
9. PERIODIC PROPERTIES - (A.R, I.R & I.E)

SOLUTIONS

TEACHING TASK

JEE MAINS LEVEL QUESTIONS

1. Which of the following species has the smallest ionic radius?
A) O^{2-} B) F^- C) Cl^- D) Na^+

Answer:D

Solution: Na^+ has the smallest ionic radius because it has the fewest electrons and the highest effective nuclear charge among the given ions.

2. Among the following, which species would have the largest size?
A) Ar B) Mg^{2+} C) K^+ D) Cl^-

Answer:D

Solution: Cl^- has the largest size because it has the most electrons and the lowest effective nuclear charge among the given species.

3. Which of the following ions would have the largest radius?
A) Na^+ B) Mg^{2+} C) O^{2-} D) F^-

Answer:C

Solution: O^{2-} has the largest radius among the given ions because it has the most electrons and the lowest effective nuclear charge.

4. Arrange the following elements in decreasing order of atomic radii:
A) Na, Be, Mg B) Be, Na, Mg C) Mg, Na, Be D) Na, Mg, Be

Answer:D

Solution:Atomic radii decrease across a period ($Na > Mg > Be$) because effective nuclear charge increases.

5. Which element has the highest first ionization energy?
A) Beryllium (Be) B) Boron (B) C) Carbon (C) D) Nitrogen (N)

Answer:D

Solution:Nitrogen has the highest first ionization energy among the given elements due to its stable half-filled p-orbital configuration.

6. What is the trend of ionization energies within a period and down a group?
A) Ionization energy decreases across a period and increases down a group.
B) Ionization energy increases across a period and decreases down a group.
C) Ionization energy increases across a period and also increases down a group.
D) Ionization energy decreases across a period and also decreases down a group.

Answer:B

Solution: Ionization energy increases across a period (due to increasing nuclear charge) and decreases down a group (due to increasing atomic size and shielding).

7. Which of the following has the lowest ionization energy?

- A) Na B) K C) Li D) Rb

Answer:D

Solution: Rb has the lowest ionization energy because it is the largest atom among the given alkali metals, and ionization energy decreases down a group.

8. Which of the following elements has the highest second ionization energy?

- A) Li B) Na C) Mg D) Al

Answer:A

Solution: Li has the highest second ionization energy because removing a second electron from Li^+ (which has a helium-like $1s^2$ configuration) requires significantly more energy.

9. If an element has the following ionization energies: $I_1 = 520 \text{ kJ/mol}$, $I_2 = 1000 \text{ kJ/mol}$, $I_3 = 1600 \text{ kJ/mol}$, what is its likely charge in its common ionic form?

- A) +1 B) +2 C) +3 D) -1

Answer:C

Solution: the ionization energies rise smoothly with no huge jump after I_1 or I_2 , suggesting loss of three electrons is common (forms +3).

10. Which of the following species would have the highest ionization energy?

- A) Ne B) Li^+ C) Mg^{2+} D) Al

Answer:C

Solution: Mg^{2+} has the highest ionization energy because it has a noble gas configuration (Ne-like), and removing an electron from a stable, small, highly charged ion requires a lot of energy.

11. Which of the following ions would experience the greatest increase in ionization energy after the first electron is removed?

- A) Na^+ B) Al^{3+} C) Mg^{2+} D) F^-

Answer:B

Solution: Al^{3+} — all choices are Ne-like ($10 e^-$), but Al^{3+} has the largest nuclear charge ($Z=13$), so removing the next electron shows the biggest IE increase

12. Given the following first ionization energies for an element: 1180 kJ/mol (I_1), 2380 kJ/mol (I_2), and 4800 kJ/mol (I_3), what can be concluded about its group?

- A) It's an alkali metal. B) It's a noble gas.
C) It's an alkaline earth metal. D) It's a halogen.

Answer:C

Solution: The large jump between I_2 (2380 kJ/mol) and I_3 (4800 kJ/mol) suggests that the element loses two electrons easily (characteristic of alkaline earth metals).

JEE ADVANCED LEVEL QUESTIONS

Multi correct answer type:

13. Which of the following factors affect the ionic radius of an atom? (Select all that apply)

- A) Number of electrons removed or added**
- B) Effective nuclear charge**
- C) Electron-electron repulsion**
- D) Atomic mass**

Answer:A,B,C

Solution:A) Correct

Adding electrons (forming anions) increases ionic radius, while removing electrons (forming cations) decreases it.

B)Correct

Higher effective nuclear charge pulls electrons closer, reducing ionic radius.

C)Correct

More electrons (in anions) increase repulsion, expanding the ionic radius.

D) InCorrect

Mass does not directly affect ionic radius; nuclear charge and electron configuration are key.

14. A high ionization energy is associated with which of the following characteristics? (Select all that apply)

- A) Small atomic radius**
- B) High nuclear attraction**
- C) Low shielding effect**
- D) Presence of half-filled or fully filled orbitals**

Answer:A,B,C,D

Solution:

A) Small atomic radius

Smaller atoms hold electrons more tightly, requiring more energy to remove them.

B) High nuclear attraction

Stronger attraction between nucleus and electrons increases ionization energy.

C) Low shielding effect

Less electron shielding means outer electrons feel a stronger nuclear pull, increasing ionization energy.

D) Presence of half-filled or fully filled orbitals

Extra stability (e.g., N with half-filled p-orbitals, noble gases) increases ionization energy.

Statement Type:

- A) Statement-I, Statement-II both are true and Statement-II is the correct explanation of Statement-I.
B) Statement-I, Statement-II both are true but Statement-II is not the correct explanation of Statement-I.
C) Statement-I is true, Statement-II is false.
D) Statement-I is false, Statement-II is true.

- 15. Statement I : Anions are larger than their parent atoms.**
Statement II : Addition of electrons increases electron-electron repulsion and expands the electron cloud.

Answer:A

Solution:When an atom gains electrons to form an anion, the increased electron-electron repulsion causes the electron cloud to expand.
Thus, anions are larger than their parent atoms.

- 16. Statement I : Noble gases have the highest ionization energies in their periods.**
Statement II : Noble gases have completely filled orbitals, making electron removal energetically unfavorable.

Answer:A

Solution:Noble gases have stable, fully filled electron configurations ($ns^2 np^6$), making it very difficult to remove an electron.
Hence, they have the highest ionization energy in their respective periods.

Matrix Matching Type:

17. Column-I

- a) Ionization energy \propto
b) Units of ionization energy
c) Ionization energy decreases
d) Ionization energy increases

Column-II

- 1) On moving left to right in a period
2) e.V/atom or K.cal/mole
3) On moving down the group
4) Nuclear charge
5) Stable electronic configuration

Answer:a-4,5,b-2,c-3,d-1

Solution:

- | | |
|--------------------------------|--|
| a) Ionization energy \propto | 4) Nuclear charge |
| b) Units of ionization energy | 5) Stable electronic configuration |
| c) Ionization energy decreases | 2) e.V/atom or K.cal/mole |
| d) Ionization energy increases | 3) On moving down the group |
| | 1) On moving left to right in a period |

Comprehension Type:

Ionization energy is the minimum energy required to remove the most loosely bound electron from a neutral gaseous atom.

First ionization energy (IE_1) removes the first outermost electron.

Successive ionization energies (IE_2 , IE_3 , etc.) are always higher because removing an electron from a positively charged ion requires more energy.

Factors affecting ionization energy include atomic size, nuclear charge, electron configuration, and shielding effect.

Elements with stable electronic configurations (e.g., noble gases, half-filled or fully filled subshells) show unusually high ionization energies.

A sudden jump in ionization energy helps identify the number of valence electrons.

18. Which of the following factors decreases the ionization energy of an atom?

- A) Increase in effective nuclear charge**
- B) Decrease in atomic size**
- C) Increase in shielding by inner electrons**
- D) Stable noble gas configuration**

Answer:C

Solution:Shielding by inner electrons reduces the effective nuclear charge felt by the outermost electron, making it easier to remove (lower IE).

19. Why is the first ionization energy of beryllium greater than that of boron?

- A) Beryllium has more protons**
- B) Beryllium has a higher atomic radius**
- C) Beryllium has a completely filled 2s orbital**
- D) Boron has no 2p electrons**

Answer:C

Solution:Be ($1s^2 2s^2$) has a stable, fully filled 2s subshell, requiring more energy to disrupt.

B ($1s^2 2s^2 2p^1$) has a single 2p electron that is easier to remove (lower IE).

LEARNERS TASK

CONCEPTUAL UNDERSTANDING QUESTIONS (CUQ'S)

Single answer type:

1. Atomic radius is defined as:

- A) Half the distance between two nuclei of bonded atoms**
- B) The distance from nucleus to valence electrons**
- C) The radius of the nucleus**
- D) Distance between two protons**

Answer:A

Solution:Atomic radius is defined as half the distance between nuclei of two identical bonded atoms.

2. Which of the following has the largest atomic radius?

- A) Li**
- B) C**
- C) F**
- D) Ne**

Answer:A

Solution:Atomic radius decreases across a period ($\text{Li} \rightarrow \text{Ne}$), so Li (Group 1) has the largest radius

3. Down a group in the periodic table, atomic radius:

- A) Increases due to added shells**
- B) Decreases due to more protons**
- C) Remains constant**
- D) Decreases due to increasing electronegativity**

Answer:A

Solution:Down a group, atomic radius increases because additional electron shells are added.

4. Which species has the smallest radius?

- A) O^{2-}**
- B) F^-**
- C) Na^+**
- D) Mg^{2+}**

Answer:D

Solution: Mg^{2+} has the smallest radius because it loses 2 electrons, reducing electron-electron repulsion and increasing effective nuclear charge.

5. The ionic radius of an anion is generally:

- A) Smaller than its neutral atom**
- B) Equal to its neutral atom**
- C) Larger than its neutral atom**
- D) Cannot be predicted**

Answer:C

Solution:Anions are larger than their parent atoms due to added electron-electron repulsion.

6. Ionization energy is:

- A) The energy required to add an electron**
- B) The energy released when an electron is removed**
- C) The energy required to remove an electron from a gaseous atom**
- D) The potential energy of an electron**

Answer:C

Solution:Ionization energy is the minimum energy needed to remove the outermost electron from a gaseous atom.

7. First ionization energy increases across a period due to:

- A) Increase in atomic size**
- B) Decrease in nuclear charge**
- C) Increase in shielding**
- D) Increase in nuclear attraction**

Answer:D

Solution:Across a period, IE increases because nuclear charge increases, pulling electrons closer

8. The first ionization energy of potassium is lower than that of calcium because:

- A) K is a nonmetal**
- B) K has a higher atomic number**
- C) K has less nuclear charge**
- D) K has only one valence electron**

Answer:D

Solution:K has lower IE than Ca because its single valence electron is easier to remove than Ca's two valence electrons.

9. Which element has the highest first ionization energy?

- A) Na B) Mg C) Ne D) Al

Answer:C

Solution:Ne (noble gas) has the highest IE in its period due to its stable, fully filled electron configuration.

10. Why does Be have a higher ionization energy than B?

- A) Be is smaller and has a filled 2s orbital
B) Be is heavier
C) B is a metal
D) B has a higher nuclear charge

Answer:A

Solution:Be has higher IE than B because its $2s^2$ configuration is more stable than B's $2s^2 2p^1$.

JEE MAINS LEVEL QUESTIONS

1. Which of the following has the smallest atomic radius, yet the largest nuclear charge among the given elements?

- A) Fluorine B) Oxygen C) Lithium D) Neon

Answer:D

Solution:Ne has the smallest atomic radius in its period (rightmost element) and the largest nuclear charge among given options ($Z=10$)

2. The atomic radius of nitrogen is smaller than that of lithium. This is mainly because:

- A) Nitrogen has more protons and more shells
B) Nitrogen has more protons but the same number of shells
C) Lithium has fewer electrons
D) Lithium's nucleus pulls electrons more tightly

Answer:B

Solution:Both are in Period 2, but N ($Z=7$) has higher nuclear charge than Li ($Z=3$), pulling electrons closer.

3. In isoelectronic series such as O^{2-} , F^- , Na^+ , and Mg^{2+} , the decreasing order of radius is due to:

- A) Increase in shielding effect
B) Decrease in electron number
C) Increase in nuclear charge with constant electron count
D) Atomic mass differences

Answer:C

Solution:In isoelectronic series, radius decreases as nuclear charge increases

4. A metal M forms a cation M^{2+} by losing its two valence electrons. Which of the following changes is NOT expected?
- A) Ionic radius decreases
 - B) Effective nuclear charge increases
 - C) Electron-electron repulsion increases
 - D) The ion becomes more compact

Answer:C

Solution:Forming M^{2+} reduces electron count, decreasing repulsion. Other options are true: radius decreases, nuclear charge increases, ion becomes compact.

5. Why is the ionic radius of Na^+ much smaller than Na, but the change in Cl to Cl^- shows a much larger increase in size?
- A) Na loses a shell while Cl gains one
 - B) Cl^- adds a shell and increases repulsion
 - C) Cl gains an electron, increasing repulsion without extra nuclear pull
 - D) Na and Cl follow different periodic trends

Answer:C

Solution: Na^+ shrinks by losing an electron shell; Cl^- expands due to added electron repulsion, with no change in nuclear charge.

6. The first, second, third, fourth, fifth ionization potential values of an element are 6.11, 11.87, 51.21, 67.0, 84.39 eV respectively. The element is
- A) Calcium
 - B) Potassium
 - C) Aluminium
 - D) Carbon

Answer:A

Solution:Large jump after I_2 (11.87 \rightarrow 51.21 eV) indicates removal of core electrons, matching Ca's $[Ar]4s^2$ configuration

7. The ionization potential values of an element are in the following order $I_1 < I_2 < \dots < I_3 < I_4 < I_5$. The element is
- A) alkali metal
 - B) chalcogen
 - C) halogen
 - D) alkaline earth metals

Answer:D

Solution:Alkaline earth metals — big jump after I_2 implies two valence electrons (group 2)

8. The I_1 values of Li, Be and C are 5.4 eV/atom, 9.32 eV/atom and 11.26 eV/atom. The I_1 value of Boron is
- A) 13.6 eV/atom
 - B) 8.29 eV/atom
 - C) 14.5 eV/atom
 - D) 21.5 eV/atom

Answer:B

Solution:Boron's IE_1 (8.29 eV) is lower than Be (9.32 eV) due to penetration effect in 2p vs 2s, despite higher Z

9. The first ionization potential of four consecutive elements, present in the second period of the periodic table are 8.3, 11.3, 14.5 and 13.6 eV respectively. Which one of the following is the first ionization potential (in eV) of nitrogen?
- A) 13.6
 - B) 11.3
 - C) 8.3
 - D) 14.5

Answer:D

Solution: Order: Be (9.3), B (8.3), C (11.3), N (14.5), O (13.6). N has higher IE than O due to half-filled 2p stability

- 10. Elements X, Y and Z have atomic numbers 19, 37 and 55 respectively. Which of the following statements is true about them?**

A) Their ionization potential would increase with increasing atomic number
B) 'Y' would have an ionization potential between those of X and Z
C) Z would have the highest ionization potential
D) Y would have the highest ionization potential

Answer:B

Solution: IE decreases down Group 1: X (K, Z=19) > Y (Rb, Z=37) > Z (Cs, Z=55)

- 11. The high ionization potential of magnesium compared with aluminium, is due to**

A) filled orbitals in magnesium
B) high nuclear charge in magnesium
C) low radius of magnesium atom
D) low effective nuclear charge in magnesium

Answer:A

Solution: (Mg ([Ne]3s²) has higher IE than Al ([Ne]3s²3p¹) due to stable filled 3s subshell.

- 12. A sudden large jump between the values of second and third ionization energies of an element would be associated with the electronic configuration**

A) 1s², 2s²p⁶, 3s¹
B) 1s², 2s²p⁶, 3s²p¹
C) 1s², 2s²p⁶, 3s²p²
D) 1s², 2s²p⁶, 3s²

Answer:D

Solution: Large I₂ → I₃ jump occurs when removing a core electron (e.g., Mg: 3s² → Mg²⁺ requires breaking noble gas config).

- 13. The incorrect 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 potential of Mg is greater than the third ionisation potential of Al

Answer:B

Solution: In reality Na's I₂ is much larger than Mg's I₂ because removing a second electron from Na⁺ breaks into a noble-gas core

JEE ADVANCED LEVEL QUESTIONS

Multi correct answer type:

14. If two atoms have the same number of shells but different effective nuclear charges, the one with the higher nuclear charge will likely:

- A) Have a smaller atomic radius B) Have a larger atomic radius
C) Show no change in radius D) Expand due to electron repulsion

Answer:A

Solution: Higher effective nuclear charge (Z_{eff}) means the nucleus pulls electrons more strongly, reducing atomic radius.

15. Arrange the following types of atomic radii in decreasing order of magnitude typically observed in non-metallic elements:

- A) Van der Waals radius > covalent radius > metallic radius
B) Crystal radius > covalent radius > Van der Waals radius
C) Van der Waals radius > crystal radius > covalent radius
D) Covalent radius > Van der Waals radius > crystal radius

Answer:C

Solution: Van der Waals radius (distance between non-bonded atoms) is the largest (weak forces).

Crystal radius (in ionic compounds) is intermediate (ions are closer than non-bonded atoms but farther than covalent bonds).

Covalent radius (bonded atoms) is the smallest (strong shared-electron pull).

Statement Type:

- A) Statement-I, Statement-II both are true and Statement-II is the correct explanation of Statement-I.
B) Statement-I, Statement-II both are true but Statement-II is not the correct explanation of Statement-I.
C) Statement-I is true, Statement-II is false.
D) Statement-I is false, Statement-II is true.

16. Statement I : The term "covalent radius" is primarily used when referring to the atomic sizes of metals.

Statement II : Van der Waals radii are, on average, approximately 40% smaller than covalent radii.

Answer:E

Solution: Covalent radius is used for non-metals (e.g., Cl_2 , O_2) or metalloids, not primarily for metals. Metals are typically described by metallic radius.

Van der Waals radii are larger than covalent radii (by ~40%) because they represent distances between non-bonded atoms (weak interactions).

17. Statement I : The order of radii from largest to smallest is: Cation > Atom > Anion.

Statement II : When an atom gains electrons, it forms a positive ion known as a cation.

Answer:E

Solution: The correct order is Anion > Atom > Cation (anions expand due to added electrons, cations shrink due to electron loss).

Gaining electrons forms a negative ion (anion), not a cation. Cations are formed by losing electrons.

Matrix Matching Type:18. **Column-I**

- a) Size of anion \propto
- b) Size of cation $\frac{1}{\alpha}$
- c) Atomic radii in a period
- d) Atomic radii in a group

Column-II

- 1) Increases
- 2) Decreases
- 3) Effective nuclear charge
- 4) Number of orbits
- 5) Electronic repulsion

Answer:a-5,b-3,c-2,d-1,4

Solution:

- | | |
|--------------------------------------|-----------------------------------|
| a) Size of anion \propto | 5) Electronic repulsion |
| b) Size of cation $\frac{1}{\alpha}$ | 3) Effective nuclear charge |
| c) Atomic radii in a period | 2) Decreases |
| d) Atomic radii in a group | 1) Increases, 4) Number of orbits |

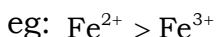
Comprehension Type:

When a neutral atom loses one (or) more electrons a positive ion called cation is formed.



The ionic radius of cation is less than that of neutral atom. It is because the cation has higher effective nuclear charge. eg: $\text{Na} > \text{Na}^+$

Among the cation as the positive charge increases, the ionic radius decreases.



19. Na^+ , Mg^{2+} , Al^{3+} , Si^{4+} are isoelectronics. Their ionic size follows the order:

- | | |
|--|--|
| A) $\text{Na}^+ < \text{Mg}^{2+} < \text{Al}^{3+} < \text{Si}^{4+}$ | B) $\text{Na}^+ > \text{Mg}^{2+} < \text{Al}^{3+} < \text{Si}^{4+}$ |
| C) $\text{Na}^+ < \text{Mg}^{2+} > \text{Al}^{3+} > \text{Si}^{4+}$ | D) $\text{Na}^+ > \text{Mg}^{2+} > \text{Al}^{3+} > \text{Si}^{4+}$ |

Answer:D

Solution: All these ions are isoelectronic (10 electrons, Ne-like configuration). Higher nuclear charge ($\text{Si}^{4+} > \text{Al}^{3+} > \text{Mg}^{2+} > \text{Na}^+$) pulls electrons more strongly, reducing ionic size.

Thus, Na^+ (lowest charge) is largest, while Si^{4+} (highest charge) is smallest.

20. In the isoelectronic series: K^+ , Cl^- , S^{2-} , Ca^{2+} the largest size is of :

A) K^+

B) Cl^-

C) Ca^{2+}

D) S^{2-}

Answer:D

Solution:All these ions have 18 electrons (Ar-like configuration).

Size depends on nuclear charge (Z):

S^{2-} (Z=16): Lowest effective nuclear charge (16 protons for 18 electrons) →largest size.

Cl^- (Z=17): Slightly smaller than S^{2-} due to higher Z.

K^+ (Z=19): Much smaller (19 protons for 18 electrons).

Ca^{2+} (Z=20): Smallest (highest Z, strongest pull on electrons).

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

Integer type:

21. Third Ionisation potential is the removal of electron from the ion having magnitude of the charge of _____

Answer:2

Solution:The third ionization energy (IE3) removes an electron from a doubly charged cation (M^{2+}).

22. Vander waals radius is _____% greater than covalent radii?

Answer:40

Solution:Van der Waals radius (distance between non-bonded atoms) is typically ~40% larger than the covalent radius (bonded atoms).

KEY

TEACHING TASK									
JEE MAINS LEVEL QUESTIONS									
1	2	3	4	5	6	7	8	9	10
D	D	C	D	D	B	D	A	C	C
11	12								
B	C								
JEE ADVANCED LEVEL QUESTIONS									
13	14	15	16	17		18	19		
A,B,C	A,B,C,D	A	A	a-4,5,b-2,c-3,d-1	C	C			
LEARNERS TASK									
CUQ'S									
1	2	3	4	5	6	7	8	9	10
A	A	A	D	C	C	D	D	C	A
JEE MAINS LEVEL QUESTIONS									
1	2	3	4	5	6	7	8	9	10
D	B	C	C	C	A	D	B	D	B
11	12	13							
A	D	B							
JEE ADVANCED LEVEL QUESTIONS									
14	15	16	17	18		19	20	21	22
A	C	E	E	a-5,b-3,c-2,d-1,4	D	D		2	40