Chapter 3. Classification of Elements and Periodicity in Properties

1. The element $Z = 114$ has been discovered recently. It will belong to which of the following family/group and electronic configuration?
(a) Carbon family, [Rn] $5f^{14}\ 6d^{10}\ 7s^2\ 7p^2$
(b) Oxygen family, [Rn] $5f^{14}\ 6d^{10}\ 7s^2\ 7p^4$
(c) Nitrogen family, [Rn] $5f^{14}\ 6d^{10}\ 7s^2\ 7p^6$
(d) Halogen family, [Rn] $5f^{14}\ 6d^{10}\ 7s^2\ 7p^5$
(NEET 2017)

2. In which of the following options the order of arrangement does not agree with the variation of property indicated against it?
(a) I < Br < Cl < F (increasing electron gain enthalpy)
(b) Li < Na < K < Rb (increasing metallic radius)
(c) $Al^{3+} < Mg^{2+} < Na^+ < F^-$ (increasing ionic size)
(d) B < C < N < O (increasing first ionisation enthalpy) *(NEET-I 2016)*

3. The species Ar, K^+ and Ca^{2+} contain the same number of electrons. In which order do their radii increase?
(a) $Ca^{2+} < K^+ < Ar$ (b) $K^+ < Ar < Ca^{2+}$
(c) $Ar < K^+ < Ca^{2+}$ (d) $Ca^{2+} < Ar < K^+$
(2015, Cancelled)

4. Which of the following orders of ionic radii is correctly represented?
(a) $H^- > H^+ > H$ (b) $Na^+ > F^- > O^{2-}$
(c) $F^- > O^{2-} > Na^+$ (d) $Al^{3+} > Mg^{2+} > N^{3-}$
(2014)

5. Which one of the following arrangements represents the correct order of least negative to most negative electron gain enthalpy for C, Ca, Al, F and O?
(a) Al < Ca < O < C < F
(b) Al < O < C < Ca < F
(c) C < F < O < Al < Ca
(d) Ca < Al < C < O < F
(Karnataka NEET 2013)

6. Identify the wrong statement in the following.
(a) Amongst isoelectronic species, smaller the positive charge on the cation, smaller is the ionic radius.
(b) Amongst isoelectronic species, greater the negative charge on the anion, larger is the ionic radius.
(c) Atomic radius of the elements increases as one moves down the first group of the periodic table.
(d) Atomic radius of the elements decreases as one moves across from left to right in the 2nd period of the periodic table.
(2012)

7. What is the value of electron gain enthalpy of Na^+ if IE_1 of Na = 5.1 eV?
(a) –5.1 eV (b) –10.2 eV
(c) +2.55 eV (d) +10.2 eV
(Mains 2011)

8. The correct order of the decreasing ionic radii among the following isoelectronic species is
(a) $Ca^{2+} > K^+ > S^{2-} > Cl^-$
(b) $Cl^- > S^{2-} > Ca^{2+} > K^+$
(c) $S^{2-} > Cl^- > K^+ > Ca^{2+}$
(d) $K^+ > Ca^{2+} > Cl^- > S^{2-}$ *(2010)*

9. Which of the following represents the correct order of increasing electron gain enthalpy with negative sign for the elements O, S, F and Cl?
(a) Cl < F < O < S (b) O < S < F < Cl
(c) F < S < O < Cl (d) S < O < Cl < F
(2010)

10. Among the elements Ca, Mg, P and Cl, the order of increasing atomic radii is
(a) Mg < Ca < Cl < P (b) Cl < P < Mg < Ca
(c) P < Cl < Ca < Mg (d) Ca < Mg < P < Cl
(Mains 2010)

11. Among the following which one has the highest cation to anion size ratio?
(a) CsI (b) CsF (c) LiF (d) NaF
(Mains 2010)

12. Amongst the elements with following electronic configurations, which one of them may have the highest ionisation energy?

(a) Ne $[3s^2\ 3p^2]$ (b) Ar $[3d^{10}\ 4s^2\ 4p^3]$
(c) Ne $[3s^2\ 3p^1]$ (d) Ne $[3s^2\ 3p^3]$
(2009)

13. Which one of the following arrangements does not give the correct picture of the trends indicated against it?
(a) $F_2 > Cl_2 > Br_2 > I_2$: Bond dissociation energy
(c) $F_2 > Cl_2 > Br_2 > I_2$: Electronegativity
(c) $F_2 > Cl_2 > Br_2 > I_2$: Oxidizing power
(d) $F_2 > Cl_2 > Br_2 > I_2$: Electron gain enthalpy
(2008)

14. Identify the correct order of the size of the following:
(a) $Ca^{2+} < K^+ < Ar < Cl^- < S^{2-}$
(b) $Ar < Ca^{2+} < K^+ < Cl^- < S^{2-}$
(c) $Ca^{2+} < Ar < K^+ < Cl^- < S^{2-}$
(d) $Ca^{2+} < K^+ < Ar < S^{2-} < Cl^-$ *(2007)*

15. With which of the following electronic configuration an atom has the lowest ionisation enthalpy?
(a) $1s^2\ 2s^2\ 2p^3$ (b) $1s^2\ 2s^2\ 2p^5\ 3s^1$
(c) $1s^2\ 2s^2\ 2p^6$ (d) $1s^2\ 2s^2\ 2p^5$
(2007)

16. Which one of the following ionic species has the greatest proton affinity to form stable compound?
(a) NH_2^- (b) F^- (c) I^- (d) HS^-
(2007)

17. Which one of the following orders is not in accordance with the property stated against it?
(a) $F_2 > Cl_2 > Br_2 > I_2$: Bond dissociation energy
(b) $F_2 > Cl_2 > Br_2 > I_2$: Oxidising power
(c) HI > HBr > HCl > HF : Acidic property in water
(d) $F_2 > Cl_2 > Br_2 > I_2$: Electronegativity
(2006)

18. Which one of the following arrangements represents the correct order of electron gain enthalpy (with negative sign) of the given atomic species?
(a) S < O < Cl < F (b) Cl < F < S < O
(c) F < Cl < O < S (d) O < S < F < Cl
(2005)

19. Ionic radii are
(a) inversely proportional to effective nuclear charge
(b) inversely proportional to square of effective nuclear charge
(c) directly proportional to effective nuclear charge
(d) directly proportional to square of effective nuclear charge. *(2004)*

20. The ions O^{2-}, F^-, Na^+, Mg^{2+} and Al^{3+} are isoelectronic. Their ionic radii show
(a) a significant increase from O^{2-} to Al^{3+}
(b) a significant decrease from O^{2-} to Al^{3+}
(c) an increase from O^{2-} to F^- and then decrease from Na^+ to Al^{3+}
(d) a decrease from O^{2-} to F^- and then increase from Na^+ to Al^{3+}. *(2003)*

21. Which statement is wrong?
(a) Bond energy of $F_2 > Cl_2$
(b) Electronegativity of F > Cl
(c) F is more oxidising than Cl
(d) Electron affinity of Cl > F *(2000)*

22. Which of the following elements has the maximum electron affinity?
(a) I (b) Br (c) Cl (d) F
(1999)

23. The first ionization potentials (eV) of Be and B respectively are
(a) 8.29, 8.29 (b) 9.32, 9.32
(c) 8.29, 9.32 (d) 9.32, 8.29
(1998)

24. Which one of the following is correct order of the size of iodine species?
(a) $I^+ > I^- > I$ (b) $I^- > I > I^+$
(c) $I > I^- > I^+$ (d) $I > I^+ > I^-$
(1997)

25. Which of the following ion is the largest in size?
(a) K^+ (b) Ca^{2+} (c) Cl^- (d) S^{2-}
(1996)

26. Which of the following has the smallest size?
(a) Al^{3+} (b) F^- (c) Na^+ (d) Mg^{2+}
(1996)

27. The electronics configuration of an element is $1s^2 2s^2 2p^6 3s^2 3p^3$. What is the atomic number of the element, which is just below the above element in the periodic table?
(a) 33 (b) 34 (c) 36 (d) 49
(1995)

28. One would expect proton to have very large
(a) charge
(b) ionization potential
(c) hydration energy
(d) radius. *(1993)*

29. Na^+, Mg^{2+}, Al^{3+} and Si^{4+} are isoelectronic. the order of their ionic size is
(a) $Na^+ > Mg^{2+} < Al^{3+} < Si^{4+}$
(b) $Na^+ < Mg^{2+} > Al^{3+} > Si^{4+}$
(c) $Na^+ > Mg^{2+} > Al^{3+} > Si^{4+}$
(d) $Na^+ < Mg^{2+} > Al^{3+} < Si^{4+}$ *(1993)*

30. If the atomic number of an element is 33, it will be placed in the periodic table in the
(a) first group (b) third group
(c) fifth group (d) seventh group. *(1993)*

31. In the periodic table from left to right in a period, the atomic volume
(a) decreases
(b) increases
(c) remains same
(d) first decrease then increases. *(1993)*

32. Which electronic configuration of an element has abnormally high difference between second and third ionization energy?
(a) $1s^2, 2s^2, 2p^6, 3s^1$
(b) $1s^2, 2s^2, 2p^6, 3s^1 3p^1$
(c) $1s^2, 2s^2, 2p^6, 3s^2 3p^2$
(d) $1s^2, 2s^2, 2p^6, 3s^2$ *(1993)*

33. One of the characteristic properties of non-metals is that they
(a) are reducing agents
(b) form basic oxides
(c) form cations by electron gain
(d) are electronegative. *(1993)*

34. Pauling's electronegativity values for elements are useful in predicting
(a) polarity of the molecules
(b) position in the E.M.F. series
(c) coordination numbers
(d) dipole moments. *(1989)*

35. The electronic configuration of four elements are given below. Which elements does not belong to the same family as others?
(a) $[Xe]4f^{14}5d^{10}1s^2$
(b) $[Kr]4d^{10}5s^2$
(c) $[Ne]3s^2 3p^5$
(d) $[Ar]3d^{10}4s^2$ *(1989)*

36. In the periodic table, with the increase in atomic number, the metallic character of an element
(a) decreases in a period and increases in a group
(b) increases in a period and decreases in a group
(c) increases both in a period and the group
(d) decreases in a period and the group. *(1989)*

Answer Key

1.	(a)	**2.**	(a, d)	**3.**	(a)	**4.**	(None)		**5.**	(d)	**6.**	(a)	**7.**	(a)	**8.**	(c)	**9.**	(b)
10.	(b)	**11.**	(b)	**12.**	(d)	**13.**	(a, d)	**14.**	(a)	**15.**	(b)	**16.**	(a)	**17.**	(a)	**18.**	(d)	**19.**	(a)
20.	(b)	**21.**	(a)	**22.**	(c)	**23.**	(d)	**24.**	(b)	**25.**	(d)	**26.**	(a)	**27.**	(a)	**28.**	(c)	**29.**	(c)
30.	(c)	**31.**	(d)	**32.**	(d)	**33.**	(d)	**34.**	(a)	**35.**	(c)	**36.**	(a)						

EXPLANATIONS

1. (a) : The electronic configuration of the element with $Z = 114$ (flerovium) is $[Rn]5f^{14}\ 6d^{10}7s^{2}7p^{2}$.
Hence, it belongs to carbon family which has the same outer electronic configuration.

2. (a, d) : The correct order of increasing negative electron gain enthalpy is : I < Br < F < Cl and the correct order of increasing first ionisation enthalpy is B < C < O < N.

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

4. (None) : Cations lose electrons and are smaller in size than the parent atom, whereas anions add electrons and are larger in size than the parent atom. Hence, the order is $H^- > H > H^+$.
For isoelectronic species, the ionic radii decreases with increase in atomic number *i.e.* nuclear charge. Hence, the correct orders are
$O^{2-} > F^- > Na^+$ and $N^{3-} > Mg^{2+} > Al^{3+}$.

5. (d) : Electron gain enthalpy becomes less negative from top to bottom in a group while it becomes more negative from left to right within a period.

6. (a) : As positive charge on the cation increases, effective nuclear charge increases. Thus atomic size decreases.

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

8. (c) : $S^{2-} > Cl^- > K^+ > Ca^{2+}$
Among isoelectronic species, ionic radii increases with increase in negative charge. This happens because effective nuclear charge (Z_{eff}) decreases.
Similarly, ionic radii decreases with increase in positive charge as Z_{eff} increases.

9. (b) : Cl atom has the highest electron affinity in the periodic table. F being a member of group 17 has higher electron gain enthalpy than S which belongs to group 16. This in turn is higher than the electron affinity of O atom. Thus,
Cl > F > S > O
It is worth noting that the electron gain enthalpy of oxygen and fluorine, the members of the second period, have less negative values than the elements sulphur and chlorine of the third period.
This is due to small size of the atoms of oxygen and fluorine. As a result, there is a strong inter-electronic repulsion when extra electron is added to these atoms, *i.e.*, electron density is high and the addition of an extra electron is not easy.

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

11. (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 species, Cs^+ has maximum size among given cations and F^- has smallest size among given anions, thus CsF has highest r_c/r_a ratio.

12. (d) : Among options (a), (c) and (d), option (d) has the highest ionisation energy because of extra stability associated with half-filled 3*p*-orbital. In option (b), the presence of $3d^{10}$ electrons offers shielding effect, as a result the $4p^3$ electrons do not experience much nuclear charge and hence the electrons can be removed easily.

13. (a,d) : In case of diatomic molecules (X_2) of halogens the bond dissociation energy decreases in the order :
$Cl_2 > Br_2 > F_2 > I_2$
The oxidising power, electronegativity and reactivity decrease in the order :
$F_2 > Cl_2 > Br_2 > I_2$
Electron gain enthalpy of halogens follows the given order :
$Cl_2 > F_2 > Br_2 > I_2$
The low value of electron gain enthalpy (electron enthalpy) of fluorine is probably due to small size of fluorine atom.

14. (a) : Among isoelectronic ions, ionic radii of anions is more than that of cations. Further size of the anion increases with increase in negative charge and size of the cation decreases with increase in positive charge.

15. (b) : The larger the atomic size, smaller is the value of the ionisation enthalpy. Again higher the screening effect, lesser is the value of ionisation potential. Hence option (b) has lowest ionisation enthalpy.

16. (a) : In going from left to right across a period in the periodic table, the basicity (*i.e.* proton affinity) decreases as the electronegativity of the atom possessing the lone pair of electrons increases. Hence basicity of NH_2^- is higher than F^-. In moving down a group, as the atomic mass increases, basicity decreases. Hence F^- is more basic than I^- and HO^- is more basic than HS^-. Hence among the given ionic species, NH_2^- has maximum proton affinity.

17. (a) :

$X-X$ bond	F – F	Cl – Cl	Br – Br	I – I
Bond dissociation energy (kcal/mol)	38	57	45.5	35.6

The lower value of bond dissociation energy of fluorine is due to the high inter-electronic repulsion between non-bonding electrons in the 2*p*-orbitals of fluorine. As a result F – F bond is weaker in comparison to Cl – Cl and Br – Br bonds.

18. (d) : The molar enthalpy change accompanying the addition of an electron to an atom (or ion) is known as electron gain enthalpy.

Generally it increases on moving from left to right in a period and in a group it decreases as the size increases.

Exception: Because of the small size of F, electron-electron repulsion present in its relatively compact 2*p*-subshell, do not easily allow the addition of an extra electron. On the other hand, Cl because of its comparatively bigger size than F, allows the addition of an extra electron more easily.

O	<	S	<	F	<	Cl
–1.48		–2.0		–3.6		–3.8

19. (a) : Ionic radius in the n^{th} orbit is given by

$$r_n = \frac{n^2 a_0}{Z^*} \quad \text{or,} \quad r_n \propto \frac{1}{Z^*}$$

Where n is principal quantum number, a_0 the Bohr's radius of H-atom and Z^*, the effective nuclear charge.

20. (b) : Amongst isoelectronic ions, ionic radii of anions is more than that of cations. Further size of the anion increases with increase in –ve charge and size of cation decreases with increase in +ve charge. Hence, correct order is

$O^{2-} > F^- > Na^+ > Mg^{2+} > Al^{3+}$.

21. (a) : Due to more repulsion in between non-bonding electron pair (2*p*) of two fluorines (due to small size of F-atom) in comparison to non-bonding electron pair (3*p*) in chlorine, the bond energy of F_2 is less than Cl_2.

$BE\ (F_2) = 158 \cdot 5$ kJ/mole and

$BE\ (Cl_2) = 242 \cdot 6$ kJ/mole.

22. (c) : Among the halogens the electron affinity value of 'F' should be maximum. But due to small size the 7-electrons in its valence shell are much more crowded, so that it feels difficulty in entry of new electrons. Thus, the E.A. value is slightly lower than chlorine and the order is

I < Br < F < Cl.

23. (d) : $_4Be \rightarrow 1s^2\ 2s^2$, $_5B \rightarrow 1s^2\ 2s^2\ 2p^1$

Due to stable fully-filled '*s*'-orbital arrangement of electrons in 'Be' atom, more energy is required to remove an electron from the valence shell than 'B'atom. Therefore 'Be' has higher ionisaton potential than 'B'.

24. (b) : Positive ion is always smaller and negative ion is always larger than the parent atom.

25. (d) : Since all of these ions contain 18 electrons each, so these are isoelectronic. For isoelectronic ions, smaller the positive nuclear charge, greater is the size of the ion.

26. (a) : These are isoelectronic ions (ions with same number of electrons) and for isoelectronic ions, greater the positive nuclear charge, greater is the force of attraction on the electrons by the nucleus and the smaller is the size of the ion. Thus Al^{3+} has the smallest size.

27. (a) : Atomic no. of given element = 15, thus it belongs to 5^{th} group.

Now, atomic no. of the element below the above element = 15 + 18 = 33

28. (c) : Proton (H^+) being very small in size would have very large hydration energy.

29. (c) : In isoelectronic ions, the size of the cation decreases as the magnitude of the positive charge increases.

30. (c) : Electronic configuration of an element is

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^3$

Hence it lies in fifth or 15^{th} group.

31. (d) : Atomic volume is the volume occupied by one gram of an element. Within a period from left to right, atomic volume first decreases and then increases.

32. (d) : Abnormally high difference between 2^{nd} and 3^{rd} ionisation energy means that the element has two valence electrons, which is a case in configuration (d).

33. (d)

34. (a) : Pauling introduced the electronegativity concept. He introduced the idea that the ionic character of a bond varies with the difference in electronegativity. A large difference in electronegativity leads to a bond with high degree of polar character, *i.e.* the bond is predominantly ionic or vice versa.

35. (c) : Elements (a), (b) and (d) belong to the same group since each one of them has two electrons in valence shell. In contrast, element (c) has seven electrons in the valence shell, and hence it lies in other group.

36. (a) : Metallic character decreases in a period and increases in a group.