JELET Chemistry Sample Paper-1

Duration: 25 Minutes **Maximum Marks: 25**

Instructions

- This paper contains **20** Multiple Choice Questions divided into **2 Sections**.
- **Section A (Q1–Q15):** Each correct answer carries **+1 mark**. Incorrect answer: **−0.25** marks. Only **one** correct option.
- **Section B (Q16–Q20):** Each correct answer carries **+2 marks**. **No negative marking**. One or **more** correct options may be correct; full marks only if all correct options are marked.
- Unattempted questions carry **0** marks.
- Use of mobile phones, smartwatches, calculators, or any electronic gadgets is strictly prohibited.

Section–A — 15 Questions × 1 Mark Each
(Negative Marking: −0.25) [Single Correct]

Q1. An electron transition in a hydrogen-like atom occurs from an initial state to a final state such that the kinetic energy of the electron increases by a factor of 4. If the initial state Bohr radius is r_1, what is the final state Bohr radius r_2?

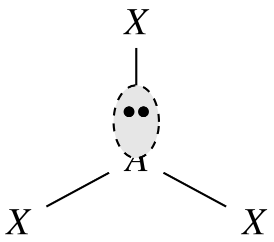
(A) $4r_1$

(B) $2r_1$

(C) $\frac{r_1}{2}$

(D) $\frac{r_1}{4}$

Q2. Consider the following molecular geometry configuration containing a central atom A bound to peripheral atoms X. If the central atom possesses one lone pair of electrons, which of the following species matches the spatial representation shown below?



(A) BF_3

(B) PCl_3

(C) ICl_3

(D) $AlCl_3$

Q3. The quantum numbers of the outermost electron of a ground-state atom are given as $n = 3$, $l = 1$, $m = -1$, and $s = +\frac{1}{2}$. If this element reacts with a highly electropositive metal to form an ionic halide, the ground-state electronic configuration of the anion must strictly obey which sequence?

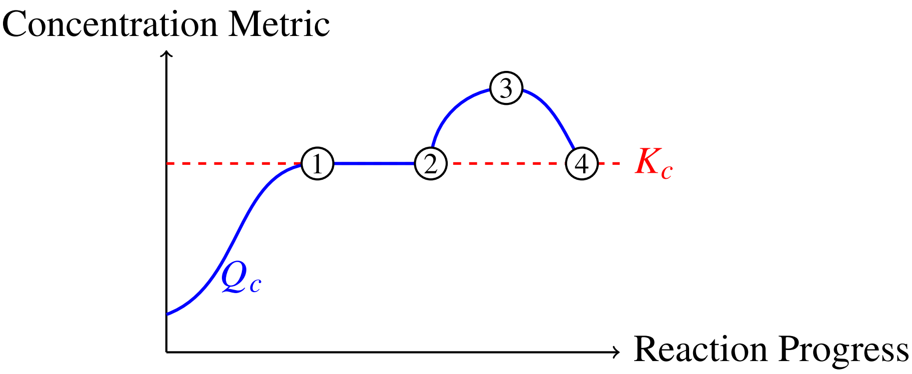
(A) $1s^2 2s^2 2p^6 3s^2 3p^5$

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

(C) $1s^2 2s^2 2p^6 3s^2 3p^4$

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

Q4. A dynamic chemical system involving gaseous reactants and products reaches equilibrium inside a variable volume cylinder. The variation of the reaction quotient Q_c and equilibrium constant K_c over a sequence of external adjustments is illustrated in the schematic path below:



If the modification initiated exactly at state 2 corresponds to a sudden compression of the container volume at constant temperature, which of the following reversible reactions matches the observed trajectory towards state 4?

(A) $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

(B) $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

(C) $N_2O_4(g) \rightleftharpoons 2NO_2(g)$

(D) $C(s) + CO_2(g) \rightleftharpoons 2CO(g)$

Q5. An aqueous solution contains a mixture of 0.1 M CH_3COOH and 0.1 M CH_3COONa. If the acid dissociation constant K_a of CH_3COOH is 1.8×10^{-5}, what is the resulting pH of this system after the addition of 0.02 M anhydrous HCl gas without any volume modification?

(A) $4.74 + \log\left(\frac{0.12}{0.08}\right)$

(B) $4.74 - \log\left(\frac{0.12}{0.08}\right)$

(C) $4.74 + \log\left(\frac{0.10}{0.10}\right)$

(D) $4.74 - \log\left(\frac{0.10}{0.10}\right)$

Q6. According to the Lewis theory of acids and bases, which of the following chemical interactions represents a valid coordination mechanism where the highlighted species behaves strictly as a Lewis acid?

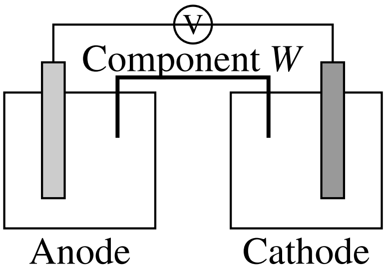
(A) NH_3 reacting with H^+ to yield NH_4^+

(B) BF_3 reacting with F^- to yield BF_4^-

(C) H_2O reacting with H^+ to yield H_3O^+

(D) Cl^- reacting with Ag^+ to yield $AgCl(s)$

Q7. An electrochemical setup consists of two separate compartments filled with standard electrolyte solutions connected via a component, as depicted in the diagram below:



If the spontaneous chemical cell reaction generates a sustained electrical current, what is the primary structural role of Component W?

(A) To facilitate the direct transfer of electrons between the electrolyte reservoirs

(B) To maintain electrical neutrality by permitting migration of ions while preventing bulk mixing

(C) To oxidize metallic cations accumulating at the cathode surface

(D) To act as a sacrificial catalyst that speeds up the reduction rate

Q8. During the electrolysis of an aqueous solution of metal sulfate $M_x(SO_4)_y$ using inert platinum electrodes, a constant current of 2.5 A is passed through the cell for exactly 965 seconds. If 0.0125 moles of the pure metal M deposit at the cathode, what is the oxidation state of the metal ion in the electrolyte solution?

(A) +1

(B) +2

(C) +3

(D) +4

Q9. Which of the following redox pairs undergoes a self-sustained disproportionation reaction when dissolved in a strongly alkaline aqueous medium at elevated temperature?

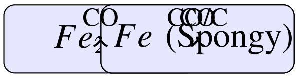
(A) Cl_2 gas converting to Cl^- and ClO_3^-

(B) Fe^{2+} ions converting to Fe^0 and Fe^{3+}

(C) MnO_4^{2-} converting to MnO_2 and MnO_4^- in an acidic medium

(D) Cu^+ converting to Cu^0 and Cu^{2+} in an analytical matrix

Q10. In the industrial extraction of iron from its oxide ores using a blast furnace, the chemical transformations follow distinct thermodynamic boundaries at varying internal temperature levels. Consider the strategic reduction steps summarized in the flowchart below:



Which compound acts as the primary flux added to the charge to remove the main acidic impurities via slag formation during this metallurgical sequence?

(A) Silica (SiO_2)

(B) Calcium oxide (CaO) generated from Limestone ($CaCO_3$)

(C) Coke matrix (C)

(D) Alumina (Al_2O_3)

Q11. The industrial synthesis of nitric acid via the Ostwald process relies on the regulated catalytic oxidation of ammonia gas. If the catalyst chamber undergoes a technical breakdown dropping the efficiency of the initial phase, which specific intermediate molecule drops in concentration first?

(A) Nitric oxide (NO)

(B) Nitrogen dioxide (NO_2)

(C) Dinitrogen pentoxide (N_2O_5)

(D) Ammonium nitrate (NH_4NO_3)

Q12. An analytical evaluation of a water sample reveals high permanent hardness. Chemical treatment using the Permutit process swaps structural ions inside an aluminosilicate framework. What specific ion is exchanged from the structural core of the zeolite matrix into the hard water to mitigate this issue?

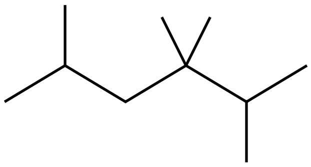
(A) Ca^{2+}

(B) Mg^{2+}

(C) Na^+

(D) H^+

Q13. What is the systematic IUPAC name for the highly branched organic compound whose skeletal representation is detailed below?



(A) 2,4,4-trimethyl-5-ethylhexane

(B) 3,3,5-trimethyl-2-ethylhexane

(C) 2,4,4,5-tetramethylheptane

(D) 3,4,4,6-tetramethylheptane

Q14. The structural hybridisation state of individual carbon atoms determines their electronegativity profile and directional bonding characteristics. In the molecule acrylic acid ($CH_2 = CH - COOH$), what is the sequential hybridisation state of the three carbon atoms moving from left to right?

(A) sp^2, sp^2, sp^3

(B) sp^2, sp^2, sp^2

(C) sp^3, sp^2, sp^2

(D) sp^2, sp, sp^2

Q15. Photochemical smog is a modern environmental hazard observed in dense urban zones during bright daylight conditions. Which pair of chemical pollutants acts as the primary primary precursors required to generate this irritating atmospheric secondary layer?

(A) Carbon dioxide and particulate moisture

(B) Unburnt hydrocarbons and nitrogen oxides (NO_x)

(C) Sulfur dioxide and chlorofluorocarbons

(D) Excess ozone and carbon monoxide

Section–B — 5 Questions × 2 Marks Each (No Negative Marking) [One or More Correct]

Q16. Which of the following physical and chemical features match correctly with the postulates of the Bohr atomic model and modern quantum mechanical interpretations for a hydrogenic atom?

(A) The orbital angular momentum of an electron in a $2s$ orbital is equal to zero according to quantum mechanics.

(B) The radius of a stable electron orbit is directly proportional to the square of the principal quantum number n.

(C) According to Pauli's exclusion principle, two electrons in the same orbital can have identical spin values if $l = 0$.

(D) Hund's rule of maximum multiplicity applies only to configuration matching d-orbitals and does not influence p-subshells.

Q17. A chemical reaction system involving a gaseous catalyst is allowed to reach dynamic equilibrium. According to Le Chatelier's principle and active kinetic equations, which of the following interventions will alter the equilibrium composition or shift the path of the system?

(A) Increasing the total pressure of the container by injecting an inert gas like Argon at constant volume.

(B) Introducing an alternative solid catalyst that provides a lower activation energy pathway for the forward reaction.

(C) Decreasing the temperature of an exothermic reaction system, thereby increasing the net concentration of products at equilibrium.

(D) Removing a portion of a gaseous product continuously from the reaction assembly, driving the net process forward.

Q18. Consider the standard electrode potential data presented below at 298 K for three distinct metallic redox couples:

$$E^\circ(A^{2+}/A) = -0.76\ \text{V}$$
$$E^\circ(B^{3+}/B) = -0.44\ \text{V}$$
$$E^\circ(C^{+}/C) = +0.34\ \text{V}$$

Which of the following predictive statements are scientifically accurate based on this electrochemical information?

(A) Species A can spontaneously reduce B^{3+} ions to metallic B under standard state conditions.

(B) Metallic C will dissolve readily in an aqueous mineral acid solution to liberate hydrogen gas.

(C) The galvanic cell constructed using the couples A^{2+}/A and C^{+}/C will exhibit a standard electromotive force (E°_{cell}) of $+1.10$ V.

(D) Element A possesses a higher thermodynamic driving force for oxidation compared to element B.

Q19. The industrial management of waste resources and processing materials requires critical steps for the extraction of copper from copper pyrites ($CuFeS_2$). Which of the following operations represent standard chemical transformations during the metallurgy of copper?

(A) Partial roasting of the concentrated ore to convert iron sulfides preferentially into iron oxides (FeO).

(B) Addition of silica (SiO_2) during the smelting phase to remove iron oxide impurities as a fusible slag ($FeSiO_3$).

(C) Self-reduction of copper oxide (Cu_2O) by remaining copper sulfide (Cu_2S) in the Bessemer converter to produce blister copper.

(D) The utilize of an aluminum-based reducing agent (aluminothermic process) to isolate copper from its molten matte layer.

Q20. The greenhouse effect is an essential thermal regulation layer of the Earth's atmosphere, but anthropogenic emissions have skewed its equilibrium. Which of the following chemical gases contribute directly to the enhanced greenhouse effect and accelerated climate forcing?

(A) Methane (CH_4) originating from agricultural cultivation and anaerobic decay matrices.

(B) Dinitrogen oxide (N_2O) released through chemical fertilizer application and industrial combustion.

(C) Chlorofluorocarbons ($CFCs$) functioning as strong radiative forcing agents alongside ozone depletion capability.

(D) Pure Diatomic Nitrogen (N_2) acting as the principal infrared absorbing molecular species in the tropospheric envelope.

(E) Water vapor ($H_2O_{(g)}$) acting through positive atmospheric feedback loops.

Detailed Solutions

Q1.

Solution

Concept:
Bohr's atomic model relates an electron's kinetic energy to its orbital radius and principal quantum number. In a hydrogen-like atom, the kinetic energy is inversely proportional to the orbit radius, while the Bohr radius itself scales quadratically with the principal quantum number.

Solution:

(a) The total energy of an electron in a stable Bohr orbit is negative, and by the virial theorem, the kinetic energy (KE) is equal to the negative of the total energy: $KE = -E$.

(b) The expression for the Bohr radius of a hydrogenic atom is $r_n = \frac{n^2 r_0}{Z}$, indicating that r is proportional to n^2.

(c) The energy, and thus the kinetic energy, is given by $KE_n \propto \frac{Z^2}{n^2}$. Combining this with the radius relationship yields $KE \propto \frac{1}{r}$.

(d) Given that the final kinetic energy increases by a factor of 4 ($KE_2 = 4 \cdot KE_1$), we can establish the inverse ratio: $\frac{KE_2}{KE_1} = \frac{r_1}{r_2}$.

(e) Substituting the factor gives $4 = \frac{r_1}{r_2}$, which simplifies directly to $r_2 = \frac{r_1}{4}$.

Final Answer: $\mathrm{r}_1\,\overline{4}$

Answer: (D)

Go Back to Question 1

Q2.

Solution

Concept:
Valence Shell Electron Pair Repulsion (VSEPR) theory determines molecular geometry based on steric numbers. A central atom A forming three σ-bonds with one lone pair possesses a steric number of 4, yielding a trigonal pyramidal shape derived from a tetrahedral electron geometry.

Solution:

(a) The TikZ illustration depicts a central atom A bound to three peripheral X atoms with a single lone pair residing on the vertical axis. This spatial arrangement defines a trigonal pyramidal geometry.

(b) Boron trifluoride (BF_3) and aluminum chloride ($AlCl_3$) contain central atoms with three valence electrons. They form three bonds with zero lone pairs, adopting a trigonal planar geometry (sp^2).

(c) Iodine trichloride (ICl_3) has seven valence electrons, forming three bonding pairs and two lone pairs. This yields a steric number of 5, which corresponds to a T-shaped geometry (sp^3d).

(d) Phosphorus trichloride (PCl_3) contains a central phosphorus atom with five valence electrons. It uses three electrons for bonding with chlorine atoms, leaving one lone pair (sp^3 hybridised).

(e) Therefore, PCl_3 perfectly matches the trigonal pyramidal configuration shown in the schematic template.

Final Answer: $\mathrm{PCl_3}$

Answer: (B)

Go Back to Question 2

Q3.

Solution

Concept:
Quantum numbers determine the exact electronic position and shell configuration of an element. The principal quantum number n and azimuthal quantum number l designate the specific energy subshell, dictating how an atom interacts to achieve a stable octet configuration.

Solution:

(a) The outermost valence electron has quantum numbers $n = 3$ and $l = 1$. This explicitly places the valence shell in the $3p$ subshell.

(b) Since $m = -1$ and $s = +\frac{1}{2}$, this corresponds to the first electron entering the $3p$ orbitals. For a ground-state neutral atom following Hund's rule, the configuration ends in $3s^2 3p^1$ (Aluminum).

(c) However, the question specifies that this neutral element reacts with a highly electropositive metal to form an ionic halide, meaning our target element must act as the halogen/anion provider in the final compound.

(d) Re-evaluating the configuration for a typical halide forming element with valence electrons in $n = 3, l = 1$, a halogen like Chlorine ($3s^2 3p^5$) accepts an electron from the electropositive metal.

(e) Upon gaining one electron to achieve a stable noble gas octet, the resulting anion forms a completely filled $3p$ subshell, yielding the stable electronic sequence $1s^2 2s^2 2p^6 3s^2 3p^6$.

Final Answer: $1\mathrm{s}^2 2s^2 2p^6 3s^2 3p^6$

Answer: (B)

Go Back to Question 3

Q4.

Solution

Concept:

Le Chatelier's principle dictates that a system at equilibrium responds to external stresses by shifting in a direction that minimizes the disturbance. A change in container volume alters the partial pressures of gaseous components, disturbing the reaction quotient.

Solution:

(a) The graph illustrates that the system is initially at equilibrium because the reaction quotient Q_c is equal to the equilibrium constant K_c between states 1 and 2.

(b) At state 2, a sudden compression reduces the volume, instantly increasing the molar concentrations of all gaseous species. This causes a vertical spike in Q_c above the baseline K_c value.

(c) For Q_c to increase sharply upon compression, the concentration of products in the expression must be raised to a higher power than the reactants, meaning $\Delta n_g > 0$ for the forward direction.

(d) Following this disturbance, the system shifts in the reverse direction to decrease total gaseous moles, gradually lowering Q_c back down to merge with K_c at state 4.

(e) Among the choices, the dissociation of dinitrogen tetroxide, $N_2O_4(g) \rightleftharpoons 2NO_2(g)$, has $\Delta n_g = +1$. Sudden compression causes $Q_c = \frac{[NO_2]^2}{[N_2O_4]}$ to spike, matching the path perfectly.

Final Answer: $\mathrm{N}_2O_4(g) \rightleftharpoons 2NO_2(g)$

Answer: (C)

Go Back to Question 4

Q5.

Solution

Concept:
An aqueous mixture of a weak acid and its conjugate salt forms an acidic buffer solution. The pH of such a system can be quantitatively evaluated using the Henderson-Hasselbalch equation, which remains operational under minor strong acid additions.
Solution:

(a) The initial buffer solution contains 0.1 M CH_3COOH (weak acid) and 0.1 M CH_3COONa (conjugate base). The base value $pK_a = -\log(1.8 \times 10^{-5}) = 4.74$.

(b) When 0.02 M of anhydrous strong acid HCl gas is dissolved, it dissociates completely to release 0.02 M of H^+ ions into the buffer matrix.

(c) These added H^+ ions react stoichiometrically with the conjugate base present: $CH_3COO^- + H^+ \rightarrow CH_3COOH$.

(d) Consequently, the concentration of the salt decreases by 0.02 M (0.10 − 0.02 = 0.08 M), and the concentration of the weak acid increases by 0.02 M (0.10 + 0.02 = 0.12 M).

(e) Applying these modified equilibrium concentrations into the Henderson-Hasselbalch framework yields: $pH = pK_a + \log\left(\frac{[\text{Salt}]}{[\text{Acid}]}\right) = 4.74 + \log\left(\frac{0.08}{0.12}\right)$, which mathematically equates to $4.74 - \log\left(\frac{0.12}{0.08}\right)$.

Final Answer: 4.74 - log $\left(\frac{0.12}{0.08}\right)$

Answer: (B)

Go Back to Question 5

Q6.

Solution

Concept:

The Lewis theory defines acids as electron-pair acceptors and bases as electron-pair donors. A classic Lewis acid-base interaction involves the transfer of an unshared pair of electrons from a nucleophilic donor to an electrophilic acceptor shell.

Solution:

(a) In option A, NH_3 uses its lone pair to bind with a proton (H^+), meaning NH_3 acts as a Lewis base while H^+ acts as the acid.

(b) In option B, Boron trifluoride (BF_3) features a central boron atom surrounded by six valence electrons, leaving an incomplete octet with a vacant $2p$ orbital.

(c) When reacting with a fluoride ion (F^-), the electron-deficient BF_3 molecule accepts a lone pair of electrons from F^- to complete its octet and form a stable BF_4^- coordination complex.

(d) This absolute requirement for an external electron pair classifies the highlighted BF_3 molecule strictly as a Lewis acid during this synthesis path.

(e) Options C and D show water acting as a base and silver ions forming a bulk precipitate rather than highlighting a strict molecular Lewis acid reactant.

Final Answer: BF_3 reacting with F^- to yield BF_4^-

$\boxed{\textbf{Answer: (B)}}$

Go Back to Question 6

Q7.

Solution

Concept:
A galvanic or voltaic cell converts chemical energy from spontaneous redox reactions into electrical energy. The physical separation of the half-cells necessitates an ionic bridging channel to close the electrical loop.

Solution:

(a) The given schematic depicts a classic electrochemical cell where the two half-cells are connected externally by wires passing through a voltmeter, and internally linked via Component W.

(b) Component W represents a salt bridge, typically packed with an inert electrolyte in an agar-agar gel matrix, such as potassium chloride (KCl) or ammonium nitrate (NH_4NO_3).

(c) As oxidation proceeds at the anode and reduction occurs at the cathode, an uncompensated charge accumulation begins to build up in both electrolyte reservoirs.

(d) The primary structural duty of the salt bridge is to maintain electrical neutrality within each container by allowing specific anions and cations to migrate into the respective half-cells.

(e) Simultaneously, it physically isolates the two solutions to prevent rapid mechanical mixing, ensuring that electron flow is forced through the external circuit rather than via direct internal transfer.

Final Answer: To maintain electrical neutrality by permitting migration of ions while preventing bulk mixing

Answer: (B)

Go Back to Question 7

Q8.

Solution

Concept:

Faraday's laws of electrolysis establish a direct quantitative relationship between the total electrical charge passed through an electrolyte and the chemical mass of substance liberated at an electrode.

Solution:

(a) First, calculate the total electrical charge (Q) passed through the electrolytic cell using the current (I) and time (t) values: $Q = I \times t = 2.5 \text{ A} \times 965 \text{ s} = 2412.5$ Coulombs.

(b) Convert this total charge from Coulombs into Faradays by dividing by the Faraday constant ($F = 96500$ C/mol): Moles of electrons $= \frac{2412.5}{96500} = 0.025$ moles of electrons.

(c) The relationship between the moles of metal deposited, the moles of electrons consumed, and the valency factor (z) of the metal ion is given by: Moles of metal $= \frac{\text{Moles of electrons}}{z}$.

(d) Substituting our calculated parameters into the equation yields $0.0125 = \frac{0.025}{z}$. Solving for the valency factor gives $z = \frac{0.025}{0.0125} = 2$.

(e) Since the valency factor corresponds to the total positive charge neutralized at the cathode, the oxidation state of the metal ion in solution is +2.

Final Answer: +2

Answer: (B)

Go Back to Question 8

Q9.

Solution

Concept:
A disproportionation reaction is a specific subclass of redox behavior where a single chemical species simultaneously undergoes both oxidation and reduction to form two distinct products with different oxidation states.

Solution:

(a) Disproportionation requires the reacting element to exist in an intermediate oxidation state, allowing it to transition to both higher and lower oxidation levels.

(b) When elemental chlorine gas (Cl_2, oxidation state 0) is dissolved in a hot, concentrated alkaline medium (such as aqueous $NaOH$), it undergoes a rapid self-redox reaction.

(c) A portion of the chlorine atoms is reduced to chloride ions (Cl^-, oxidation state -1), while the remaining portion is oxidized to chlorate ions (ClO_3^-, oxidation state $+5$).

(d) The balanced chemical equation for this alkaline process is expressed as: $3Cl_2 + 6OH^- \rightarrow 5Cl^- + ClO_3^- + 3H_2O$.

(e) While option C also represents a valid disproportionation reaction for manganate ions, it takes place specifically in an acidic medium, leaving option A as the only choice that satisfies the alkaline condition.

Final Answer: Cl_2 gas converting to Cl^- and ClO_3^-

$\boxed{\textbf{Answer: (A)}}$

Go Back to Question 9

Q10.

Solution

Concept:
Metallurgical extraction in a blast furnace requires the addition of a chemical flux to remove non-fusible gangue materials. The choice of flux depends on the chemical nature of the impurities present in the ore matrix.

Solution:

(a) Hematite (Fe_2O_3) ore naturally contains a high proportion of sandy, acidic impurities, primarily consisting of silicon dioxide or silica (SiO_2).

(b) To remove this high-melting infusible gangue, a basic flux must be introduced into the furnace charge. Limestone ($CaCO_3$) is added along with the ore and coke.

(c) As the charge descends into the higher temperature zones of the blast furnace, limestone undergoes thermal decomposition: $CaCO_3 \rightarrow CaO + CO_2$.

(d) The resulting calcium oxide (CaO) is a highly reactive basic oxide. It combines with the acidic silica impurities via an acid-base neutralization reaction: $CaO + SiO_2 \rightarrow CaSiO_3$.

(e) This forms calcium silicate ($CaSiO_3$), known as slag. Because the molten slag is less dense than liquid iron, it floats on top and is easily skimmed off, leaving behind pure spongy iron.

Final Answer: Calcium oxide (CaO) generated from Limestone ($CaCO_3$)

$\boxed{\textbf{Answer: (B)}}$

Go Back to Question 10

Q11.

Solution

Concept:
The Ostwald process converts ammonia to nitric acid through sequential oxidation steps. The initial step requires a platinum-rhodium catalyst to selectively oxidize ammonia into nitric oxide gas, which serves as the fundamental building block for subsequent nitrogen dioxide and nitric acid formations.

Solution:

(a) The industrial sequence begins in the catalyst chamber, where ammonia gas reacts with atmospheric oxygen at high temperatures: $4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$. This oxidation must happen efficiently to sustain production.

(b) This reaction converts ammonia directly into nitric oxide (NO). If a technical breakdown occurs within this catalytic zone, the efficiency of this baseline conversion drops instantly.

(c) Because the formation of downstream products relies entirely on the continuous availability of nitric oxide, any decrease in initial reaction efficiency affects NO production immediately.

(d) Subsequent chambers oxidize the generated NO to nitrogen dioxide ($2NO + O_2 \rightleftharpoons 2NO_2$), which is later absorbed in water to yield nitric acid (HNO_3).

(e) Since nitric oxide is the direct primary product of the first catalytic step, its concentration drops first before the decrease propagates down to the secondary and tertiary intermediates like NO_2 or N_2O_5.

Final Answer: Nitric oxide (NO)

Answer: (A)

Go Back to Question 11

Q12.

Solution

Concept:

The Permutit process is an ion-exchange method used to mitigate permanent water hardness caused by dissolved calcium and magnesium ions. It employs synthetic or natural hydrated sodium aluminosilicates, known as zeolites, as a medium for active cation exchange.

Solution:

(a) Permanent hardness in water samples is primarily due to the presence of soluble chlorides and sulfates of calcium (Ca^{2+}) and magnesium (Mg^{2+}). These divalent cations form undesirable scales and scum.

(b) The Permutit or zeolite matrix is chemically represented as $Na_2Al_2Si_2O_8 \cdot xH_2O$, which can be simplified as Na_2Z, where Z represents the complex insoluble aluminosilicate framework.

(c) When hard water is passed through the column filled with this exchange material, a displacement reaction occurs at the surface. The framework has a higher thermodynamic affinity for divalent ions than for monovalent ions.

(d) The active sodium ions (Na^+) present within the structural core of the zeolite matrix detach and migrate out into the water, while the hardness-causing Ca^{2+} and Mg^{2+} ions take their place.

(e) The chemical exchange follows the path: $Na_2Z + Ca^{2+} \to CaZ + 2Na^+$. Thus, harmless sodium ions are exchanged into the water, leaving the hard scaling components trapped inside the matrix.

Final Answer: Na^+

Answer: (C)

Go Back to Question 12

Q13.

Solution

Concept:
The systematic IUPAC nomenclature of branched alkanes requires identifying the longest continuous carbon chain as the parent framework. Substituents are then numbered from the end of the chain that gives the lowest possible locant set for all branch points.

Solution:

(a) Analyzing the provided skeletal structure, the longest continuous carbon chain contains seven carbon atoms, which establishes a heptane parent framework rather than a hexane framework.

(b) Numbering the main chain from left to right places the branch locants at positions 2, 4, 4, and 5. Numbering from right to left would yield positions 3, 4, 4, and 6.

(c) Comparing the two sets of locants, the set (2, 4, 4, 5) is lower than (3, 4, 4, 6) at the first point of difference, so the left-to-right numbering direction is chosen.

(d) Identifying the specific alkyl groups attached to this heptane core reveals four distinct single-carbon fragments, which are classified collectively as methyl substituents.

(e) Combining the positional locants with the substituent prefixes and parent name results in the single consolidated title: 2,4,4,5-tetramethylheptane.

Final Answer: 2,4,4,5-tetramethylheptane

Answer: (C)

Go Back to Question 13

Q14.

Solution

Concept:

The orbital hybridization of a carbon atom depends on its steric number, which is the sum of its σ-bonds and lone pairs. In organic structures, single bonds represent σ-bonds, double bonds contain one σ and one π bond, and carboxylic groups have characteristic geometries.

Solution:

(a) The structural formula of acrylic acid is written explicitly as $CH_2 = CH - COOH$. We analyze each carbon atom from left to right to determine its individual coordination and hybridization.

(b) The first carbon atom forms two single σ-bonds with hydrogen atoms and one double bond with the neighboring carbon. This double bond consists of one σ and one π bond, giving a steric number of 3 (sp^2).

(c) The second carbon atom forms one single σ-bond with hydrogen, one single σ-bond with the carbonyl carbon, and participates in the double bond. It also has three σ-bonds and zero lone pairs, making it sp^2 hybridized.

(d) The third carbon atom belongs to the carboxylic acid group ($-COOH$). It forms one σ-bond with the adjacent alkene carbon, one σ-bond with the hydroxyl group, and one double bond ($\sigma + \pi$) with the carbonyl oxygen.

(e) Having a steric number of 3, this carbonyl carbon also adopts a trigonal planar arrangement, meaning all three carbon atoms sequentially maintain an sp^2 hybrid state.

Final Answer: sp^2, sp^2, sp^2

Answer: (B)

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Q15.

Solution

Concept:

Photochemical smog is a secondary air pollution layer that forms in the lower troposphere. Its generation requires solar radiation to drive chemical reactions between primary anthropogenic pollutants, producing harmful compounds like ozone and peroxyacetyl nitrates.

Solution:

(a) Photochemical smog thrives in urban areas with high vehicular density and intense sunlight. Unlike industrial smog, which stems from sulfur oxides, this variety depends heavily on internal combustion engine emissions.

(b) The primary components emitted by vehicles include unburnt volatile organic compounds (hydrocarbons) and various oxides of nitrogen, collectively abbreviated as NO_x (primarily NO and NO_2).

(c) When exposed to ultraviolet solar radiation, nitrogen dioxide undergoes photolysis to release reactive atomic oxygen: $NO_2 + h\nu \to NO + O$. This free oxygen atom combines with atmospheric oxygen to generate tropospheric ozone (O_3).

(d) Simultaneously, the unburnt hydrocarbons react with nitric oxide and oxygen to form highly irritating secondary peroxyacetyl nitrate (PAN) molecules and acrolein derivatives.

(e) Because the entire photochemical chain reaction requires both nitrogen oxides and volatile hydrocarbons to sustain its cyclic pathway, these two families of chemicals act as the essential primary precursors.

Final Answer: Unburnt hydrocarbons and nitrogen oxides (NO_x)

$\boxed{\textbf{Answer: (B)}}$

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Q16.

Solution

Concept:

Atomic models track electron properties using mathematical frameworks. Bohr's model defines classical orbital trajectories based on quantized angular momentum, whereas quantum mechanics uses wave functions and probability densities to map atomic structures.

Solution:

(a) Statement A: In quantum mechanics, orbital angular momentum is governed by $L = \sqrt{l(l+1)}\hbar$. For any s-orbital, the azimuthal quantum number $l = 0$, yielding an angular momentum of exactly zero. This statement is correct.

(b) Statement B: Bohr's model states that the radius of a stable electron orbit is $r_n = \frac{n^2 h^2 \epsilon_0}{\pi m e^2 Z}$. The orbit radius scales in direct proportion to n^2, verifying this classical postulate. This statement is correct.

(c) Statement C: Pauli's exclusion principle dictates that no two electrons within a single atom can share the exact same set of four quantum numbers. If two electrons occupy the same orbital, their spins must be opposed. This statement is incorrect.

(d) Statement D: Hund's rule of maximum multiplicity governs the filling sequence of all degenerate subshells, including p, d, and f subshells, dictating that orbitals must be singly occupied before pairing. This statement is incorrect.

Final Answer: A, B

Answer: (A,B)

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Q17.

Solution

Concept:

Le Chatelier's principle establishes that a dynamic chemical system at equilibrium will undergo a net shift to counteract any external modifications in concentration, temperature, or pressure, thereby establishing a new equilibrium state.

Solution:

(a) Statement A: When an inert gas is introduced at constant volume, the total pressure increases, but partial pressures and molar concentrations of the reacting species remain unchanged. No equilibrium shift occurs. This statement is incorrect.

(b) Statement B: A catalyst increases the rates of both forward and reverse reactions equally by lowering the activation energy pathway. It accelerates the speed to reach equilibrium but does not alter the final composition. This statement is incorrect.

(c) Statement C: For an exothermic reaction, heat is liberated as a product. According to thermodynamic principles, lowering the system temperature shifts the equilibrium toward the forward direction to generate heat, increasing product concentration. This statement is correct.

(d) Statement D: Continuously removing a gaseous product from the reaction vessel drops its partial pressure, forcing the system to shift forward to replenish the lost component and driving the net conversion. This statement is correct.

Final Answer: C, D

$\boxed{\textbf{Answer: (C,D)}}$

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Q18.

Solution

Concept:

Standard reduction potentials quantify the thermodynamic tendency of a chemical species to acquire electrons and undergo reduction. A lower reduction potential indicates a stronger reducing agent, whereas a higher positive potential indicates a stronger oxidizing agent.

Solution:

(a) Statement A: The potentials show that $E^\circ(A^{2+}/A) = -0.76$ V is more negative than $E^\circ(B^{3+}/B) = -0.44$ V. This confirms metallic A has a greater tendency to lose electrons, spontaneously reducing B^{3+} ions. This statement is correct.

(b) Statement B: For a metal to dissolve in a mineral acid and liberate hydrogen gas, it must possess a negative standard reduction potential. Since $E^\circ(C^{+}/C) = +0.34$ V is positive, metallic C will not dissolve. This statement is incorrect.

(c) Statement C: A galvanic cell utilizing these couples uses the higher potential couple as cathode and the lower as anode: $E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}} = +0.34\text{ V} - (-0.76\text{ V}) = +1.10$ V. This statement is correct.

(d) Statement D: Because the reduction potential of A is more negative than that of B, the corresponding oxidation potential of A is higher, giving element A a higher thermodynamic driving force for oxidation. This statement is correct.

Final Answer: A, C, D

Answer: (A,C,D)

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Q19.

Solution

Concept:

The extractive metallurgy of copper from copper pyrites ($CuFeS_2$) involves enrichment steps including froth flotation, roasting to oxidize sulfides, smelting to remove iron as a silicate slag, and self-reduction within a Bessemer converter.

Solution:

(a) Statement A: During roasting, the concentrated copper pyrites ore is heated with oxygen. This treatment converts the iron sulfide component preferentially into iron oxide (FeO) due to iron's higher affinity for oxygen. This statement is correct.

(b) Statement B: In the smelting furnace, silica (SiO_2) is added as an acidic flux. It reacts with basic iron oxide to form a fusible liquid layer known as iron silicate slag ($FeSiO_3$). This statement is correct.

(c) Statement C: In the Bessemer converter, a controlled air blast causes a self-reduction process. The copper oxide reacts directly with the remaining copper sulfide to form metallic blister copper. This statement is correct.

(d) Statement D: Isolation of copper from its matte layer relies entirely on self-reduction chemistry. An aluminum-based reducing agent (aluminothermic process) is not used for copper extraction, being reserved for electropositive metals. This statement is incorrect.

Final Answer: A, B, C

Answer: (A,B,C)

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Q20.

Solution

Concept:
The enhanced greenhouse effect results from the accumulation of gases that absorb and emit infrared radiation within the troposphere. This trapping mechanism prevents thermal energy from escaping back into space, altering the global radiative equilibrium.

Solution:

(a) Statement A: Methane (CH_4) is a prominent greenhouse gas that exhibits high infrared absorption efficiency, released via anaerobic decomposition pathways in wetlands, rice fields, and digestive tracts of livestock. This statement is correct.

(b) Statement B: Dinitrogen oxide (N_2O), produced through microbial denitrification processes amplified by chemical fertilizers and high-temperature industrial combustion, acts as a potent greenhouse gas. This statement is correct.

(c) Statement C: Chlorofluorocarbons ($CFCs$) are synthetic compounds possessing immense global warming potentials alongside their capacity to destroy stratospheric ozone, trapping considerable infrared energy. This statement is correct.

(d) Statement D: Diatomic nitrogen (N_2) constitutes 78 percent of the atmosphere. However, being a homonuclear diatomic molecule, it cannot undergo a net change in dipole moment, meaning it cannot absorb infrared radiation. This statement is incorrect.

Final Answer: A, B, C

Answer: (A,B,C)

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Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	D	2	B	3	B	4	C	5	B
6	B	7	B	8	B	9	A	10	B
11	A	12	C	13	C	14	B	15	B
16	A,B	17	C,D	18	A,C,D	19	A,B,C	20	A,B,C