Selection Examination for the Master's and Doctoral

Programa de Pós-graduação Multicêntrico em Química de Minas Gerais

PPGMQ-MG – 1/2026

Registration Code		**Date:** December 9, 2025
		Time: 1:30 PM – 5:30 PM

GENERAL INSTRUCTIONS FOR CANDIDATES (READ CAREFULLY!)

1. **Identification:** Identify your exam using only your registration code. Do not write your name on any part of the question booklet or the answer sheet.
2. **Header:** When signing the attendance list, verify your code and fill in the identification fields on every page of the exam.
3. **Allowed and Prohibited Materials:**
   - The exam must be completed using a blue ink ballpoint pen.
   - The use of a simple scientific calculator is permitted.
   - The use of cell phones, smartwatches, headphones, or any other electronic devices is strictly prohibited. These must remain turned off and stored away.
   - Consulting references or personal notes is not permitted.
4. **Duration and Departure:**
   - The exam will have a total duration of 4 hours.
   - Candidates may only submit their exam and leave the room after 15 minutes have elapsed since the start.
   - Upon finishing the exam, the candidate must hand in the question booklet along with the filled-out answer sheet to the proctor responsible for their location.
5. **Periodic Table:** The periodic table can be found at the end of the booklet and may be detached for reference.
6. **Filling out the Answer Sheet:**
   - All answers must be transcribed onto the Answer Sheet (page 02).
   - Completely fill in the square corresponding to the alternative you believe to be correct using a pen.
   - **Attention:** Only the answer sheet will be considered for grading. Erasures, double marking, or failure to fill in a response will result in a score of zero for that question.
7. **Questions:** No clarifications regarding the content of the questions will be provided during the exam.

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ANSWER SHEET

1.	☐ A	☐ B	☐ C	☐ D	☐ E	21.	☐ A	☐ B	☐ C	☐ D	☐ E
2.	☐ A	☐ B	☐ C	☐ D	☐ E	22.	☐ A	☐ B	☐ C	☐ D	☐ E
3.	☐ A	☐ B	☐ C	☐ D	☐ E	23.	☐ A	☐ B	☐ C	☐ D	☐ E
4.	☐ A	☐ B	☐ C	☐ D	☐ E	24.	☐ A	☐ B	☐ C	☐ D	☐ E
5.	☐ A	☐ B	☐ C	☐ D	☐ E	25.	☐ A	☐ B	☐ C	☐ D	☐ E
6.	☐ A	☐ B	☐ C	☐ D	☐ E	26.	☐ A	☐ B	☐ C	☐ D	☐ E
7.	☐ A	☐ B	☐ C	☐ D	☐ E	27.	☐ A	☐ B	☐ C	☐ D	☐ E
8.	☐ A	☐ B	☐ C	☐ D	☐ E	28.	☐ A	☐ B	☐ C	☐ D	☐ E
9.	☐ A	☐ B	☐ C	☐ D	☐ E	29.	☐ A	☐ B	☐ C	☐ D	☐ E
10.	☐ A	☐ B	☐ C	☐ D	☐ E	30.	☐ A	☐ B	☐ C	☐ D	☐ E
11.	☐ A	☐ B	☐ C	☐ D	☐ E	31.	☐ A	☐ B	☐ C	☐ D	☐ E
12.	☐ A	☐ B	☐ C	☐ D	☐ E	32.	☐ A	☐ B	☐ C	☐ D	☐ E
13.	☐ A	☐ B	☐ C	☐ D	☐ E	33.	☐ A	☐ B	☐ C	☐ D	☐ E
14.	☐ A	☐ B	☐ C	☐ D	☐ E	34.	☐ A	☐ B	☐ C	☐ D	☐ E
15.	☐ A	☐ B	☐ C	☐ D	☐ E	35.	☐ A	☐ B	☐ C	☐ D	☐ E
16.	☐ A	☐ B	☐ C	☐ D	☐ E	36.	☐ A	☐ B	☐ C	☐ D	☐ E
17.	☐ A	☐ B	☐ C	☐ D	☐ E	37.	☐ A	☐ B	☐ C	☐ D	☐ E
18.	☐ A	☐ B	☐ C	☐ D	☐ E	38.	☐ A	☐ B	☐ C	☐ D	☐ E
19.	☐ A	☐ B	☐ C	☐ D	☐ E	39.	☐ A	☐ B	☐ C	☐ D	☐ E
20.	☐ A	☐ B	☐ C	☐ D	☐ E	40.	☐ A	☐ B	☐ C	☐ D	☐ E

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Question 1: The size of atoms is determined by several factors, among them the principal quantum number and the effective nuclear charge (Z_{eff}). These variables directly influence the atomic radius, which presents systematic variations across the periods and groups of the Periodic Table. Based on this information and the concepts of electronic structure, select the **correct alternative** regarding the variations of the atomic radius:

A) Across a period of the Periodic Table, from left to right, an increase in the atomic radius is observed, which is consistent with the progressive increase in the effective nuclear charge.

B) The radius of an anion is always smaller than the radius of the corresponding neutral atom, since the addition of electrons increases the nucleus-electron electrostatic attraction.

C) Across a period in the Periodic Table, a strong correlation between the effective nuclear charge and the atomic radius is observed: the higher the Z_{eff}, the smaller the radius, due to the greater attraction of the nucleus on the electrons of the valence shell.

D) The atomic radius of elements in the same group decreases with the increase in atomic number, because the increase in shielding reduces the effect of the addition of electron shells.

E) Elements located in the same period have approximately equal atomic radii, because they possess the same number of electron shells, and the variation of the effective nuclear charge does not significantly influence atomic size.

Question 2: Periodic properties allow for the prediction of reactivity and the ease of ion formation, guiding the development of materials with specific electrical and chemical characteristics.

Consider the hypothetical neutral atoms V, X, Y, and Z in the gaseous state and their respective electronic configurations in the ground state:

V(g): [noble gas] $(n-1)d^{10}\ ns^2\ np^3$

X(g): [noble gas] ns^2

Y(g): [noble gas] $(n-1)d^{10}\ ns^2\ np^6\ (n+1)s^2$

Z(g): [noble gas] $(n-1)d^{10}\ ns^2\ np^5$

In the configurations above, [noble gas] represents the electronic configuration in the Linus Pauling diagram for the same noble gas, and n is the same principal quantum number for all species. Based on this information, it is **CORRECT** to state that:

A) Atom V has the highest electron affinity among the cited species.

B) Atom X has the smallest atomic radius among the cited species.

C) The first ionization energy of atom Z is the highest among the cited species.

D) The first ionization energy of Y is greater than that of X.

E) The electronegativity of V is greater than that of Z.

Question 3: Consider three chemical elements belonging to the same period of the Periodic Table:

Element A, with atomic number 12.
Element B, with atomic number 15.
Element C, with atomic number 17.

Based on the periodic trends for **atomic radius**, **ionization energy**, and **electron affinity** across a period, select the correct alternative.

A) The atomic radius increases from A → B → C, while ionization energy and electron affinity decrease.

B) The atomic radius decreases from A → B → C, while ionization energy increases, but electron affinity decreases.

C) The atomic radius decreases from A → B → C, while ionization energy and electron affinity increase.

D) The atomic radius and ionization energy increase from A → B → C, while electron affinity decreases.

E) The atomic radius increases from A → B → C, while ionization energy increases and electron affinity remains constant.

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Question 4: Calcination is a fundamental step in the beneficiation of carbonate ores, such as iron ore and zinc ore, and is used to remove carbon dioxide (CO_2) to obtain the metal oxide.

Consider the thermal decomposition of siderite ($FeCO_3$), represented by the equation:

$$FeCO_3(s) \xrightarrow{\Delta} FeO(s) + CO_2(g)$$

In a calcination process where 460 g of $FeCO_3$ are fully decomposed, calculate:

I. the approximate mass of FeO obtained;

II. the approximate volume of CO_2 released (in L), measured at 0 °C and 1 atm.

A) 223 g of FeO and 90 L of CO_2
B) 223 g of FeO and 22.4 L of CO_2
C) 280 g of FeO and 90 L of CO_2
D) 280 g of FeO and 22.4 L of CO_2
E) 460 g of FeO and 22.4 L of CO_2

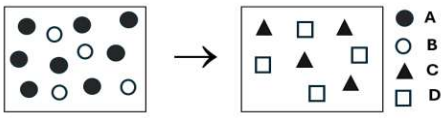
Question 5: A 10.0 g solid sample, consisting solely of calcium carbonate ($CaCO_3$) and magnesium carbonate ($MgCO_3$), is heated strongly to constant mass so that all carbonates decompose into their respective oxides (CaO and MgO) and carbon dioxide (CO_2), according to the equations:

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$
$$MgCO_3(s) \rightarrow MgO(s) + CO_2(g)$$

After heating, the solid residue (a mixture of CaO and MgO) has a mass of 5.20 g. Use the following molar masses ($g.mol^{-1}$): $CaCO_3$ = 100; $MgCO_3$ = 84; CaO = 56; MgO = 40; CO_2 = 44.
The **mass percentage** of $CaCO_3$ in the initial sample is:

A) 34.1%
B) 52.3%
C) 47.7%
D) 60.0%
E) 78.0%

Question 6: In the diagram below, the geometric symbols represent chemical species. Which of the following equations represents the symbolized reaction?



A) $8A + 4B \rightarrow C + D$
B) $4A + 8B \rightarrow 4C + 4D$
C) $2A + B \rightarrow C + D$
D) $4A + 2B \rightarrow 4C + 4D$
E) $2A + 4B \rightarrow C + D$

Question 7: Despite the determination of the existence of a nucleus by the Rutherford Model, the Bohr atomic model was the first to use concepts of the quantum theory proposed by Planck to define atomic structure. Regarding these atomic models, indicate the incorrect alternative:

A) Rutherford's results indicate that the positive particles of the atom are concentrated in a region of negligible volume, the nucleus.
B) The model proposed by Rutherford is not consistent with the stability of electrons in the electrosphere.
C) The alpha particle bombardment experiments on metal foils evidenced the presence of positive and negative particles in the atom.
D) Bohr's model implies the existence of orbits for electrons in the electrosphere of an atom.
E) Bohr's model implies the quantization of the energy of electronic transitions between orbits.

Question 8: In the modern atomic approach, the description of atomic systems has been refined; therefore, it can be stated that electrons:

A) Remain static in the atomic nucleus.
B) Move around the nucleus in a "zig-zag" pattern.
C) Exhibit a uniform circular trajectory around the nucleus.
D) Have their state described by the wave function.
E) Move together with protons in the nucleus.

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Question 9: The atomic models of Niels Bohr and Erwin Schrödinger/Max Born present distinct approaches to describe the electronic structure of atoms. Analyze the following statements regarding these models and their theoretical foundations.

I. In Niels Bohr's model, each line of the hydrogen atom's emission spectrum corresponds to the transition of an electron between quantized energy levels, emitting a photon whose energy is equal to the difference between these levels.
II. The Erwin Schrödinger/Max Born model replaces Bohr's idea of circular orbits with orbitals, which represent regions of high probability of finding the electron, resulting from the solutions to the Schrödinger equation.
III. According to Bohr's model and the Erwin Schrödinger/Max Born model, the electron can occupy any continuous energy within the atom, provided it does not violate the Heisenberg uncertainty principle.
IV. Bohr's model is mainly suitable for monoelectronic (one-electron) atoms, while the Erwin Schrödinger/Max Born model is applicable to multielectronic systems, which, considering the treatment of electron repulsion and spin, allows for the explanation of the fine splitting of spectral lines.
V. The frequency of the radiation emitted in an electronic transition can be related to the difference between the initial and final energy levels by the Planck relation, $\Delta E = h\nu$.

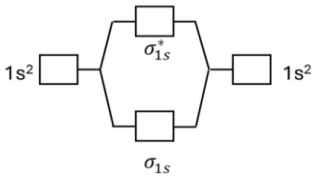
Select the alternative containing the **ONLY INCORRECT** statement.

A) Only statement III is incorrect.
B) Only statement I is incorrect.
C) Only statement II is incorrect.
D) Only statement IV is incorrect.
E) Statements I and II are incorrect.

Question 10: When analyzing the physical properties of molecular liquids and solids, how does the strength of intermolecular interactions relate to the boiling point of a liquid?

A) The stronger the intermolecular interactions, the more volatile the liquid is, resulting in a lower boiling point.
B) The boiling point is not influenced by intermolecular interactions, but rather by atmospheric pressure.
C) The weaker the intermolecular interactions, the higher the temperature at which the liquid boils.
D) The stronger the intermolecular interactions, the higher the temperature at which the liquid boils.
E) Molecular polarity is the sole determining factor of the boiling temperature of substances.

Question 11: Considering the Molecular Orbital diagram for H_2^-, if this ion is excited by the absorption of a photon:



A) H_2^-* will be more stable than H_2^-.
B) H_2^-* will be less stable than H_2^-.
C) Both will have the same stability.
D) It is not possible to predict this using Molecular Orbital Theory.
E) It is possible to predict this using Molecular Orbital Theory, but there is insufficient information.

Question 12: Regarding the PCl_5 molecule, it can be stated that:

A) The valence electrons of the five chlorine (Cl) atoms use the five empty d-orbitals of the phosphorus (P) atom for bonding.
B) The PCl_5 molecule presents a trigonal bipyramidal geometry, with sp^3 hybridization.
C) The PCl_5 molecule exhibits sp^3d hybridization, with five phosphorus orbitals participating in the hybridization.
D) The PCl_5 does not exist, due to the configuration of the phosphorus (P) atom.
E) The five sigma (σ) type bonds formed between the chlorine and phosphorus atoms originate from the lateral interaction of the chlorine orbitals and the hybrid orbitals of phosphorus.

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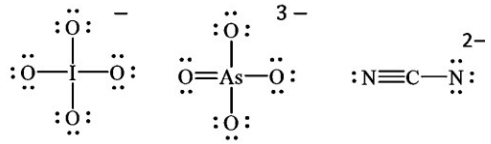
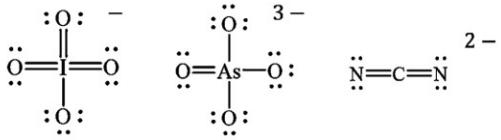
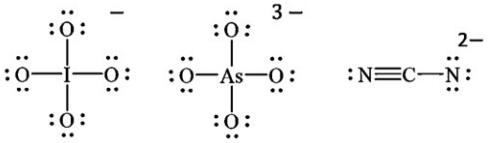
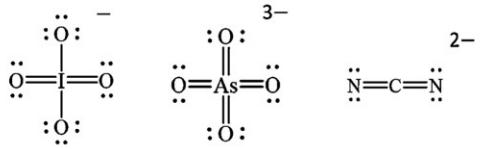
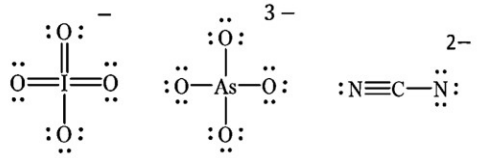
Question 13: Select the alternative that presents the Lewis structure of greatest contribution (lowest energy) for the species: $(IO_4)^-, (AsO_4)^{3-}$ e $(N_2C)^{2-}$.

A) 

B) 

C) 

D) 

E) 

Question 14: 5.00 g of $CoCl_2$ were initially dissolved in a certain amount of water and transferred to a 100.0 mL volumetric flask, with the volume made up with water to the calibration mark. The concentration, in mol.L^{-1}, of $CoCl_2$ in the obtained solution is:

A) 0.122
B) 0.567
C) 1.012
D) 0.668
E) 0.385

Question 15: A commercial vinegar has an acetic acid concentration of 4.2% w/v (weight per volume). 30.00 mL of this vinegar were transferred into a 250.00 mL volumetric flask , and the volume was made up to the calibration mark with distilled water. What is the molar concentration of acetic acid in the prepared solution? Given: Molar Mass of CH_3CO_2H: 60.052 g.mol^{-1}.

A) 0.084 mol.L^{-1}
B) 0.070 mol.L^{-1}
C) 0.840 mol.L^{-1}
D) 0.280 mol.L^{-1}
E) 0.028 mol.L^{-1}

Question 16: A doctor prescribed a syrup containing codeine ($C_{18}H_{21}NO_3$) for a patient complaining of a cough. Assume that 150 mL of this syrup contains 30 g of the active ingredient (codeine) and that, prior to dispensing, the pharmacist diluted the concentrated solution to a final volume of 500 mL. If the doctor prescribed 3.00×10^{-3} mol of the active ingredient per day, administered in three equal doses (every 8 hours), what volume of the diluted solution must the patient take every 8 hours?

A) 15 mL
B) 7.5 mL
C) 5.0 mL
D) 10 mL
E) 12.5 mL

Question 17: In the titration of 0.100 mol.L^{-1} HCl with 0.100 mol.L^{-1} NaOH at 25 ºC, the pH at the equivalence point is:

A) 3
B) 5
C) 7
D) 9
E) 11

Question 18: 25 mL of 1.0×10^{-3} mol.L^{-1} $Pb(NO_3)_2$ are mixed with 25 mL of 1.0×10^{-3} mol.L^{-1} Na_2SO_4. Given $K_{ps}(PbSO_4) = 1.6 \times 10^{-8}$. Will precipitation occur after mixing? (Consider Q to be the reaction quotient).

A) No, because $Q = 2.5 \times 10^{-7} < K_{ps}$
B) Yes, because $Q = 2.5 \times 10^{-7} > K_{ps}$
C) No, because $Q = 5.0 \times 10^{-4} < K_{ps}$
D) Yes, because $Q = 1.0 \times 10^{-6} < K_{ps}$
E) No, because $Q = K_{ps}$

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Question 19: Consider a galvanic cell represented by:

$Pt(s)|H_2(g,1atm)|H^+(aq, 1\ M)||Cu^{2+}(aq,1\ M)|Cu(s)$

Knowing that:

$E°\ (H^+/H_2) = 0.00$ V e $E°\ (Cu^{2+}/Cu) = +0.34$ V

Analyze the statements below:

I. The hydrogen electrode acts as the anode, since the oxidation of H_2 to H^+ occurs.

II. The overall reaction is spontaneous in the direction $H_2(g) + Cu^{2+}(aq) \rightarrow 2H^+(aq) + Cu(s)$.

III. The standard cell potential is positive, indicating that $\Delta G° < 0$.

IV. If the H^+ concentration is increased to 10.0 $mol.L^{-1}$, the tendency for hydrogen oxidation increases, making E smaller.

V. The cell will convert chemical energy into electrical energy, characterizing it as a galvanic cell.

Select the correct alternative:

A) Only statements I, II, III, and V are correct.
B) Only statements I, II, and III are correct.
C) Only statements II, III, and V are correct.
D) All statements are correct.
E) Only statements III and IV are correct.

Question 20: The Nernst equation is an important relationship in electrochemistry that relates cell voltage measurements to the reaction quotient, represented at 298 K by:

$$E = E^0 - \left(\frac{0.0591}{n}\right) logQ$$

Suppose this equation is applied to construct an experimental curve of the variation of E as a function of log Q, with the following electrochemical cell:

$Ni(s)|Ni^{2+}(aq, 0.001\ mol.L^{-1})||Cu^{2+}(aq, 2.0\ mol.L^{-1})|Cu(s)$

Based on the information presented, evaluate the following statements:

I. An increase in Cu^{2+} concentration occurs in the cathodic compartment.

II. An increase in Ni^{2+} concentration occurs in the anodic compartment.

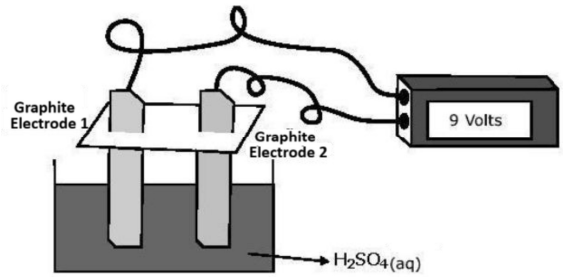
III. At the beginning of the measurement, the cell potential (E) is greater than the standard potential (E°).

IV. When the cell no longer exhibits a potential difference, the reaction quotient (Q) will be equal to the equilibrium constant (K).

It is correct only what is stated in:

A) I e III
B) I e IV
C) II e III
D) I, II e IV
E) II, III e IV.

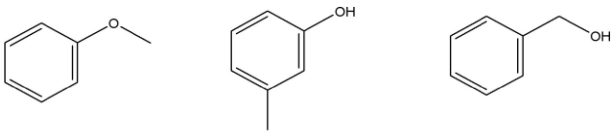
Question 21: The following figure represents a device for performing the aqueous electrolysis of a sulfuric acid solution, where electrode 1 was connected to the positive pole of the power source, while electrode 2 was connected to the negative pole.



Based on the diagram above and knowledge regarding the subject, select the INCORRECT alternative:

A) Oxygen gas will be produced at electrode 1.
B) Hydrogen gas will be produced at electrode 2.
C) The amount of substance, in moles, of sulfuric acid at the beginning of the process is equal to the final amount.
D) After the production of a large amount of H_2, the sulfuric acid concentration decreases.
E) Obtaining hydrogen from the aqueous sulfuric acid solution consumes electrical energy.

Question 22: There are several isomers with the formula C_7H_8O, such as those presented below:



X Y Z

Considering these compounds, evaluate the statements below:
I. Compound "X" belongs to the ether functional group.
II. Compound "Y" exhibits positional isomerism.
III. Compound "Z" is a phenol.
IV. The three compounds belong to distinct functional groups.
Based on the analysis, only the following statements are correct:

A) I e II
B) I e IV
C) II e IV
D) I, II e III
E) I, II e IV

Question 23: Compounds I, II, III, and IV are frequently identified in fermented beverages, such as beers and wines, as they are natural byproducts of microorganism metabolism during alcoholic fermentation or due to microbiological contamination in uncontrolled processes.

I — Methyl 2-methylpropanoate
II — 2-Methylbutanoic acid
III — 3-Methyl-2-butanol
IV — 2,3-Butanediol

The alternative that correctly represents the number of asymmetric carbons (chiral centers) of compounds I, II, III, and IV is:

A) 1; 0; 1; 1
B) 0; 1; 1; 2
C) 0; 0; 2; 1
D) 1; 1; 2; 2
E) 0; 1; 1; 1

Question 24: The oxidation of cyclohexene using **$KMnO_4/OH^-$/cold** and **$KMnO_4/H^+$/heat** yields, respectively:

A) 1,3-cyclohexanediol and hexanoic acid
B) 1,2-cyclohexanediol and hexanedioic acid
C) 1,2-cyclohexanediol and hexanoic acid
D) Cyclohexanol and cyclohexanoic acid
E) Cyclohexanol and 1,3-cyclohexanediol

Question 25: 1.0 mol of oxygen gas (O_2), at 25 °C, occupies a volume of approximately 24.5 L at 1 atm. Assuming ideal gas behavior, what would be the occupied volume if the pressure were reduced by half, while keeping the temperature constant?

A) 12.3 L
B) 24.5 L
C) 36.8 L
D) 49.0 L
E) 73.5 L

Question 26: Carbon dioxide gas (CO_2) exhibits real behavior under certain conditions. At 300 K and 50 atm, the experimental molar volume of CO_2 is smaller than that predicted by the ideal gas equation. This difference occurs because:

A) Attractive interactions predominate, decreasing the volume.
B) Repulsive interactions predominate, decreasing the volume.
C) The volume of the molecules themselves is negligible.
D) Kinetic energy increases, expanding the gas.
E) The gas behaves ideally at high pressures.

Question 27: Consider the reactions:

$C(graphite) + O_2(g) \rightarrow CO_2(g)$ $\Delta H_1 = -393.5\ kJ.mol^{-1}$

$CO(g) + \frac{1}{2}\ O_2(g) \rightarrow CO_2(g)$ $\Delta H_2 = -283.0\ kJ.mol^{-1}$

Determine ΔH for: $C(graphite) + \frac{1}{2}\ O_2(g) \rightarrow CO(g)$.

A) $+110.5\ kJ.mol^{-1}$
B) $-110.5\ kJ.mol^{-1}$
C) $+676.5\ kJ.mol^{-1}$
D) $-676.5\ kJ.mol^{-1}$
E) zero

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Question 28: Consider the following thermochemical reactions:

a. $C_3H_6(g) + H_2(g) \rightarrow C_3H_8(g)$
$\Delta H° = -124\ kJ.mol^{-1}$

b. $C_3H_8(g) + 5\ O_2(g) \rightarrow 3\ CO_2(g) + 4\ H_2O(l)$
$\Delta H° = -2220\ kJ.mol^{-1}$

c. $H_2(g) + ½\ O_2(g) \rightarrow H_2O(l)$
$\Delta H° = -286\ kJ.mol^{-1}$

Based on Hess's Law and the manipulation of thermochemical equations, analyze the statements:

I. When inverting equation (c), the value of ΔH° must change sign, as the direction of the process has been reversed.

II. Hess's Law indicates that the total enthalpy of a reaction depends on the path followed; therefore, summing the enthalpies of intermediate reactions can lead to different results from the enthalpy of the overall reaction, depending on the steps chosen.

III. By correctly combining the reactions and their respective ΔH° values, the enthalpy of combustion of propene results in ΔH° = −2058 kJ.mol-1, indicating an exothermic process.

Select the alternative that presents only the incorrect statement(s):

A) I
B) II
C) III
D) I e III
E) I e II

Question 29: The enthalpy of combustion of methane (CH_4) is –890.3 $kJ.mol^{-1}$. What is the enthalpy change corresponding to the complete combustion of 4.00 g of methane?

A) –222.6 kJ
B) –356.1 kJ
C) –890.3 kJ
D) –1780.6 kJ
E) –445.2 kJ

Question 30: Benzoic acid (C_6H_5COOH), a common food preservative, is a weak acid with a pK_a of approximately 4.20. In an aqueous solution, it establishes an equilibrium with its conjugate base, the benzoate ion ($C_6H_5COO^-$). What will be the approximate ratio between the concentrations of benzoic acid ([HA]) and benzoate ion ($[A^-]$) in a buffered solution with $pH = 5.20$?

A) [HA] approximately equal to $[A^-]$
B) [HA] > 100 x $[A^-]$
C) $[A^-]$ approximately equal to 10 x [HA]
D) [HA] approximately equal to 10 x $[A^-]$
E) $[A^-]$ > 100 x [HA]

Question 31: The acidity of compounds or mixtures can be expressed in terms of pH. In human saliva, for example, the medium is typically acidic, and marked variations may indicate health problems. If a sample X of a person's saliva has a pH of 6.0 and a sample Y of another person's saliva has an $[H_3O^+]$ equal to $1.0 \times 10^{-5}\ mol.L^{-1}$, it can be stated that:

A) Sample X is less alkaline.
B) The $[OH^-]$ of sample Y is greater than that of sample X.
C) The ingestion of milk of magnesia, which contains $Mg(OH)_2$, increases the acidity of both samples.
D) Sample Y is more acidic.
E) The $[H_3O^+]$ of sample Y is lower than that of sample X.

Question 32: Consider the hydrolysis reaction of tert-butyl chloride ($(CH_3)_3CCl$)) in an aqueous solution, which follows an S_N1 mechanism, forming tert-butanoll ($(CH_3)_3COH$)). The experimental rate law for this reaction is given by: Rate = $k[(CH_3)_3CCl)]$. If the initial concentration of tert-butyl chloride is doubled and the concentration of water (the nucleophile and also the solvent) is kept constant (although in large excess), what will happen to the initial rate of the reaction?

A) The rate will decrease by half.
B) The rate will not change, as the reaction is zero-order.
C) The rate will double.
D) The rate will quadruple.
E) The rate will increase, but it is not possible to determine by how much without the value of k.

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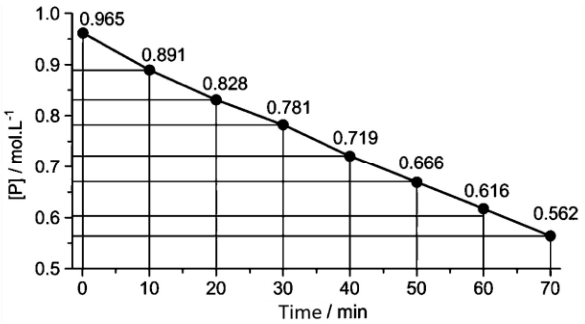
Question 33: A graduate student investigated the decontamination of organic pollutants present in industrial effluents to study the efficiency of their new nanomaterial for the proposed application. Upon using Ultraviolet-Visible (UV-Vis) spectroscopy to monitor the decrease in the pollutant concentration **([P])** as a function of time, the curve below was obtained.



Based on the analysis of the curve, it is correct to state:

A) This is a 2nd order reaction.
B) The reaction half-life does not depend on the initial pollutant concentration.
C) The rate of this reaction is constant.
D) The instantaneous rate at 120 min is 5 x 10^{-4} mol.L^{-1}.min^{-1}.
E) The rate law for the reaction is v = k[P].

Question 34: In 1912, the German chemist Fritz Haber developed a process to synthesize ammonia, currently known as the Haber-Bosch process, in honor of Carl Bosch, who developed the industrial process for ammonia production according to the equation below.

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

Select the alternative that indicates the procedure that does NOT favor ammonia production.

A) Partial removal of produced NH_3.
B) Reduction of volume and increase of the total system pressure.
C) Increase of volume and reduction of the total system pressure.
D) Addition of 1 mol of $N_2(g)$.
E) Addition of 1 mol of $H_2(g)$.

Question 35: The kinetics of the following reaction, carried out at 904 °C, were studied and generated the results shown in the table.

$$2\ NO(g) + 2\ H_2(g) \rightarrow N_2(g) + 2\ H_2O(g)$$

[NO] (mol.L^{-1})	[H_2] (mol.L^{-1})	Rate (mol.L^{-1}.s^{-1})
0.420	0.122	0.1400
0.210	0.122	0.0350
0.105	0.122	0.00875
0.210	0.244	0.0700
0.210	0.366	0.1050

Regarding this reaction, it is correct to state that the rate law is:

A) $v = k[NO][H_2]$
B) $v = k[NO]^2[H_2]$
C) $v = k[H_2]$
D) $v = k[NO]^4[H_2]^2$
E) $v = k[NO]^2[H_2]^2$

Question 36: Hydrocyanic acid (HCN) is a weak acid found in small amounts in certain fruits and is used in industrial processes. In an aqueous medium, HCN undergoes partial ionization according to the equation:

$$HCN(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CN^-(aq)$$

Given that the ionization constant of hydrocyanic acid is $K_a = 6.2\times10^{-10}$ and the initial acid concentration in a solution is 0.020 mol.L^{-1}, determine the concentration of CN^- at equilibrium.

A) 1.1×10^{-5} mol.L^{-1}
B) 3.5×10^{-6} mol.L^{-1}
C) 7.0×10^{-7} mol.L^{-1}
D) 2.2×10^{-5} mol.L^{-1}
E) 3.1 x 10^{-6} mol.L^{-1}

Question 37: The molecular formula $C_4H_{10}O$ can give rise to compounds belonging to how many different organic functional groups?

A) 2 (ketone and alcohol)
B) 2 (alcohol and ether)
C) 2 (ether and aldehyde)
D) 3 (ether, alcohol, and ketone)
E) 3 (aldehyde, alcohol, and ether)

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Question 38: The strength of London dispersion forces tends to increase with the increase of which of the following molecular characteristics?

A) Decrease in dipole moment.
B) Decrease in molecular mass.
C) Increase in polarizability.
D) More compact and spherical molecular symmetry.
E) Increase in resistance to flow (viscosity).

Question 39: Hydrogen peroxide can be prepared in the laboratory by the reaction of barium peroxide with phosphoric acid. Given that the barium peroxide to be used has a purity of 80%, what mass of hydrogen peroxide will be obtained from 5.00 g of BaO_2?

Unbalanced equation:

$$BaO_2 + H_3PO_4 \rightarrow Ba_3(PO_4)_2 + H_2O_2$$

A) 0.80 g
B) 0.85 g
C) 1.00 g
D) 0.27 g
E) 1.25 g

Question 40: Sodium nitrite ($NaNO_2$) is used as a preservative in meat products, acting in color fixation and bacterial inhibition. However, its excessive use poses a toxicological risk. The presence of the nitrite ion can be identified by reaction with ferrous sulfate in a strongly acidic medium, according to the balanced chemical equation:

$$2FeSO_4 + 2NaNO_2 + 2H_2SO_4 \rightarrow Fe_2(SO_4)_3 + 2NO + 2H_2O + Na_2SO_4$$

The nitric oxide (NO) formed reacts with excess Fe^{2+} ions, forming the brown nitrosyl complex, $[Fe(H_2O)_5(NO)]^{2+}$.

In an assay, 100.0 mL of 0.200 $mol.L^{-1}$ $FeSO_4$ solution was added to a 10 g meat sample containing $NaNO_2$ (in a strongly acidic medium). After some time, a brown coloration was observed due to the formation of the nitrosyl complex. After the reaction and complete formation of the complex, the remaining Fe^{2+} was titrated with 0,100 $mol.L^{-1}$ Ce(IV) (acidic medium), consuming 20 mL to the endpoint. Consider that Ce(IV) quantitatively oxidizes $Fe^{2+} \rightarrow Fe^{3+}$ with a 1:1 molar ratio.

Consider that the reaction is conducted in a closed system and strongly acidic medium, ensuring that all produced NO remains available to form the complex with Fe^{2+}. Assume a 1:1 molar ratio between formed NO and complexed Fe^{2+} and that Iron remains in the 2+ state in the complex. Thus, determine the mass of $NaNO_2$ (in mg) present in the meat sample.

A) 78 mg
B) 156 mg
C) 310 mg
D) 621 mg
E) 1242 mg

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