CHAPTER 3

Classification of Elements and Periodicity in Properties

Key Notes and Formulae

Ionic Radius

Size of the anion is larger than the parent atom while size of the cation is smaller than the parent atom. In case of iso-electronic ions, the higher the nuclear charge, smaller is the size, e.g., $Al^{3+} < Mg^{2+} < Na^{+} < F^{-} < O^{2-} < N^{3-}$.

The order of radii is :

covalent radius < metallic radius < van der Waal's radius.

Ionisation Enthalpy (IE)

It is the amount of energy required to remove the loosely bound electron from the isolated gaseous atom.

Various factors with which IE varies are:

i. Atomic size : varies inversely

ii. Screening effect : varies inversely

iii. Nuclear charge : varies directly

Electron Gain Enthalpy

It is the amount of energy released when an electron is added in an isolated gaseous atom.

Various factors with which electron gain enthalpy varies are:

i. Atomic size : varies directly

iii. Nuclear charge : varies directly

Electronegativity

It is defined as the tendency of an atom to attract the shared electron pair towards itself in a covalent bond. Various factors with which electronegativity varies are :

i. Atomic size : varies inversely

ii. Charge on the ion : varies directly

iii. Hybridisation : varies directly on the s - character in the hybrid orbital.

Valency

It is defined as the combining capacity of the element.

Chemical Reactivity

Reactivity of metal increases with decrease in IE, electronegativity and increase in atomic size as well as electropositive character.

Melting and Boiling Points

On moving down the group, the melting point and boiling point for metallic elements go on decreasing due to the decreasing forces of attraction. However, for non-metals, melting point and boiling point generally increase down the group.

Electropositivity or Metallic Character

The tendency of an atom of the element to lose valence electrons and form positive ion is called electropositivity. Greater the electropositive character, greater is the metallic character. Electropositive character decrease on moving across the period and increases on moving down the group.

Diagonal Relationship

Certain elements of 2nd period show similariy in properties with their diagonal elements in the 3rd period.

Group	1	2	13	14
2nd period	Li	Be	B	C
3rd period	Na	Mg	Al	Si

Previous Years' Questions

NEET

1. The correct increasing order of trans-effect of the following species is **[July 2016]**

(a) $CN^- > Br^- > C_6H_5^- > NH_3$

(b) $NH_3 > CN^- > Br^- > C_6H_5^-$

(c) $CN^- > C_6H_5^- > Br^- > NH_3$

(d) $Br^- > CN^- > NH_3 > C_6H_5^-$

2. In which of the following options the order arrangement does not agree with the variation property indicated against it? **[May 2016]**

(a) $Al^{3+} < Mg^{2+} < Na^+ < F^-$ (increasing ionic size)

(b) B<C<N<O (increasing first ionisation enthalpy)

(c) I<Br<Cl<F (Increasing electron gain enthalpy)

(d) Li<Na<K<Rb (increasing metallic radius)

AIPMT

3. The species Ar, K^+ and Ca^{2+} contain the same number of electrons. In which order do their radii increase? **[2015]**

(a) $Ca^{2+} < K^+ < Ar$ (b) $K^+ < Ar < Ca^{2+}$

(c) $Ar < K^+ < Ca^{2+}$ (d) $Ca^{2+} < Ar < K^+$

4. Which of the following orders of ionic radii is correctly represented ? **[2014]**

(a) $H^- > H^+ > H$

(b) $Na^+ > F^- > O^{2-}$

(c) $F^- > O^{2-} > Na^+$

(d) $Al^{3+} > Mg^{2+} > N_3^-$

5. What is the value of electron gain enthalpy of Na^+ if IE_1 of Na = 5.1 eV? **[2011]**

(a) -5.1 eV (b) -10.2 eV

(c) +2.55 eV (d) + 10.2 eV

6. The correct order of the decreasing ionic radii among the following isoelectronic species is **[2010]**

(a) $Ca^{2+} > K^+ > S^{2-} > Cl^-$

(b) $Cl^- > S^{2-} > Ca^{2+} > K^+$

(c) $S^{2-} > Cl^- > K^+ > Ca^{2+}$

(d) $K^+ > Ca^{2+} > Cl^- > S^{2-}$

7. Which of the following represents the correct order of increasing electron gain enthalpy with negative sign for the elements O, S, F and Cl ? **[2010]**

(a) Cl <F<O<S (b) O<S<F<Cl

(c) F <S<O<Cl (d) S<O<Cl<F

8. Among the elements Ca, Mg, P and Cl, the order of increasing atomic radii is **[2010]**

(a) Mg <Ca<Cl<P

(b) Cl< P<Mg<Ca

(c) P<Cl<Ca<Mg

(d) Ca<Mg<P<Cl

9. Among the following which one has the highest cation to anion size ratio? **[2010]**

(a) CsI (b) CsF

(c) LiF (d) NaF

10. Amongst the elements with the following electronic configurations, which one of them may have the highest ionisation energy ? **[2009]**

(a) Ne[$3s^2 3p^2$] (b) Ar[$3d^{10} 4s^2 4p^3$]

(c) Ne[$3s^2 3p^1$] (d) Ne[$3s^2 3p^3$]

Answer key

1.	(c)	2.	(b&c)	3.	(a)	4.	(NA)	5.	(a)
6.	(c)	7.	(b)	8.	(b)	9.	(b)	10.	(d)

Detailed Solutions

1. (c). Trans effect: The intensity of trans effect depend on increase in rate of substitution of the trans ligand.

$F^- < NH_3 < Cl^- < Br^- < Ph^- < CH_3^- < CN^-$

2. (b&c)

(b) B <C<N<O (given I.P order)

B <C<O<N (correct)

(c) I<Br<Cl<F (given ΔH_{eg} order)

Li< Br< F< Cl (correct)

3. (a). In case of isoelectric species, radius decreases with increase in nuclear charge.

4. (No option is correct).

It is known that radius of a cation is always smaller than that of a neural atom due to decrease in number of orbits,

Whereas, the radius of anion is always greater than a cation due to decrease in effective nuclear charge.

Hence the correct order is $H^- > H > H^+$

5. (a). $Na \rightarrow Na^+ + e^-$; ΔH = 5.1 eV

$Na^+ + e^- \rightarrow Na$; ΔH = - 5.1 eV

6. (c). ionic radii α charge on anion

$$\alpha \frac{1}{\text{charge on cation}}$$

When a cation is formed, e's are lost from outer shell and thus the remaining e's are attracted more towards the nucleus $\Rightarrow$ Radii decreases.

However, in case of anion formation, the addition of electron (s) takes place in the same outer shell, thus the hold of nucleus on the electrons of outer shell decrease and this results in increased ionic radii,

Thus, the correct order of ionic radii is

$S^{2-} > Cl^- > K^+ > Ca^{2+}$

7. (b). Electron gain enthalpy, generally increases in a period from left to right and decrease in a group on moving downwards, However, members of 111 period have somewhat higher electron gain enthalpy as compared to the corresponding members of second period, because of their small size.

O and S belong to VI A (16) group and Cl and F belong to VIIA (17) group. Thus the electron gain enthalpy of Cl and F is higher as compared to O and S.

Cl and F > O and S

Between Cl and F. Cl has higher electron gain enthalpy as in F, the incoming electron experiance a greater force of repulsion because of small size of F atom. Similar is true in case of O and S ie, the electron gain enthalpy of S is higher as compared to O due to it's small size. Thus, the correct order of electron gain enthalpy of given element is

O <S<F<Cl

8. (b). The atomic radii decrease on moving from left to right in a period . thus order of size for Cl P and Mg is Cl <P <Mg. Down the group size increases. Thus overall order is ; Cl<P<Mg<Ca

9. (b). The cation to anion size ratio will be maximum when the cation is of largest size and the

Answer key

1.	(c)	2.	(b&c)	3.	(a)	4.	(NA)	5.	(a)
6.	(c)	7.	(b)	8.	(b)	9.	(b)	10.	(d)

Detailed Solutions

1. (c). Trans effect: The intensity of trans effect depend on increase in rate of substitution of the trans ligand.

$F^- < NH_3 < Cl^- < Br^- < Ph^- < CH_3^- < CN^-$

2. (b&c)

(b) B <C<N<O (given I.P order)

B <C<O<N (correct)

(c) I<Br<Cl<F (given ΔH_{eg} order)

Li< Br< F< Cl (correct)

3. (a). In case of isoelectric species, radius decreases with increase in nuclear charge.

4. (No option is correct).

It is known that radius of a cation is always smaller than that of a neural atom due to decrease in number of orbits,

Whereas, the radius of anion is always greater than a cation due to decrease in effective nuclear charge.

Hence the correct order is $H^- > H > H^+$

5. (a). $Na \rightarrow Na^+ + e^-$; $\Delta H = 5.1$ eV

$Na^+ + e^- \rightarrow Na$; $\Delta H = -5.1$ eV

6. (c). ionic radii α charge on anion

$$\alpha \frac{1}{\text{charge on cation}}$$

When a cation is formed, e^-s are lost from outer shell and thus the remaining e^-s are attracted more towards the nucleus $\Rightarrow$ Radii decreases.

However, in case of anion formation, the addition of electron (s) takes place in the same outer shell, thus the hold of nucleus on the electrons of outer shell decrease and this results in increased ionic radii,

Thus, the correct order of ionic radii is

$S^{2-} > Cl^- > K^+ > Ca^{2+}$

7. (b). Electron gain enthalpy, generally increases in a period from left to right and decrease in a group on moving downwards, However, members of 111 period have somewhat higher electron gain enthalpy as compared to the corresponding members of second period, because of their small size.

O and S belong to VI A (16) group and Cl and F belong to VIIA (17) group. Thus the electron gain enthalpy of Cl and F is higher as compared to O and S.

Cl and F > O and S

Between Cl and F. Cl has higher electron gain enthalpy as in F, the incoming electron experiance a greater force of repulsion because of small size of F atom. Similar is true in case of O and S ie, the electron gain enthalpy of S is higher as compared to O due to it's small size. Thus, the correct order of electron gain enthalpy of given element is

O <S<F<Cl

8. (b). The atomic radii decrease on moving from left to right in a period . thus order of size for Cl P and Mg is Cl <P <Mg. Down the group size increases. Thus overall order is ; Cl<P<Mg<Ca

9. (b). The cation to anion size ratio will be maximum when the cation is of largest size and the

anion is of smallest size. Among the given cation Cs^+ has the largest size and F^- has smallest size among given anions, thus CsF has highest r_c/r_a ratio.

10. (d). Ne $[3s^2, 3p^3]$ has the highest ionisation energy because of extra stability associated with half-filled 3p - orbital. In option (b). The presence of $3d^{10}$electrons offers shielding effects, as a result the $4p^3$ electrons do not experience much nuclear charge and hence the electrons can be removed easily.