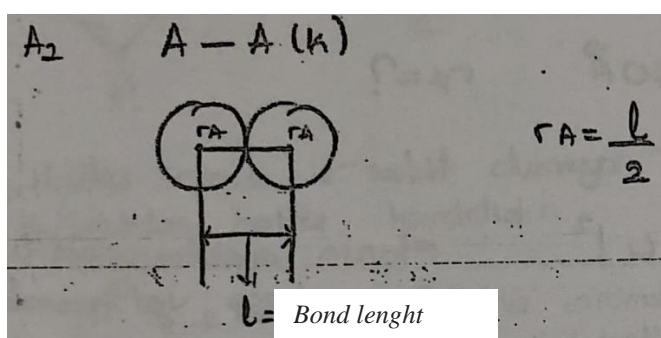
Electron configuration of transition metals

ATOMIC SIZE

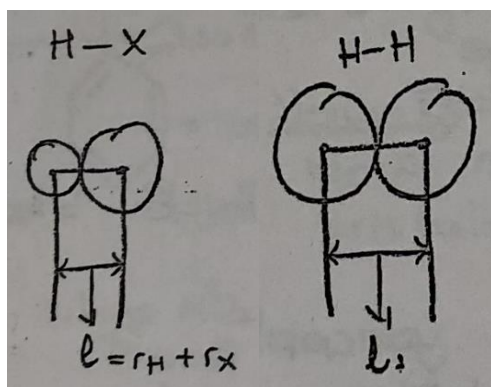


Covalent Radius

Radius in apolar covalent bond (homonuclear molecules): *The radius is half of the distance between the atomic centers.*

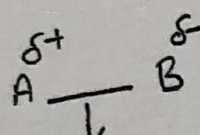


Radius in polar covalent bond (heteronuclear molecules): *The radius is the distance obtained by shearing the distance between atomic centers in polar covalently bound compounds.*



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Polar covalent bond

$$r_{AB} = r_A + r_B - 0.09 |x_A - x_B|$$

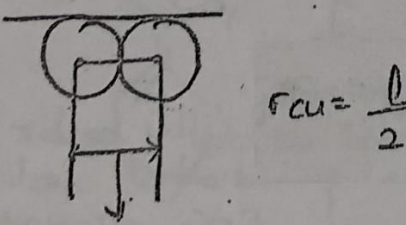
Shoemaker and Stevenson equation

$$r_{AB} = r_A + r_B - 0.07 |x_A - x_B|^2$$

Metallic radius

Metallic radius is half of the distance between metal centers in a metallic crystal.

Cu (s)



$r_{Cu} = \frac{l}{2}$

$l =$ Bond length

In the periodic table, in A groups, the covalent and metallic radius decrease from the left to the right. Because, the atomic number increases from the left to the right, the shielding decreases, the effective nuclear charge increases.

	Li	Be	B	C	N	O	F
Z :	3	4	5	6	7	8	9
	$1s^2 \ 2s^1$	$1s^2 \ 2s^2$	$1s^2 \ 2s^2 \ 2p^1$	$1s^2 \ 2s^2 \ 2p^2$	$1s^2 \ 2s^2 \ 2p^3$	$1s^2 \ 2s^2 \ 2p^4$	$1s^2 \ 2s^2 \ 2p^5$
Z^* :	1,30	1,99	2,60	3,25	3,90	4,55	5,20

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In the periodic table, in A groups, the covalent and metallic radius increase from top to bottom. Because, the effective nuclear charge decreases and the shielding increases.

Z^* :	$\frac{Li}{1,30}$	$\frac{Na}{2,30}$	$\frac{K}{2,20}$	$\frac{Rb}{1,90}$
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reverse order for these two

When moving from left to right in transition metals, the atomic radius decreases as expected. However, there are some deviations in the atomic radius when moving from left to right. The first one is seen in the 1st row transition metals. In the 1st row transition metals, the radius increases to the middle of the row. The increase in the radius is due to the symmetry of the 3d orbitals. The metal atoms in the crystal structure generally have an octahedral environment. In an octahedral geometry, d orbitals are divided into two groups as t_{2g} and e_g . After Fe, the electrons begin to enter into e_g orbitals, and since the electrons in the e_g orbitals are less pulled by the nucleus, the radius increases after Fe. Radius from top to bottom increases as expected.

However, there is a large increase between the 4th and 5th periods and a lower increase between the 5th and 6th periods. This is due to the lanthanide contraction.

Radius of transition metals

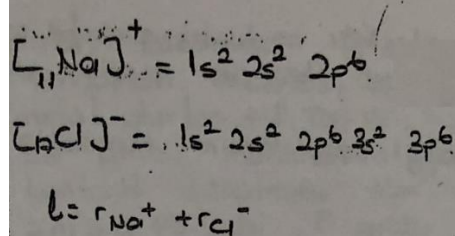
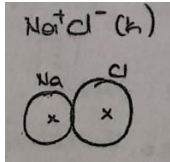
Period	IIB	IVB	VB	VIB	VIIIB	VIIIB			IB	IIB
4 th	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
	162	147	134	127	126	126	125	124	128	138
5 th	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd
	180	160	146	139	136	134	134	137	144	154
6 th	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg
	187	162	146	139	137	135	136	138	144	157

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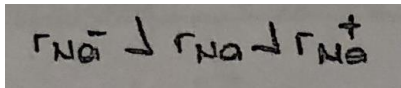
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Ionic Radius

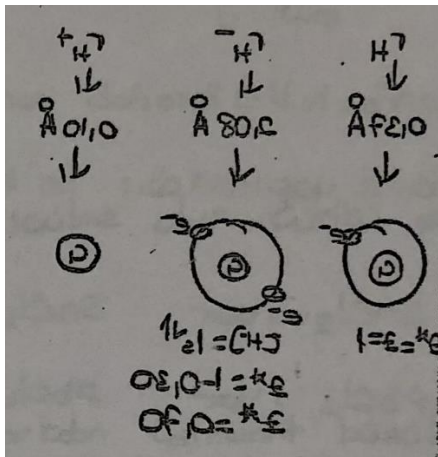
It is the radius in which the ions appear to have in ionic crystals.



The radius of Na^+ in NaCl and the radius of NaNO_3 is different. Negatively charged ions have a larger radius. The positively charged ones have a smaller radius.



186 pm 102 pm



$$r_{\text{H}^-} > r_{\text{H}} > r_{\text{H}^+}$$

effective nucleus charge increases, radius decreases

The covalent radius of the Fe atom is 117 pm

The ionic radius of the Fe^{2+} is 78 pm

The ionic radius of the Fe^{3+} is 64.5 pm

The covalent radius of Cl atom is 99 pm

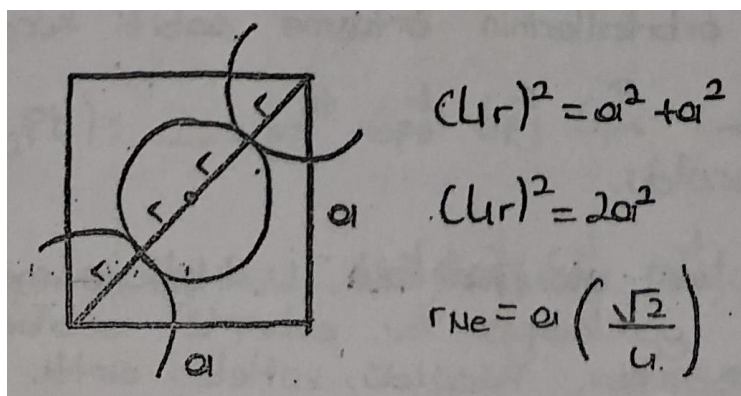
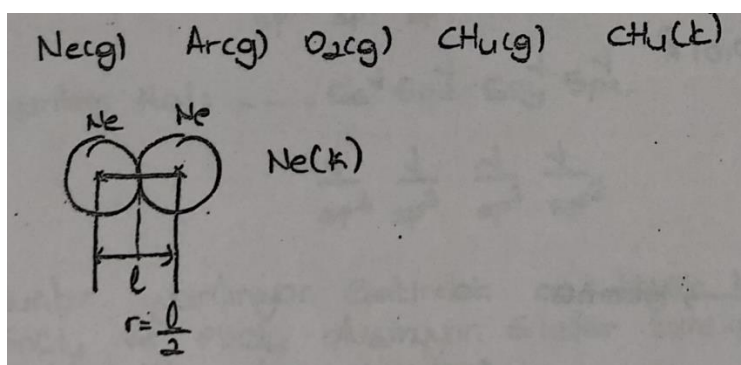
The ionic radius of Cl^- is 184 pm

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Van der Waals Radius

Van der Waals radius can be written for all molecules, atoms and inert gases. It is the distance between the nucleus and the valence electrons, which is the shortest distance where the 2 atoms approach each other in inert gases, or it is the distance that the minimum force which applied by the nucleus to the valence electrons can reach, or it is the distance between the nucleus and the atomic body where the electron density is zero, or it is the distance where possibility of an existence of the nucleus and electron is the lowest in the atomic body. Van der Waals radius is the largest one.



THE LANTHANIDE CONTRACTION

The lanthanide contraction describes the atomic radius trend that the lanthanide series exhibit and applies to all 14 elements included in the lanthanide series. The decrease in radius in the lanthanide series is called lanthanide contraction. In this series, the difference between the radii of two consecutive metals is about $\sim 0.01 \text{ \AA}$, and this value is less than the difference between the radii of two consecutive metals in other periods. There are 2 electrons in the s orbital of the lanthanides. While moving from left to right, the principal quantum number remains constant and electrons enter the f orbitals. Since the shielding effect of electrons in f orbitals are small, so, as the atomic number increases, the effective nuclear charge increases. Increasing the effective nuclear charge also decreases the radius. While moving from left to right, since the difference between the radii of metals is small, the lanthanides have similar characteristics. The lanthanide contraction affects the properties of 3rd row transition metals. When moving down transition metals, the difference between the radius of the 2nd and 3rd row transition metals is smaller than the difference between the radius of the 1st and 2nd row transition metals. The most striking example of this is that the radius of Zr (160 pm) and the radius of Hf (162 pm) metals remain almost the same. The radius of 4d transition metals and 5d transition metals are approaching to each other and therefore their sublimation enthalpies approach each other. The radius of the element is getting smaller, its mass is increasing and its density is increasing and it becomes the heaviest metal. Hf, Ta, W, Au and Hg are the heaviest metals.

