MCQ 50 marks

1. **D. Extra stability of half-filled and completely filled d-subshells**
Explanation: The $3d^5$ (half-filled) and $3d^{10}$ (fully filled) arrangements have symmetric electron distribution, which gives extra exchange energy. This stabilisation outweighs the energy cost of promoting one electron from 4s to 3d.
So Cr = $[Ar]3d^5 4s^1$ and Cu = $[Ar]3d^{10}4s^1$, not the expected $3d^4 4s^2$ and $3d^9 4s^2$.

2. **B.** 16 **and** 32
Explanation: Here, $n = 4$
Total number of orbitals = $n^2 = 4^2 = 16$
Maximum electron capacity = $2n^2 = 2 \times 16 = 32$
Therefore, there are 16 orbitals and 32 electrons.

3. **C.** $l = 4,\ n = 5$
Explanation: The subshells s, p, d, f, g correspond to $l = 0, 1, 2, 3, 4$, so $l = 4$ for g.
l ranges from 0 to $(n - 1)$, so $l = 4$ requires at least $n = 5$.
Therefore, $l = 4$ and $n = 5$.

4. **D.** 4 **and** 5
Explanation: Fe = $[Ar]3d^6 4s^2$
Fe^{2+} = $[Ar]3d^6$ (two electrons removed from 4s)
By Hund's rule, $3d^6$ has four singly occupied orbitals and one pair, so unpaired = 4
Fe^{3+} = $[Ar]3d^5$, one electron in each d-orbital, so unpaired = 5
Therefore, the answer is 4 and 5.

5. **B.** 2d, 3f
Explanation: l ranges from 0 to $(n - 1)$.
2d: for $n = 2$ the maximum l is 1, but d needs $l = 2$, so 2d is impossible.
3f: for $n = 3$ the maximum l is 2, but f needs $l = 3$, so 3f is impossible.

6. **A.** 3d
Explanation: $n = 3$ indicates the principal shell.
$l = 2$ indicates the d subshell ($l = 0, 1, 2, 3 \Rightarrow$ s, p, d, f).
So the electron is in a 3d orbital.

7. **A.** 2, **the** xz **and** yz **planes**
Explanation: The number of angular nodal planes of a d-orbital = $l = 2$
The wave function of d_{xy} is $\propto xy$, so it is zero at $x = 0$ (the yz plane) and at $y = 0$ (the xz plane)
So the two nodal planes are xz and yz.

8. **D.** 434.2 nm**, Balmer series**
Explanation: Transitions ending at $n_1 = 2$ form the Balmer series.
$\frac{1}{\lambda} = R_H \left(\frac{1}{2^2} - \frac{1}{5^2}\right) = 1.09678 \times 10^7\ m^{-1} \times (0.25 - 0.04)$
$\frac{1}{\lambda} \approx 2.303 \times 10^6\ m^{-1}$
Therefore, $\lambda \approx 4.342 \times 10^{-7}$ m = 434.2 nm, Balmer series.

9. **B.** $n = 3,\ l = 3,\ m = +1,\ s = +\frac{1}{2}$
Explanation: l must range from 0 to $(n - 1)$.
For $n = 3$, the maximum l is 2, so $l = 3$ is impossible.
So $(n = 3,\ l = 3,\ m = +1,\ s = +\frac{1}{2})$ is not allowed.

10. **C. About** 10^2 MeV
Explanation: By Heisenberg's principle, $\Delta p \geq \frac{h}{4\pi\Delta x}$
Here, $\Delta p \geq \frac{6.626 \times 10^{-34}}{4\pi \times 10^{-15}} \approx 5.27 \times 10^{-20}\ kgms^{-1}$
Also, $pc \approx 5.27 \times 10^{-20} \times 3 \times 10^8 \approx 1.58 \times 10^{-11}$ J ≈ 99 MeV
This is far greater than $m_e c^2 = 0.511$ MeV, so the electron is relativistic and $KE \approx pc \approx 10^2$ MeV
So this energy is many times larger than nuclear binding energies (a few MeV), and the electron cannot stay inside the nucleus.

11. **A.** $(1, 0, 0, +\frac{1}{2})$ **and** $(1, 0, 0, -\frac{1}{2})$
Explanation: He = $1s^2$; both electrons have the same $n = 1,\ l = 0,\ m = 0$.
By Pauli's principle, no two electrons can have all four quantum numbers identical, so their spins must be opposite.
So the correct pair is $(1, 0, 0, +\frac{1}{2})$ and $(1, 0, 0, -\frac{1}{2})$.

12. C. $Cr,\ Cu$

Explanation: $Cr\ (Z = 24)$: actual configuration $3d^5 4s^1$ instead of the expected $3d^4 4s^2$.
$Cu\ (Z = 29)$: actual configuration $3d^{10} 4s^1$ instead of the expected $3d^9 4s^2$.
Both are exceptions to the Aufbau principle due to the stability of half-filled or fully filled d-subshells.

13. C. $CO,\ N_2,\ CN^-$

Explanation: CO: $6 + 8 = 14$; N_2: $7 + 7 = 14$; CN^-: $6 + 7 + 1 = 14$ — all three have 14 electrons, so they are isoelectronic.

14. A. $4d < 5p < 6s < 4f$

Explanation: $(n + l)$ values: $4d = 4 + 2 = 6$; $5p = 5 + 1 = 6$; $4f = 4 + 3 = 7$; $6s = 6 + 0 = 6$
For equal $(n + l)$, the lower n has lower energy, so $4d\ (n = 4) < 5p\ (n = 5) < 6s\ (n = 6)$
$4f$ has the largest $(n + l) = 7$, so it comes last.
So the order is $4d < 5p < 6s < 4f$.

15. A. 6

Explanation: Here, $l = 1$ means a p-subshell.
Number of orbitals in the p-subshell $= 2l + 1 = 3\ (m = -1, 0, +1)$
Each orbital holds at most 2 electrons.
Therefore, maximum electrons $= 3 \times 2 = 6$.

16. D. 6

Explanation: $Fe = [Ar]3d^6 4s^2$
To form Fe^{2+}, two electrons are removed first from 4s, so $Fe^{2+} = [Ar]3d^6$
So the number of d-electrons is 6.

17. B. $6\,\alpha,\ 4\,\beta$

Explanation: Change in mass number $\Delta A = 232 - 208 = 24$
Each α particle reduces the mass number by 4, so number of $\alpha = \frac{24}{4} = 6$
With α emission alone, the atomic number would be $90 - 2 \times 6 = 78$
The actual atomic number is 82 and each β particle raises it by 1, so number of $\beta = 82 - 78 = 4$
Therefore, 6 α particles and 4 β particles.

18. C. 15 **minutes**

Explanation: Let the number of half-lives elapsed be n
$\frac{N}{N_0} = \left(\frac{1}{2}\right)^n = \frac{1}{8} = \left(\frac{1}{2}\right)^3 \Rightarrow n = 3$
Also, $t = n \times t_{1/2}$
$45 = 3 \times t_{1/2} \Rightarrow t_{1/2} = 15$
Therefore, the half-life is 15 minutes.

19. B. $Mn^{2+}\ (Z = 25)$

Explanation: $Cr^{3+} = [Ar]3d^3$, unpaired = 3
$Mn^{2+} = [Ar]3d^5$, unpaired = 5
$Fe^{2+} = [Ar]3d^6$, unpaired = 4
$Zn^{2+} = [Ar]3d^{10}$, unpaired = 0
So Mn^{2+} has the most unpaired electrons (5).

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

Explanation: $S\ (Z = 16) = 1s^2 2s^2 2p^6 3s^2 3p^4$; S^{2-} gains two electrons and completes $3p^6$.
By Hund's rule, the first 3 electrons enter $m = -1, 0, +1$ with $s = +\frac{1}{2}$; the next 3 pair up in the same order with $s = -\frac{1}{2}$.
So for the 6th (last) electron, $n = 3,\ l = 1,\ m = +1,\ s = -\frac{1}{2}$.

21. C. About 7450 **times**

Explanation: In pure water, $S_{water} = \sqrt{K_{sp}} = \sqrt{1.8 \times 10^{-10}} \approx 1.34 \times 10^{-5}\ molL^{-1}$
In 0.1 M NaCl, $[Cl^-] = 0.1$ M; by the common-ion effect $S \ll 0.1$, so $K_{sp} \approx S \times 0.1$
So, $S_{NaCl} = \frac{1.8 \times 10^{-10}}{0.1} = 1.8 \times 10^{-9}\ molL^{-1}$
Therefore, $\frac{S_{water}}{S_{NaCl}} = \frac{1.34 \times 10^{-5}}{1.8 \times 10^{-9}} \approx 7450$ times.

22. B. 1.2×10^{-1} M

Explanation: Here, $pH = 9 \Rightarrow pOH = 14 - 9 = 5 \Rightarrow [OH^-] = 10^{-5}$ M
$K_{sp} = [Mg^{2+}][OH^-]^2$
$[Mg^{2+}]_{max} = \frac{K_{sp}}{[OH^-]^2} = \frac{1.2 \times 10^{-11}}{(10^{-5})^2} = \frac{1.2 \times 10^{-11}}{10^{-10}}$
Therefore, $[Mg^{2+}]_{max} = 0.12\ M = 1.2 \times 10^{-1}$ M
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23. A. 91.2 nm **and** 121.6 nm

Explanation: In the Lyman series, $n_1 = 1$.
Longest wavelength ($n_2 = 2$): $\lambda_{max} \approx 121.6$ nm
Shortest wavelength (series limit, $n_2 = \infty$):
$\lambda_{min} = \frac{1}{R_H} \approx 91.2$ nm
Therefore, the shortest is 91.2 nm and the longest is 121.6 nm.

24. D. 12.09 eV

Explanation: Here, $E_1 = -13.6\,\text{eV}$

$E_3 = \frac{-13.6}{3^2} = -1.51\,\text{eV}$

Energy absorbed $= E_3 - E_1 = -1.51 - (-13.6)$

Therefore, energy absorbed = 12.09 eV.

25. C. $1.09 \times 10^6\,\text{ms}^{-1}$

Explanation: Speed in the n-th orbit is $v_n = \frac{v_1}{n}$

Here, $n = 2$

$v_2 = \frac{2.18 \times 10^6}{2}$

Therefore, $v_2 = 1.09 \times 10^6\,\text{ms}^{-1}$.

26. B. $5331.6\,\text{cm}^{-1}$

Explanation: In the Paschen series, $n_1 = 3$; for the first line, $n_2 = 4$

$\bar{\nu} = R_H\left(\frac{1}{3^2} - \frac{1}{4^2}\right) = 109678 \times \left(\frac{1}{9} - \frac{1}{16}\right)$

$\bar{\nu} = 109678 \times 0.04861$

Therefore, $\bar{\nu} \approx 5331.6\,\text{cm}^{-1}$.

27. A. $2.01 \times 10^{-24}\,\text{kgms}^{-1}$

Explanation: de Broglie equation: $\lambda = \frac{h}{p} \Rightarrow p = \frac{h}{\lambda}$

Here, $p = \frac{6.626 \times 10^{-34}}{0.33 \times 10^{-9}}$

Therefore, $p \approx 2.01 \times 10^{-24}\,\text{kgms}^{-1}$.

28. D. 0.485 nm

Explanation: $\lambda = \frac{h}{m_e v}$

Here, $\lambda = \frac{6.626 \times 10^{-34}}{9.1 \times 10^{-31} \times 1.5 \times 10^6}$

Therefore, $\lambda \approx 4.85 \times 10^{-10}\,\text{m} = 0.485\,\text{nm}$.

29. D. $\frac{h}{2\pi}$

Explanation: By Bohr's postulate, angular momentum $L = \frac{nh}{2\pi}$

Here, for the 1st orbit $n = 1$

Therefore, $L = \frac{h}{2\pi} \approx 1.05 \times 10^{-34}\,\text{Js}$.

30. A. 121.6 nm**, UV**

Explanation: Here, $Z = 3$ for Li^{2+}

$E = 13.6Z^2\left(\frac{1}{3^2} - \frac{1}{6^2}\right) = 13.6 \times 9 \times \frac{1}{12} = 10.2\,\text{eV}$

Also, $\lambda = \frac{1240\,\text{eV}\cdot\text{nm}}{10.2\,\text{eV}} \approx 121.6\,\text{nm}$

Therefore, the wavelength is 121.6 nm, which lies in the ultraviolet (UV) region.

31. D. $1.93\,\text{mgL}^{-1}$

Explanation: $S = \sqrt{K_{sp}} = \sqrt{1.8 \times 10^{-10}} \approx 1.342 \times 10^{-5}\,\text{molL}^{-1}$

Here, molar mass of AgCl = 108 + 35.5 = $143.5\,\text{gmol}^{-1}$

Solubility $= 1.342 \times 10^{-5} \times 143.5 \approx 1.93 \times 10^{-3}\,\text{gL}^{-1}$

Therefore, solubility $\approx 1.93\,\text{mgL}^{-1}$.

32. C. 40.8 eV**,** 30.4 nm**, ultraviolet**

Explanation: Here, $Z = 2$ for He^+

$E = 13.6Z^2\left(\frac{1}{1^2} - \frac{1}{2^2}\right) = 13.6 \times 4 \times 0.75 = 40.8\,\text{eV}$

Also, $\lambda = \frac{hc}{E} = \frac{1240\,\text{eV}\cdot\text{nm}}{40.8\,\text{eV}} \approx 30.4\,\text{nm}$

Therefore, energy 40.8 eV, wavelength 30.4 nm , region: ultraviolet (UV).

33. B. 0.8 eV**,** 0.8 V

Explanation: Photon energy $E = \frac{hc}{\lambda} = \frac{1240\,\text{eV}\cdot\text{nm}}{400\,\text{nm}} = 3.1\,\text{eV}$

Einstein's equation: $KE_{max} = E - \phi = 3.1 - 2.3 = 0.8\,\text{eV}$

Stopping potential $V_0 = \frac{KE_{max}}{e} = 0.8\,\text{V}$

Therefore, 0.8 eV and 0.8 V.

34. B. A precipitate will form

Explanation: On mixing equal volumes, concentrations are halved: $[Ba^{2+}] = 0.01\,\text{M}$, $[SO_4^{2-}] = 0.025\,\text{M}$

Ionic product $K_{ip} = [Ba^{2+}][SO_4^{2-}] = 0.01 \times 0.025 = 2.5 \times 10^{-4}$

Here, $K_{ip}\,(2.5 \times 10^{-4}) > K_{sp}\,(1.1 \times 10^{-10})$

Therefore, $BaSO_4$ will precipitate.

35. C. $K_{sp} = 27S^4$

Explanation: $Fe(OH)_3 \rightleftharpoons Fe^{3+} + 3OH^-$

At equilibrium, $[Fe^{3+}] = S$ and $[OH^-] = 3S$

Therefore, $K_{sp} = [Fe^{3+}][OH^-]^3 = (S)(3S)^3 = 27S^4$.

36. C. Salt 50 g**, solvent** 100 g

Explanation: A solubility of 50 means 50 g of salt dissolves in 100 g of solvent to give 150 g of saturated solution.

Here, the required solution is 150 g, exactly this amount.

Therefore, salt = 50 g and solvent = 100 g.

37. B. 3.25×10^{-4} M

Explanation: $Al(OH)_3 \rightleftharpoons Al^{3+} + 3OH^-$; let the solubility be S, so $[Al^{3+}] = S$ and $[OH^-] = 3S$

$K_{sp} = (S)(3S)^3 = 27S^4 = 3.7 \times 10^{-15}$

$S = \left(\frac{3.7\times10^{-15}}{27}\right)^{1/4} \approx 1.08 \times 10^{-4}$ M

Therefore, $[OH^-] = 3S \approx 3.25 \times 10^{-4}$ M.

38. C. 3.2×10^{-11}

Explanation: $CaF_2 \rightleftharpoons Ca^{2+} + 2F^-$

Here, $[Ca^{2+}] = S$ and $[F^-] = 2S$

$K_{sp} = [Ca^{2+}][F^-]^2 = S(2S)^2 = 4S^3$

Therefore, $K_{sp} = 4 \times (2.0 \times 10^{-4})^3 = 3.2 \times 10^{-11}$.

39. B. Solubility decreases

Explanation: Adding a strong electrolyte with a common ion to a solution of a sparingly soluble salt raises the concentration of that ion. Since K_{sp} is constant, by Le Chatelier's principle the equilibrium shifts against dissolution, so solubility decreases.

40. A. 25.0 g

Explanation: At 50°C, 180 g of solution (100 g solvent + 80 g salt) contains 80 g of salt

In 100 g of solution, salt = $\frac{80}{180} \times 100 = 44.44$ g; solvent = 55.56 g

At 20°C, that solvent can hold = $\frac{35}{100} \times 55.56 =$ 19.44 g

Therefore, amount crystallised = 44.44 − 19.44 = 25.0 g.

41. A. $0.700\ gL^{-1}$

Explanation: $PbI_2 \rightleftharpoons Pb^{2+} + 2I^-$; $K_{sp} = 4S^3$

$S = \left(\frac{1.4\times10^{-8}}{4}\right)^{1/3} \approx 1.52 \times 10^{-3}\ molL^{-1}$

Here, molar mass of $PbI_2 = 207 + 2 \times 127 = 461\ gmol^{-1}$

Therefore, solubility = $1.52 \times 10^{-3} \times 461 \approx 0.700\ gL^{-1}$.

42. B. $K_{sp} = 4S^3$

Explanation: $Ag_2CrO_4 \rightleftharpoons 2Ag^+ + CrO_4^{2-}$

Here, $[Ag^+] = 2S$ and $[CrO_4^{2-}] = S$

Therefore, $K_{sp} = [Ag^+]^2[CrO_4^{2-}] = (2S)^2(S) = 4S^3$.

43. D. $Ce_2(SO_4)_3$

Explanation: Dissolution of $Ce_2(SO_4)_3$ is exothermic; by Le Chatelier's principle, raising the temperature shifts the equilibrium against dissolution, so solubility decreases.

44. B. Temperature only

Explanation: K_{sp} is an equilibrium constant that changes only with temperature. Changes in pressure, volume or ion concentration leave the value of K_{sp} unchanged.

45. A. $CH_3COOH + CH_3COONa$

Explanation: CH_3COOH (a weak acid) and CH_3COONa both supply CH_3COO^-, which acts as the common ion and suppresses the dissociation of CH_3COOH (a buffer solution).

46. C. Unsaturated

Explanation: The ionic product K_{ip} is less than the solubility product K_{sp}, so the ions have not yet reached the limit for precipitation. Therefore, the solution is unsaturated; more solute can dissolve and no precipitate forms.

47. A. 32.4°C

Explanation: At 32.4°C, Glauber's salt loses its water of crystallisation and converts to anhydrous Na_2SO_4.

After that, solubility begins to decrease as temperature rises, so the solubility curve changes direction.

48. B. $K_2[HgI_4]$

Explanation: Nessler's reagent is potassium tetraiodomercurate(II), $K_2[HgI_4]$, used to detect the NH_4^+ ion.

49. D. Pink or pale violet

Explanation: Cobalt blue glass absorbs the golden-yellow flame of sodium, so the true pink or pale violet colour of potassium behind it becomes visible.

50. C. Henri Becquerel

Explanation: In 1896, Henri Becquerel accidentally discovered radioactivity while experimenting with uranium salts.