CLASSIFICATION OF ELEMENTS & PERIODICITY OF PROPERTIES
[JEE ADVANCED PREVIOUS YEAR SOLVED PAPERS]

JEE Advanced

Single Correct Answer Type

1. The hydration energy of Mg^{2+} is larger than that of

a. Al^{3+} **b.** Na^{+}

c. Be^{2+} **d.** Mg^{3+} **(IIT-JEE 1984)**

2. The first ionization potential in electron volts of nitrogen and oxygen atoms are respectively given by

a. 14.6, 13.6 **b.** 13.6, 14.6

c. 13.6, 13.6 **d.** 14.6, 14.6

(IIT-JEE 1987)

3. Atomic radii of fluorine and neon in Angstrom units are respectively given by
   a. 0.72, 1.60 **b.** 1.60, 1.60
   c. 0.72, 0.72 **d.** none of these
   (IIT-JEE 1987)
4. The electronegativity of the following elements increases in the order:
   a. C, N, Si, P **b.** N, Si, C, P
   c. Si, P, C, N **d.** P, Si, N, C
   (IIT-JEE 1987)
5. The first ionization potentials of Na, Mg, Al and Si are in the order:
   a. Na < Mg > Al < Si **b.** Na > Mg > Al > Si
   c. Na < Mg < Al > Si **d.** Na > Mg > Al < Si
   (IIT-JEE 1988)
6. Which one of the following is the smallest in size?
   a. N^{3-} **b.** O^{2-} **c.** F^- **d.** Na^+
   (IIT-JEE 1989)
7. Among the following elements (whose electronic configurations are given below), the one having the highest ionization energy is
   a. $[Ne]3s^2 3p^1$ **b.** $[Ne]3s^2 3p^3$
   c. $[Ne]3s^2 3p^2$ **d.** $[Ar]3d^{10} 4s^2 4p^3$
   (IIT-JEE 1990)
8. The statement that is not correct for the periodic classification of elements is
   a. The properties of elements are the periodic functions of their atomic numbers.
   b. Non-metallic elements are lesser in number than metallic elements.
   c. The first ionization energies of elements along a period do not vary in a regular manner with increases in atomic number
   d. For transition elements the d-subshells are filled with electrons monotonically with increase in atomic number. **(IIT-JEE 1992)**
9. Which has most stable +2 oxidation state?
   a. Sn **b.** Pb **c.** Fe **d.** Ag
   (IIT-JEE 1995)
10. Which of the following has the maximum number of unpaired electrons?
    a. Mg^{2+} **b.** Ti^{3+} **c.** V^{3+} **d.** Fe^{2+}
    (IIT-JEE 1996)
11. The correct statement among the following is
    a. The first ionisation potential of Al is less than the first ionisation potential of Mg
    b. The second ionisation potential of Mg is greater than the second ionisation potential of Na
    c. The first ionisation potential of Na is less than the first ionisation potential of Mg
    d The third ionisation of Mg is greater than third ionisation potential of Al **(IIT-JEE 1997)**
12. Which of the following compounds is expected to be coloured?
    a. Ag_2SO_4 **b.** CuF_2 **c.** MgF_2 **d.** CuCl
    (IIT-JEE 1997)
13. The correct order of radii is
    a. N < Be < B **b.** $F^- < O^{2-} < N^{3-}$
    c. Na < Li < K **d.** $Fe^{3+} < Fe^{2+} < Fe^{4+}$
    (IIT-JEE 2000)
14. The set representing the correct order of first ionization potential is
    a. K > Na > Li **b.** Be > Mg > Ca
    c. B > C > N **d.** Ge > Si > C
    (IIT-JEE 2001)
15. Which of the following represent the correct order of increasing IE_1 for Ca, Ba, S, Se and Ar?
    a. S < Se < Ca < Ba < Ar **b.** Ba < Ca < Se < S < Ar
    c. Ca < Ba < S < Se < Ar **d.** Ca < S < Ba < Se < Ar
    (JEE Advanced 2013)

Multiple Correct Answers Type

1. The statements that are true for the long form of the periodic table are:
   a. If reflects the sequence of filling the electrons in the order of sub-energy level *s*, *p*, *d* and *f*
   b. It helps to predict the stable valency states of the elements
   c. It reflects tends in physical and chemical properties of the elements
   d. It helps to predict the relative ionicity of the bond between any two elements **(IIT-JEE 1988)**
2. Sodium sulphate is soluble in water whereas barium sulphate is sparingly soluble because:
   a. The hydration of sodium sulphate is more than its lattice energy
   b. The lattice energy of barium sulphate is more than its hydration energy
   c. The lattice energy has no role to play in solubility
   d. The hydration energy of sodium sulphate is less than its lattice energy **(IIT-JEE 1989)**
3. Ionic radii of:
   a. $Ti^{4+} < Mn^{7+}$ **b.** $^{35}Cl^- < ^{37}Cl^-$
   c. $K^+ > Cl^-$ **d.** $p^{3+} > p^{5+}$
   (IIT-JEE 1999)

Assertion-Reasoning Type

1. **Assertion:** F atom has a less negative electron affinity than Cl atom
   Reason: Additional electrons are repelled more effectively by 3*p* electrons in Cl atom than by 2*p* electrons in F atom
   a. If both assertion and reason are correct, and reason is the correct explanation of the assertion.
   b. If the assertion and reason are correct, but reason is not the correct explanation of the assertion.
   c. If assertion is correct but reason is incorrect.
   d. If assertion is incorrect but reason is correct.
   (IIT-JEE 1998)

2. **Assertion:** The first ionisation energy of Be is greater than that of B
Reason: $2p$ orbital is lower in energy than $2s$
   a. If both assertion and reason are correct, and reason is the correct explanation of the assertion.
   b. If the assertion and reason are correct, but reason is not the correct explanation of the assertion.
   c. If assertion is correct but reason is incorrect.
   d. If assertion is incorrect but reason is correct.
(IIT-JEE 2000)

Fill in the Blanks Type

1. The energy released when an electron is added to a neutral gaseous atom is called _____ of the atom. **(IIT-JEE 1982)**
2. On Mulliken scale, the average of ionization potential and electron affinity is known as _____. **(IIT-JEE 1985)**
3. Ca^{2+} has a smaller ionic radius than K^+ because it has _____. **(IIT-JEE 1993)**
4. Compounds that formally contain Pb^{4+} are easily reduced to Pb^{2+}. The stability of the lower oxidation state is due to _____. **(IIT-JEE 1997)**

True / False Type

1. The softness of group IA metals increases down the group with increasing atomic number. **(IIT-JEE 1986)**
2. In group IA of alkali metals, the ionization potential decreases down the group. Therefore, lithium is a poor reducing agent. **(IIT-JEE 1987)**
3. The decreasing order of electron affinity of F, Cl, Br is F > Cl > Br **(IIT-JEE 1993)**
4. The basic nature of the hydroxides of group 13 (Gr. III B) decreases progressively down the group. **(IIT-JEE 1993)**

Subjective Type

1. Arrange the following in order of their
   i. Decreasing ionic size Mg^{2+}, O^{2-}, Na^+, F^-
   ii. Increasing first ionization energy Mg, Al, Si, Na
   iii. Increasing bond length F_2, N_2, Cl_2, O_2
(IIT-JEE 1985)
2. Arrange the following in the order of their increasing size:
   Cl^-, S^{2-}, Ca^{2+}, Ar **(IIT-JEE 1986)**
3. Explain the following:
"The first ionization energy of carbon atom is greater than that of boron atom, whereas the reverse is true for the second ionization energy." **(IIT-JEE 1989)**
4. Arrange the following as stated: **(IIT-JEE 1991)**
"Increasing order of ionic size"
   N^{3-}, Na^+, F^-, O^{2-}, Mg^{2+}
5. Compare qualitatively the first and second ionization potentials of copper and zinc. Explain the observation. **(IIT-JEE 1996)**
6. Arrange the following ions in order of their increasing radii **(IIT-JEE 1997)**
   Li^+, Mg^{2+}, K^+, Al^{3+}

Answer Key

JEE Advanced

Single Correct Answer Type

1. b.	**2.** a.	**3.** a.	**4.** c.	**5.** a.
6. d.	**7.** b.	**8.** d.	**9.** b.	**10.** d.
11. b.	**12.** b.	**13.** b.	**14.** b.	**15.** b.

Multiple Correct Answers Type

1. a., c., d. **2.** a., b. **3** d.

Assertion–Reasoning Type

1. c. **2.** c.

Fill in the Blanks Type

1. Electron affinity
2. Electronegativity
3. Higher effective nuclear charge
4. Inert pair effect

True/False Type

1. True	**2.** False	**3.** False	**4.** False

Hints and Solutions

JEE Advance

Single Correct Answer Type

1. b. The hydration energy of Mg^{2+} is large than of Na^+. Because

hydration energy $\propto \frac{1}{\text{size}}$ and size is

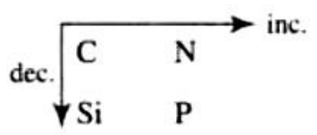
$$Be^{2+} < Al^{3+} < Mg^{2+} < Na^{+}$$

2. a. The first ionization potential of N > O because of extra stability gained by half-filled *p*-orbital of N so N doesn't want to lose e^- and go to unstable state.

$$N_7 = 1s^2, 2s^2, 2p_x^1, 2p_y^1, 2p_z^1$$
$$O_8 = 1s^2, 2s^2, 2p_x^2, 2p_y^1, 2p_z^1$$

3. a. Atomic size of fluorine is its covalent radius, while, the atomic size of neon is its van der Waals' radius. As noble gases are not involved in bond formation so their van der Waals' radii is measured.

4. c. Electronegativity increases from left to right across a period, while it decreases from top to bottom in a group of the periodic table.



$\Rightarrow N > C > P > Si$

5. a. First ionization potential increases from left to right across a period. But Mg has extra stability than Al, due to full-filled 3s-orbitals. Second it is difficult to remove electron from Mg due to more penetration of 3s electron.

$$Na_{11} = 1s^2, 2s^2, 2p^6, 3s^1$$
$$Mg_{12} = 1s^2, 2s^2, 2p^6, 3s^2$$
$$Al_3 = 1s^2, 2s^2, 2p^6, 3s^2, 3p^1$$
$$Si_{14} = 1s^2, 2s^2, 2p^6, 3s^2, 3p^2$$

Thus correct order of first ionization potential is:

$$Na < Mg > Al < Si$$

6. d. For isoelectronic ions

$$\text{Ionic size} \propto \frac{1}{\text{atomic number}}$$

	N^{3-}	O^{2-}	F^-	Na^+
Z	7	8	9	11
e^-	10	10	10	10

More $\frac{Z}{e}$, more is the force of attraction and smaller is the size.

7. b. Ionization energy increases with increasing atomic number in a period, while decreases on moving down the group.
(a) = Al (b) = P (c) = Si (d) = As.
Arrangement in periodic table

Al Si P
As

So, P has maximum I.E.

8. d. Among transition elements, electrons are not filled in *d*-sub-shell monotonically with increasing atomic number.

9. b. Pb^{2+} $(5d^{10}\ 6s^2)$, has the most stable +2 oxidation state because here the *d*-orbital is completely filled and is more stable than Fe^{2+} $(3d^6)$. Again Ag^+ $(4d^{10})$ is more stable as here again the *d*-orbital is completely filled and Ag^{2+} is not easily obtained. Pb^{2+} is more stable compared to Sn^{2+} $(4d^{10}\ 5s^2)$ because of its large size.

10. d. The electronic configuration of the given ions are as follows

$_{12}Mg^{2+} = 1s^2, 2s^2 2p^6$ (No unpaired electron)
$_{22}Ti^{3+} = 1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^1$ (One unpaired electron)
$_{23}V^{3+} = 1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^2$ (Two unpaired electrons)
$_{26}Fe^{2+} = 1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^6$ (Four unpaired electrons)

11. b. Ionisation potential or energy (IE) increases across a period but with certain breaks. IE_1 of Al $(3s^2\ p^1)$ is less than IE_1 of Mg, $(3s^2)$ as electron is to be removed from $3p$ which is easy as compared to $3s$. Further IE_3 shows the reverse trend because now for Al^{2+} $(3s^1)$ electron is to be removed from $3s$ as compared to the completely filled $2p$ orbitals in Mg^{2+}. The same becomes true for IE_2 of Na, hence option (b) is correct.

12. b. The electronic configurations of cations in the given salts are
Ag+$(4d^{10})$, $Cu^{2+}(3d^9)$, $Mg^{2+}(2s^2, 2p^6)$, $Cu^+(3d^{10})$
Only Cu^{2+} ion has one unpaired electron in $3d$ orbital. Hence, its salt is expected to be coloured.

13. b. These are iso-electronic species and their radii decreases with increasing their atomic number due to increasing effective nuclear charge (Z_{eff})

$$Z_{eff} = Z - \sigma$$

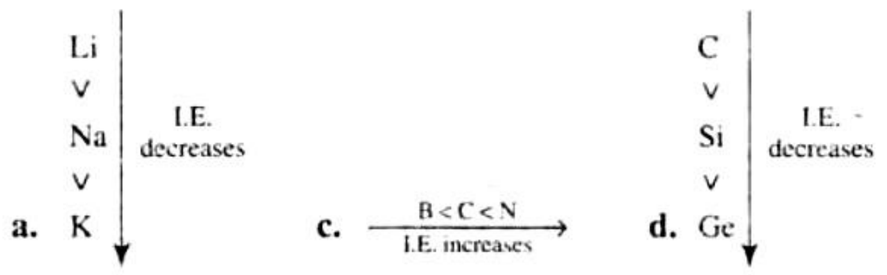
where Z = atomic number and σ = screening constant
For F^-, O^{2-} and N^{3-}, the value of σ is constant due to equal number of electrons. So, order of Z_{eff} is $F^- > O^{2-} > O^{3-}$. Hence, order of radii = $F^- < O^{2-} > O^{3-}$ $\left(\text{Radii} \propto \frac{1}{Z_{eff}}\right)$.

For (a) correct order
N < B < Be → size decreases

c. Li < Na < K ↓ size increases

d. $Fe^{4+} < Fe^{3+} < Fe^{2+}$ (more positive charge smaller radii)

14. b. Ionization potential decreases on moving from top to bottom in a group of periodic table.
Correct order of



15. b. IE_1 increases along the period and decreases down the group. Moreover Ar is inert gas, has completely filled $\bar{e}$'s (Stable structure), hence highest IE_1.

Ar (18 group, 3rd period) > S (16 group, 3rd period) > Se (16 group, 4th period) > Ca (2nd group, 4th period) > Ba (2nd group, 6th period)

Multiple Corrcect Answers Type

1. a., c., d.
In long form of periodic table, elements are arranged in increasing order of their atomic number (i.e., increasing order of energy).
Physical and chemical properties are proportional to the electronic configuration (i.e., atomic number) of element.

2. a., b.
$BaSO_4$ is sparingly soluble in water because its hydration energy is lesser than the lattice energy and thus ions are not separated from each other.
On the contrary in Na_2SO_4, the hydration energy is more than its lattice energy. Thus ions are separated from each other and pass in solution state.

3. d. Longer the positive (+) charge, lower will be radii.

Assertio-Reasoning Type

1. c. F atom has a less negative electron affinity than Cl-atom because additional electrons are repelled more effectively by $2p$-electrons in F-atom (due to small size) than by $3p$ electrons in Cl-atom.

2. c. Assertion is correct but reason is incorrect because more amount of energy is required for the removal of $2s$ electrons in comparison to $2p$ electron, i.e., energy level of $2s$ is less than $2p$-orbital.

Fill in the Blanks Type

1. Electron affinity
2. Electronegativity
3. Higher effective nuclear charge $\left(\text{Radii} \propto \frac{1}{Z_{\text{eff}}}\right)$
4. Inert pair effect

True / False Type

1. **True:**
   More is the size of kernel, less is strength of metallic bond.
2. **False:**
   Li due its smallest sized and highest hydration energy is maximum reducing.
3. **False:** Order of electron affinity Cl > F > Br because the size of F-atom is lower than that of Cl-atom, so the electron density on the surface of F is higher than that of chlorine. Thus during the addition of an additional electron, higher repulsion takes place in fluorine than chlorine.

   So more amount of energy is consumed for the accommodation of addition electron in fluorine than chlorine. Hence, not released amount of energy. This energy is higher in chlorine than fluorine, i.e., electron affinity of F < Cl.

   Bromine shows lower electron affinity than F and Cl due to its larger size.
4. **False:**
   The basic nature increases as the element becomes more electropositive or acquired metallic character.

   M – OH
   bond becomes weaker due
   to increase in size of metal
   ↓

Subjective Type

1. i. Radius $\propto \frac{1}{Z/e}$

If electrons is the same, then radius $\propto Z$

	Mg^{2+}	Na^+	F^-	O^{2-}
Z	12	11	9	8
e^-	10	10	10	10

More Z, smaller are the radii.

Decreasing ionic size:

O^{2-}, F^-, Na^+, Mg^{2+}

Because ionic radii $\propto \frac{1}{\text{effective nuclear charge}}$

ii. Na < Al < Mg < Si

First ionization energy increases from left to right across a period, but Mg is extra stable than Al, due to full-filled 3s-orbitals and more penetration effect.

$Na_{11} = 1s^2, 2s^2, 2p^6, 3s^1$

$Mg_{12} = 1s^2, 2s^2, 2p^6, 3s^2$

$Al_{13} = 1s^2, 2s^2, 2p^6, 3s^2, 3p^1$

$Si_{14} = 1s^2, 2s^2, 2p^6, 3s^2, 3p^2$

iii. Increasing bond length N_2, O_2, F_2, Cl_2

Bond length $\propto \frac{1}{\text{Bond order}} \propto$ size which increases down the group.

Bond order of $N \equiv N = 3$

$O = O = 2$

$F - F = 1$

$Cl - Cl = 1$

2. Radius $\propto \frac{1}{Z/e}$

If electrons are the same, then radius $\propto Z$

	Ca^{2+}	Ar	Cl^-	S^{2-}
Z	20	18	17	16
e^-	18	18	18	18

Increasing order of size

$Ca^{2+} < Ar < Cl^- < S^{2-}$

Radii $\propto \frac{1}{\text{Effective nuclear charge}}$

3. First I.E. of 'C' is greater than 'B' because as we go from left to right I.E. increases due to increase in effective nuclear charge. After losing one e^- B becomes $1s^2\ 2s^2$, i.e., fully filled s-subshell and more penetration effect and carbon becomes $1s^2\ 2s^2\ 2p^1$. So it becomes more difficult to lose e^- from B.

4. Radius $\propto \frac{1}{Z/e}$

If electrons is the same then radius $\propto$ Z

	Mg^{2+}	Na^+	F^-	O^{2-}	N^{3-}
Z	12	11	9	8	7
e^-	10	10	10	10	10

More Z, smaller are the radii.

Increasing order of ionic sizes:

Mg^{2+} Na^+ F^- O^{2-} N^{3-}

Ionic size $\propto \frac{1}{\text{Effective nuclear charge}}$

5. In copper ($_{29}$Cu)

$_{29}Cu = 1s^2, 2s^2\ 2p^6, 3s^2\ 3p^6\ 3d^{10}, 4s^1$

In zinc ($_{30}$Zn)

$_{30}Zn = 1s^2, 2s^2\ 2p^6, 3s^2\ 3p^6\ 3d^{10}, 4s^2$

On the basis of configuration of Cu and Zn, first ionization of Zn is greater than that of copper because in zinc the removed electron has $4s^2$ configuration while in copper it has $4s^1$ configuration. So more amount of energy is required for the removal of electron of $4s^2$ than that of $4s^1$ while the second ionization potential of Cu is higher than that of zinc because Cu^+ has $3d^{10}$ (stable configuration) in comparison to Zn^+ ($4s^1$ configuration).

6. $Al^{3+} < Mg^{2+} < L^{i+} < K^{2+}$

In these Al^{3+} and Mg^{2+} are isoelectronic species, so in these size decreases with rising atomic number because on rising atomic number, Z_{eff} decreases.

Size $\propto \frac{1}{Z_{\text{eff}}}$ (where, Z_{eff} = effective nuclear charge)

In Li^+ and K^+, K^+ is higher than Li^+ because in these on moving from top to bottom in group, size decreases.