Engineering Daily 14 [Set 03] EV

Periodic Properties of Elements and Chemical Bonding (Periodic Properties of Elements)

Total Marks: 50 **Negative Marks:** 0.25 **Time:** 1 Hour

MCQ 50 marks

1. The set of quantum numbers for the last electron of an element X is $n = 3, l = 1, m = 0, s = -\frac{1}{2}$. In which group and period is element X located?

   (A) Group 17, Period 3 (B) Group 16, Period 3

   (C) Group 14, Period 3 (D) Group 15, Period 3

2. The last subshell in the electron configuration of element Y is 3d, and the valence shell (4s + 3d) contains a total of 6 electrons, but the 4s subshell is not completely full. What is Y ?

   (A) Co (Z = 27) (B) Mn (Z = 25)

   (C) Fe (Z = 26) (D) Cr (Z = 24)

3. Which of the following sets of quantum numbers is physically impossible?

   (A) $n = 2, l = 2, m = 0, s = -\frac{1}{2}$

   (B) $n = 3, l = 2, m = +2, s = -\frac{1}{2}$

   (C) $n = 5, l = 0, m = 0, s = +\frac{1}{2}$

   (D) $n = 4, l = 3, m = -2, s = +\frac{1}{2}$

4. A transition metal ion M^{2+} has the electron configuration $[Ar]3d^7$. How many electrons in total will the parent metal M have in its 4s and 3d subshells, and what is M?

   (A) Co, 9 electrons (B) Ni, 10 electrons

   (C) Fe, 8 electrons (D) Mn, 7 electrons

5. According to Slater's rules, within the same principal shell (n same), the screening constant of (n − 1)d electrons on ns/np electrons is relatively lower compared to electrons of the (n − 1) group. Based on this, explain how the effective nuclear charge on the 4s electrons of Zn ($3d^{10}4s^2$) will compare to that of Ca ($4s^2$, no 3d).

   (A) Lower (B) Much higher

   (C) Cannot be determined (D) Equal

6. Which of the following electron configurations indicates an excited state?

   (A) $1s^2 2s^2 2p^4 3s^1$ (B) $1s^2 2s^2 2p^6$

   (C) $1s^2 2s^2 2p^6 3s^2$ (D) $1s^2 2s^2 2p^6 3s^2 3p^5$

7. The configuration of the Cu (Z = 29) atom is $[Ar]3d^{10}4s^1$. What is the main reason its first ionization energy is relatively lower than expected?

   (A) Because Cu is a lanthanide element

   (B) Because the 3d subshell is incomplete

   (C) It has only a single unpaired $4s^1$ electron

   (D) Because Cu has no valence electrons

8. For which element is a huge jump expected in the fourth ionization energy, if the element has 3 valence electrons located in the n = 3 shell?

   (A) Si (Z = 14) (B) Na (Z = 11)

   (C) Al (Z = 13) (D) P (Z = 15)

9. A d-block ion M^{3+} has the maximum possible number of unpaired electrons (5) in its 3d subshell, according to Hund's rule. What is the possible atomic number of element M?

   (A) Z = 26 (B) Z = 25 (C) Z = 24 (D) Z = 23

10. Apply the (n + l) rule to determine the correct increasing order of energy for the 5s, 4d, 4f and 6s orbitals.

    (A) 5s < 6s < 4d < 4f (B) 5s < 4d < 6s < 4f

    (C) 4d < 5s < 4f < 6s (D) 5s < 4d < 4f < 6s

11. The successive ionization energies of an element (in $kJmol^{-1}$) are $E_1 = 590, E_2 = 1145, E_3 = 4912, E_4 = 6491$. Which group does the element belong to, and what is its most likely stable oxidation number?

    (A) Group 1, oxidation number +1

    (B) Group 3, oxidation number +3

    (C) Group 4, oxidation number +4

    (D) Group 2, oxidation number +2

12. If E_I is plotted against atomic number (period 2, Li → Ne), at which two points will a local dip (a value lower than its neighbors) be seen?

    (A) B → C and O → F

    (B) There will be no dip; the graph is a perfectly linear upward line

    (C) Li → Be and C → N

    (D) Be → B and N → O

13. The first ionization energies of four period-2 elements P, Q, R, S are, respectively (in $kJmol^{-1}$), 1314, 1402, 1086, 1681. Which element does each value correspond to if the elements are located consecutively from Group 14 to Group 17?

    (A) P = O, Q = F, R = N, S = C

    (B) P = C, Q = N, R = O, S = F

    (C) P = O, Q = N, R = C, S = F

    (D) P = N, Q = O, R = C, S = F

14. Among the 5 successive ionization energies of an element, there is roughly a doubling from E_1 to E_2, but roughly a 10-fold increase from E_4 to E_5. How many valence electrons does the element have?

    (A) 2 (B) 4 (C) 3 (D) 5

15. An element has E_1 and E_2 of 738 and 1450 $kJmol^{-1}$ respectively, but $E_3 = 7730\ kJmol^{-1}$. A second, comparable element has (in $kJmol^{-1}$) $E_1 = 496$, $E_2 = 4562$. What are the groups of the two elements, respectively?

(A) Both Group 2

(B) Both Group 1

(C) First Group 1, second Group 2

(D) First Group 2, second Group 1

16. A period-3 element has $E_1 = 1000\ kJmol^{-1}$ (the actual value for Group 15's P). Why would the next element (S) in the same period have a lower E_1 than this, even though its Z_{eff} is higher?

(A) P's stability is greater than S's

(B) S's size is much larger than P's

(C) Because P has no p electrons

(D) Because S is a metal

17. A researcher mistakenly writes an $E_1 < E_2 < E_3$ sequence for an element, where $E_1 = 800$, $E_2 = 2427$, $E_3 = 3660\ kJmol^{-1}$, and claims the element is in Group 1. Where is the error in this claim?

(A) The claim is correct

(B) The element doesn't belong to any group

(C) The value of E_3 is wrong

(D) There is no jump from $E_1 \rightarrow E_2$

18. What is the correct order of the second ionization energies of Na, Mg, Al, and why?

(A) Al > Mg > Na

(B) Mg > Na > Al

(C) Na $\gg$ Mg > Al

(D) All three are approximately equal

19. From the following successive ionization energy data (in $kJmol^{-1}$: $E_1 = 1012$, $E_2 = 1903$, $E_3 = 2910$, $E_4 = 4956$, $E_5 = 6273$, $E_6 = 21269$), identify the group and period of the element.

(A) Group 13, Period 3 (Al)

(B) Group 14, Period 3 (Si)

(C) Group 16, Period 3 (S)

(D) Group 15, Period 3 (P)

20. Explain why the E_1 of noble gases (except He) is the highest, even higher than the preceding halogen in the same period, even though their (Van der Waals) radius appears larger than the halogen's (covalent) radius.

(A) A completely full electron configuration is extremely stable

(B) This is an exception with no explanation

(C) Because Z_{eff} is zero in noble gases

(D) Because noble gases have fewer protons

21. On what basis can it be said that, although Mg's E_1 is higher than Na's E_1, this increase is not linear despite both elements being in the same period, but occurs stepwise with anomalies?

(A) The extra stability of the full $3s^2$ subshell

(B) Because Na's size is smaller than Mg's

(C) Because Mg has no s electrons

(D) Both actually have the same E_1

22. An element's four successive ionization energies (in $kJmol^{-1}$) are 578, 1817, 2745, 11577. After it forms the M^{3+} ion, which noble gas will its electron configuration be equivalent to?

(A) Ar (B) He (C) Ne (D) Kr

23. Using Slater's rules, show which of an element's 4s and 3d electrons should be removed first when forming a cation, and why.

(A) 3d, because 3d is always higher in energy than 4s

(B) It depends on the element, there is no rule

(C) Both at the same time

(D) 4s; in the cation, 3d becomes lower in energy

24. A hypothetical element's successive ionization energy values increase in roughly equal steps (close to an arithmetic progression), with no huge jump among the first 7 values. For which group of elements is this least likely?

(A) Group 13 (B) Group 15

(C) Group 1 (D) Group 14

25. Comparing the electron affinities of Group 16's O and S, we find S > O, even though O is smaller in size. What is the main reason for this?

(A) Sulfur's Z_{eff} is higher than oxygen's

(B) Because sulfur is a metal

(C) Greater electron repulsion in oxygen's small size

(D) Because oxygen's electron-gain enthalpy is positive

26. If both quantum number and successive IE data are given together — an element's last electron has $n = 3, l = 0$, and no huge jump is seen at $E_1 \rightarrow E_2$, but a jump is seen at $E_2 \rightarrow E_3$ — what is the element?

(A) Al (Z = 13) (B) Mg (Z = 12)

(C) Na (Z = 11) (D) Ca (Z = 20)

27. If nitrogen's second electron affinity ($N^- \rightarrow N^{2-}$) were calculated, it would be extremely highly positive (endothermic) — why?

(A) Because N^-'s radius is infinite

(B) Because nitrogen is a noble gas

(C) Because nitrogen has an odd number of electrons

(D) Adding an electron to a negative ion causes Coulombic repulsion

28. Which elements have a first electron affinity close to zero or slightly positive, arising from the same reason (stability of a half-filled/full subshell)?

(A) O and F (B) Be and Mg

(C) N and the noble gases (D) Cl and Br

29. Although the electron affinity order of F, Cl, Br, I is Cl > F > Br > I, their electronegativity order is F > Cl > Br > I (smooth, with no exception) — what is the reason for this difference in trends between the two properties?

(A) Bromine's electron affinity is the highest

(B) The two are actually the same property, just with different names

(C) Electronegativity is an averaged property, while affinity is an individually measured energy

(D) Fluorine's electronegativity is actually the lowest

30. Which pair of elements shows an exception to the rule 'the smaller the size, the greater the electron affinity'?

(A) O and S (B) Cl and Br

(C) Br and I (D) S and Se

31. An element X has the electron configuration $[Ne]3s^2 3p^3$. How will X's electron affinity compare to its two neighboring elements in the same period ($3p^2$ and $3p^4$)?

(A) Equal to $3p^2$ (B) Lower than both

(C) Cannot be determined (D) Higher than both

32. The energy released in forming the Cl^- ion is $-349\ kJmol^{-1}$; what would be the nature of the energy change for $Cl^- \rightarrow Cl^{2-}$ (a hypothetical second step), and why?

(A) The second step will be strongly positive (endothermic)

(B) The question is irrelevant since Cl^{2-} doesn't exist anyway

(C) Both steps will release equal energy

(D) The second step will also be negative (exothermic)

33. The relationship between electron affinity and atomic radius is generally said to be inverse (smaller radius, higher affinity). But which three specific (period-2) elements most violate this simplified rule?

(A) N, O, F (B) Li, Be, B

(C) C, N, O (D) No element is an exception

34. $N^{3-}, O^{2-}, F^-, Na^+, Mg^{2+}$ — write the correct order of radii for this isoelectronic series (e = 10 each) and its mathematical basis.

(A) $N^{3-} < O^{2-} < F^- < Na^+ < Mg^{2+}$

(B) All have equal radii

(C) F^- is the largest

(D) $Mg^{2+} < Na^+ < F^- < O^{2-} < N^{3-}$

35. An element's measured electron affinity was found to be unusually low compared to other members of its group, nearly approaching that of a noble gas. If the element's configuration is ns^2np^3, what is the reasonable explanation for this observation?

(A) The element is a metal

(B) Z_{eff} is zero

(C) Reluctance to accept a new electron

(D) The element has no p electrons

36. Which of the following statements is correct regarding the relationship between Slater's screening and electron affinity?

(A) If screening increases, electron affinity always increases

(B) There is no relationship between screening and electron affinity

(C) Going down a group, screening increases and electron affinity generally decreases

(D) Screening affects only ionization energy, not electron affinity

37. What is the main reason Zr (Z = 40) and Hf (Z = 72) have nearly equal atomic radii (≈ 160 pm), even though Hf has one entire additional shell?

(A) Because both have the same number of valence electrons

(B) Contraction due to poor screening by 4f electrons

(C) It's a coincidence, with no structural reason

(D) Because Hf's nucleus is unstable

38. A cation M^{2+}'s hydrated radius in aqueous solution is many times larger than its gaseous (bare) ionic radius. In which ion (Li^+ or Cs^+) will this increase be greatest, and why?

(A) Greatest in Li^+

(B) Equal in both

(C) Greatest in Cs^+

(D) Hydration won't occur in either

39. What is the phenomenon called where Li^+ and Mg^{2+} have nearly equal ionic radii and share deep similarities in chemical properties, and what is its mathematical basis?

(A) Isoelectronic relationship

(B) Diagonal relationship

(C) Screening effect

(D) Lanthanide contraction

40. A metal oxide is insoluble in water but reacts with both HCl and NaOH to produce a salt and water. This type of oxide is most commonly seen in elements of which group?

(A) Group 17 (B) Group 13

(C) Group 18 (D) Group 1

41. If the noble gas Ne is added to a graph of covalent radii for period-2 elements (Li → F), what kind of anomaly appears in the graph, and why is this a false comparison (apples-to-oranges)?

(A) Ne has no measurable radius

(B) Ne's actual atom is the smallest, the data is wrong

(C) This is natural since Ne has the most electrons

(D) Ne's Van der Waals radius is larger than a covalent radius

42. If a transition-metal ion M^{2+} has a d^0 or d^{10} configuration, how does its ionic radius follow the normal periodic contraction trend compared to other d configurations (d^1–d^9)?

(A) In d^0, d^{10}, the radius follows the trend smoothly

(B) The radius is smallest at d^5, as per the rule

(C) The radius is most irregular at d^0 and d^{10}

(D) The radius is the same for all d configurations

43. In an ionic series, $Ca^{2+}, K^+, Cl^-, S^{2-}$ all have 18 electrons each (argon-like). Determine their radii in increasing order.

(A) All equal

(B) $S^{2-} < Cl^- < K^+ < Ca^{2+}$

(C) $Ca^{2+} < K^+ < Cl^- < S^{2-}$

(D) $K^+ < Ca^{2+} < S^{2-} < Cl^-$

44. In the lanthanide series (La → Lu), the rate of successive radius contraction is not the same (linear) for every element, but somewhat irregular. What is the main reason for this?

(A) Lanthanide radii actually increase, not decrease

(B) The contraction is actually perfectly linear, with no irregularity

(C) The 4f electron count remains the same for every element

(D) Variability of 4f configuration and inconsistency in screening

45. Which is larger between the ionic radii of Fe^{2+} and Fe^{3+}, and why, even though both hold electrons in the 3d subshell?

(A) Cannot be determined

(B) Fe^{2+} is larger

(C) Both are equal

(D) Fe^{3+} is larger

46. Among atomic radius, covalent radius, and metallic radius, which one generally gives the largest measurement for the same element (where applicable)?

(A) Covalent radius

(B) Metallic radius

(C) Ionic radius is always the largest

(D) All are equal

47. What is the fundamental reason (in terms of bond nature) behind the change of oxide nature from basic to acidic going left to right across period 3?

(A) There is no structural reason, it's coincidental

(B) Because atomic mass increases

(C) Because the amount of oxygen changes

(D) Increasing Z_{eff} makes the M − O bond covalent

48. Which of the following pairs of oxides is classified as a neutral oxide (forms no acid or base), even though the constituent elements are from different groups?

(A) CO_2 and SO_3

(B) Na_2O and MgO

(C) CO and N_2O

(D) Al_2O_3 and ZnO

49. How does the acidity of an oxoacid change with increasing oxidation number of its central atom, and what is the correct order of acidity for $HClO, HClO_2, HClO_3, HClO_4$?

(A) All have equal acidity

(B) $HClO_4 > HClO_3 > HClO_2 > HClO$

(C) $HClO_4 < HClO_3 < HClO_2 < HClO$

(D) There is no relationship between oxidation number and acidity

50. Between two oxoacids with the same oxidation number ($HClO_4$ and the hypothetical HIO_4, both with a central-atom oxidation number of +7), which will be stronger, and why?

(A) HIO_4 is stronger

(B) Both are equally strong, since the oxidation numbers are equal

(C) Strength cannot be determined

(D) $HClO_4$ is stronger, because it has higher electronegativity