Selection Examination for the Master's and Doctoral Programs in Chemistry

Programa de Pós-graduação Multicêntrico em Química de Minas Gerais

PPGMQ-MG – 2/2026

Application Code		**Date: June 22, 2026**
		Time: 1:30 PM – 5:30 PM

GENERAL INSTRUCTIONS FOR CANDIDATES (READ CAREFULLY!)

1. Identification: Identify your examination only by your application code. Do not write your name on any part of the exam booklet or answer sheet.

2. Header: Upon 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 basic 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.
- Consultation of bibliographic sources or personal notes is not permitted.

4. Duration and Departure:

- The total duration of the exam is 4 hours.
- Candidates may only submit their exam and leave the room after 15 minutes have elapsed from the start.
- Upon finishing the exam, the candidate must hand the question booklet along with the completed answer sheet to the proctor responsible for their room.
- Only the Periodic Table/Rough Work sheet may be taken by the candidate.

5. Periodic Table: The periodic table is located at the end of the booklet and may be detached for consultation.

6. Answer Sheet Completion:

- All answers must be transcribed onto the ANSWER KEY (page 02).
- Fill in the square corresponding to the option you believe is correct using a pen.
- **Attention:** Only the answer key will be considered for grading. Erasures, multiple markings, or incomplete filling will result in a score of zero for that question.

7. Questions: During the exam, no clarifications regarding the content of the questions will be provided.

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ANSWER KEY

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: Uranium (symbol U, Z = 92) is a heavy, radioactive, natural metal found in the Earth's crust. Its isotope ^{235}U is fissile, meaning it releases a large amount of thermal energy upon undergoing fission. Indicate the alternative that corresponds, respectively, to the **number of electrons** and **neutrons** of this isotope.

a) 92, and 235.
b) 92, and 143.
c) 92, and 327.
d) 235, and 92.
e) 143, and 92.

Question 2: It is known that the visible spectrum of hydrogen presents spectral lines with wavelengths of 410.1 nm (indigo), 434.0 nm (blue), 486.1 nm (blue-green), and 656.3 nm (red). Using the Rydberg equation, determine the **color associated** with the spectral line produced by the electronic transition in which the electron moves from **n = 3 to n = 2**. ($R = 1.097 \times 10^{-2}$ nm^{-1})

$$\frac{1}{\lambda} = R\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right)$$

a) Blue.
b) Blue-green.
c) Indigo.
d) Red.
e) Spectral line is outside the visible range.

Question 3: Based on the principles of modern atomic structure, consider an iron atom (Z = 26) in its ground state. What is the correct **electronic configuration** for the Fe^{3+} ion and the **number of unpaired electrons** present?

a) [Ar] $3d^5$; 5 unpaired electrons.
b) [Ar] $4s^2$ $3d^3$; 3 unpaired electrons.
c) [Ar] $3d^6$; 4 unpaired electrons.
d) [Ar] $4s^1$ $3d^4$; 5 unpaired electrons.
e) [Ar] $4s^2$ $4p^3$; 3 unpaired electrons.

Question 4: A technology company is developing new semiconductor materials and oxidizing agents for applications in electronic sensors and energy storage devices. To this end, four hypothetical neutral elements in the gaseous state, denoted **M, Q, R,** and **T**, whose ground-state electronic configurations are shown below, were selected:

- **M:** [noble gas] ns^2 np^3
- **Q:** [noble gas] ns^2
- **R:** [noble gas] ns^2 np^5
- **T:** [noble gas] $(n+1)s^1$

Consider that all elements belong to the same period or to consecutive periods of the Periodic Table, and the "[noble gas]" is the same for **M, Q, R**, and **T**. Based on the periodic properties and electronic behavior of these elements, which alternative presents the **MOST coherent association** between the species and its potential technological application?

a) Element **Q** is the most electronegative among those presented and, therefore, the most suitable to act as an oxidizing agent in electrochemical devices.
b) Element **T** has a high ionization energy, making it suitable for applications as an insulating material.
c) Element **R** has a high electron affinity, being potentially useful in oxidizing materials and electron acceptors.
d) Element **M** has the smallest atomic radius among those presented, which justifies its high tendency to form M^{3+} cations.
e) Element **Q** has a higher electron affinity than R due to the stability associated with the ns^2 subshell.

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Question 5: A student claims that "electronegativity and electron affinity are the same thing, since both measure an atom's tendency to gain/attract electrons." Regarding this statement, analyze the following propositions:

I. Electronegativity is related to the tendency of an atom to attract electrons within a chemical bond.
II. Electron affinity is related to the energy change that occurs when an isolated gaseous atom captures an electron.
III. Highly electronegative elements, such as fluorine and oxygen, tend to exhibit high electron affinity values (in magnitude).
IV. Both periodic properties are expressed in kJ mol^{-1}.

Choose the CORRECT alternative::

a) Only statements I and II are true.
b) Only statements I, II, and III are true.
c) Only statements II, III, and IV are true.
d) Only statements I, III, and IV are true.
e) Statements I, II, III, and IV are true.

Question 6: Atoms belonging to the noble gas family tend to exhibit the following values of electronegativity, ionization energy, and electron affinity, respectively:

a) null, null, high.
b) null, high, high.
c) null, high, low.
d) high, high, high.
e) low, low, low.

Question 7: Hydrofluoric acid (aqueous HF) is widely used in glass etching and corrosion processes because it reacts with silica (solid SiO_2), the main component of glass. Knowing that the products formed in this reaction are silicon tetrafluoride (aqueous SiF_4) and liquid water:

$$HF(aq) + SiO_2(s) \rightarrow SiF_4(aq) + H_2O(l)$$

Choose the alternative that gives the **sum of the smallest possible integer stoichiometric coefficients** for the correctly balanced chemical equation representing this process:

a) 4
b) 5
c) 6
d) 7
e) 8

Question 8: When aqueous solutions of silver nitrate ($AgNO_3$) and sodium chloride (NaCl) are mixed, a precipitation reaction occurs. Considering that chlorides are generally soluble in water, except for those of silver chloride (AgCl), mercury(I) chloride (Hg_2Cl_2), and lead(II) chloride ($PbCl_2$), choose the alternative that presents the **correct net ionic equation** for this process:

a) $Ag^{2+}(aq) + 2Cl^-(aq) \rightarrow AgCl_2(s)$
b) $Ag^+(aq) + NO_3^-(aq) + Na^+(aq) + Cl^-(aq) \rightarrow AgCl(s) + Na^+(aq) + NO_3^-(aq)$
c) $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$
d) $Na^+(aq) + NO_3^-(aq) \rightarrow NaNO_3(aq)$
e) $AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$

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Question 9: Photocatalytic production of ammonia from atmospheric nitrogen is considered a promising alternative for the sustainable synthesis of fertilizers. In an experimental system, molecular nitrogen and water are converted into ammonia and oxygen, according to the unbalanced reaction shown below:

$$N_2(g) + H_2O(g) \rightarrow NH_3(g) + O_2(g)$$

It is known that this process simultaneously involves the reduction of nitrogen and the oxidation of water, and that the correct balancing of the equation must respect not only mass conservation but also the electron balance of the redox process. Choose the alternative that gives the **sum of the smallest possible integer stoichiometric coefficients** for the correctly balanced chemical equation representing this process:

a) 12
b) 13
c) 14
d) 15
e) 16

Question 10: In the chemical equilibrium of weak monoprotic organic acids and bases, a technique known as volumetric titration can be used to determine the molar mass and Ka of the substance in question. In an experiment, a chemist weighed 0.500 g of an unknown weak monoprotic acid, quantitatively transferred the sample to a 2.00 L volumetric flask, and filled it to the mark with distilled water. From this solution, 100.0 mL of the unknown acid solution was transferred to an Erlenmeyer flask and titrated with a 0.050 mol L^{-1} NaOH solution. The endpoint of the titration was 4.10 mL. What is the molar mass of the unknown acid?

a) 60 g mol^{-1}
b) 88 g mol^{-1}
c) 104 g mol^{-1}
d) 122 g mol^{-1}
e) 138 g mol^{-1}

Question 11: A crude sample containing 1.2048 g of Na_2CO_3 was dissolved and reacted with a solution containing an excess of $CaCl_2$. The resulting $CaCO_3$ precipitate was isolated by precipitation, filtration, and drying, yielding 1.0262 g of solid. Assuming that the impurities present in the original sample do not contribute to the mass of the precipitate, **calculate the percentage purity** of Na_2CO_3 in the sample.

a) 82.90%
b) 89.02%
c) 90.20%
d) 92.00%
e) 95.02%

Question 12: Tricalcium phosphate, $Ca_3(PO_4)_2$, is one of the main constituents of phosphate rocks used in fertilizer production. Industrially, it is converted into calcium sulfate ($CaSO_4$) and phosphoric acid (H_3PO_4) through reaction with sulfuric acid (H_2SO_4). Considering that 31 kg of $Ca_3(PO_4)_2$ and 21 kg of H_2SO_4 are mixed in a reactor. The mass (in kg) of $CaSO_4$ produced corresponds to:

a) 13.2
b) 14.6
c) 21.4
d) 29.1
e) 40.8

Question 13: In a synthesis reaction, 100.00 g of a calcium carbonate sample ($CaCO_3$, 80% purity) reacts with an excess of hydrochloric acid (HCl). Given that 15.68 L of CO_2 is collected at standard temperature and pressure (STP), **calculate the approximate reaction yield**.
(Given: Molar volume at STP, V=22.4 L mol^{-1}).

a) 95.0%
b) 87.5%
c) 80.0%
d) 70.0%
e) 62.5%

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Question 14: Consider the chemical species $BeCl_2$, PF_5, HNO_3, and AlI_3. Based on their electronic structures, Valence Bond Theory, and related chemical concepts, evaluate the following statements:

I. The central atoms in $BeCl_2$, PF_5, HNO_3, and AlI_3 do not conform to the classical octet rule.
II. Beryllium chloride is a molecular compound in which the central atom attains stability with only four electrons in its valence shell.
III. Nitric acid exhibits a trigonal planar geometry around the nitrogen atom and contains at least two distinct N–O bond lengths.
IV. In the structure of aluminum iodide, the aluminum atom remains electron-deficient and can therefore act as a Lewis acid.

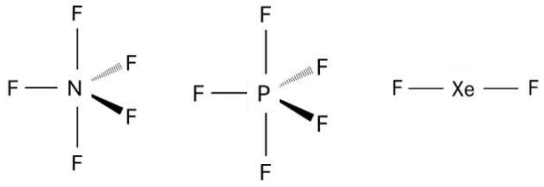
Select the alternative that contains **all the correct statements**.

a) III only.
b) I and IV only.
c) I, III, and IV only.
d) II, III, and IV only.
e) I, II, III, and IV.

Question 15: According to the Valence Shell Electron Pair Repulsion (VSEPR) model, what are the **expected molecular geometries** of XeF_4 and SF_4, respectively?

a) Tetrahedral and tetrahedral
b) Square planar and tetrahedral
c) Square planar and seesaw
d) Octahedral and trigonal pyramidal
e) Trigonal bipyramidal and seesaw

Questão 16: Consider the following compounds



Regarding these compounds and the relevant chemical concepts, **select the correct alternative**:

a) All compounds can exist due to the expansion of the octet of their central atoms.
b) Only XeF_2 cannot exist, because noble gases are unable to form compounds.
c) None of the compounds can exist, because all of them violate the octet rule.
d) Only PF_5 and XeF_2 can exist, because their central atoms are capable of expanding the octet.
e) Only NF_5 can exist, because only nitrogen can expand the octet.

Question 17: Considering the species XeO_3, SO_3^{2-}, and O_3, and based on the principles of Valence Bond Theory (VBT), hybridization, and the phenomenon of resonance, **select the correct alternative**.

a) XeO_3 and SO_3^{2-} exhibit trigonal planar geometry, possess sp^2-hybridized central atoms, and contain double bonds to the oxygen atoms.
b) O_3 exhibits π-electron delocalization over the O–O bonds, resulting in identical bond lengths and a bond order of 1.5.
c) The xenon atom in XeO_3 obeys the octet rule, contains no lone pairs, and exhibits a regular tetrahedral geometry.
d) The sulfur atom in SO_3^{2-} cannot expand its octet because it is a third-period element, which forces the ion to adopt a bent geometry.
e) XeO_3 is nonpolar, because its trigonal pyramidal geometry causes the dipole moments of the Xe–O bonds to cancel each other.

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Question 18: The phase-transition temperatures of the molecular substances methane (CH_4), boron trifluoride (BF_3), and carbon dioxide (CO_2) are significantly low, with boiling or sublimation points ranging from approximately −164 °C to −78 °C. Considering the relationship among electronic structure, molecular symmetry, and the magnitude of intermolecular interactions, select the correct alternative.

a) The low phase-transition temperatures of these substances arise exclusively from their low molar masses and are therefore independent of their electronic polarizability.
b) Although boron trifluoride (BF_3) and carbon dioxide (CO_2) contain polar covalent bonds, these molecules exhibit London dispersion forces as their intermolecular interactions.
c) Carbon dioxide exhibits a higher sublimation temperature than methane because of the formation of intermolecular hydrogen bonds involving the lone pairs of the oxygen atoms.
d) Boron trifluoride possesses a trigonal pyramidal geometry and, therefore, a large permanent dipole moment, resulting in strong dipole–dipole interactions.
e) The increase in phase-transition temperatures in the order $CH_4 < BF_3 < CO_2$ is explained primarily by the decrease in molecular symmetry and the consequent increase in the molecular dipole moment.

Question 19: Diethyl ether ($CH_3CH_2OCH_2CH_3$) is an organic solvent widely used in chemical synthesis. It exhibits a vapor pressure of 440 mmHg at 20 °C and a boiling point of 34.6 °C. Based on these properties, it is correct to state that diethyl ether:

a) exhibits low volatility.
b) evaporates readily at room temperature.
c) has a relatively low vapor pressure at 20 °C.
d) remains exclusively in the gaseous state at 20 °C.
e) exhibits intermolecular hydrogen bonding between its molecules.

Question 20: A 50.0 mL sample of commercial vinegar containing acetic acid (CH_3COOH) was diluted with water to a final volume of 250.00 mL. A 50.0 mL aliquot of this diluted solution required 25.0 mL of a 0.200 mol L^{-1} sodium hydroxide (NaOH) solution to reach the equivalent point. **Calculate the % (m/v)** of acetic acid in the commercial vinegar.

a) 0.1
b) 0.2
c) 0.5
d) 1.5
e) 3.0

Question 21: An aqueous sulfuric acid (H_2SO_4) solution with a concentration of 98% w/w has a density of 1.84 g mL^{-1}. What is the approximate molar concentration (mol L^{-1}) of this solution?

a) 1.84 mol L^{-1}.
b) 9.8 mol L^{-1}.
c) 10.0 mol L^{-1}.
d) 18.4 mol L^{-1}.
e) 20.0 mol L^{-1}.

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Question 22: The reaction

$$NO_2(g) + CO(g) \rightarrow CO_2(g) + NO(g)$$

is second order with respect to $NO_2(g)$ and zero order with respect to CO(g). Under certain pressure and temperature conditions, this reaction proceeds at a rate equal to v. If the concentration of $NO_2(g)$ is doubled and the concentration of CO(g) is tripled, **by what factor** will the new reaction rate (v_i) increase relative to the initial rate (v)?

a) 2
b) 4
c) 6
d) 9
e) 12

Question 23: Based on the kinetic theory of gases and collision theory, select the **correct** statement regarding the rate of chemical reactions.

a) Every collision between reactant molecules results in product formation, provided that the reaction occurs at an elevated temperature.
b) An increase in temperature increases the fraction of molecules possessing energy equal to or greater than the activation energy.
c) The activation energy corresponds to the average kinetic energy of all molecules in the system.
d) Catalysts increase reaction rates because they increase the average kinetic energy of the reactant molecules.
e) The Maxwell–Boltzmann distribution indicates that all molecules in a gas possess the same energy at a given temperature.

Question 24: The decomposition of reactant A was studied experimentally, and the following initial-rate data were obtained:

Experimento	[A] inicial / mol L^{-1}	Velocidade inicial / mol L^{-1} s^{-1}
1	0.10	2.0×10^{-3}
2	0.20	8.0×10^{-3}
3	0.30	1.8×10^{-2}

Assuming that the rate law is given by:

$$v = k[A]^n$$

Indicate the **correct** statement.

a) The reaction is zero order with respect to **A**, since the reaction rate is independent of the concentration.
b) The reaction is first order with respect to **A**, since the reaction rate doubles when the concentration is doubled.
c) The reaction is first order with respect to **A**, and the value of k is 0.20 mol L^{-1} s^{-1}.
d) The reaction is second order with respect to **A**, and the value of k is 0.20 L mol^{-1} s^{-1}.
e) The reaction is third order with respect to **A**, since the reaction rate increases more rapidly than the concentration.

Question 25: An aqueous ammonia (NH_3) solution was prepared with a final concentration of 0.010 mol L^{-1}. Given that the base dissociation constant of ammonia is $K_b = 1.8 \times 10^{-5}$, **the pH** of this solution is closest to:

a) 2.9
b) 3.6
c) 10.6
d) 11.1
e) 12.0

Question 26: Consider the following equilibrium:

$$N_2(g) + 3\ H_2(g) \rightleftharpoons 2\ NH_3(g) \qquad \Delta H < 0$$

Which change will result in a **greater equilibrium percentage of ammonia**?

a) Increasing the temperature and adding a catalyst.
b) Decreasing the pressure and removing nitrogen.
c) Increasing the total pressure and decreasing the temperature.
d) Increasing the volume of the reaction vessel.
e) Adding helium gas at constant volume.

Question 27: O Vinegar is essentially a solution of acetic acid (CH_3COOH) with a concentration of 4.0% (w/v). What percentage of the acetic acid is ionized in the vinegar?
(Given: $K_a=1.8\times10^{-5}$)

a) 0.1%
b) 0.2%
c) 0.5%
d) 0.8%
e) 1.0%

Question 28: Two vessels are connected by a valve that is initially closed and maintained at 40 °C. One vessel, with a volume of 10 L, contains krypton gas at a pressure of 4.0 atm, while the other vessel, with a volume of 2 L, is initially evacuated. The valve is temporarily opened and then closed. After the valve is closed, the pressure in the vessel that was initially under vacuum is measured to be 2.5 atm. Assuming ideal gas behavior and that the volume of the valve is negligible, **determine the mass of krypton remaining in the 10 L vessel.**
(Given: R=0.082 L atm $mol^{-1}K^{-1}$)

a) 12 g
b) 28 g
c) 54 g
d) 88 g
e) 114 g

Question 29: Consider the synthesis of 2.00 mol of hydrogen chloride gas, as represented by the following reaction:

$$H_2(g) + Cl_2(g) \rightarrow 2\ HCl(g) \qquad \Delta H = -184{,}64\ kJ$$

This value can be determined using the thermochemical reactions given below:

I) $NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$ $\quad \Delta H° = X\ kJ$

II) $N_2(g) + 3\ H_2(g) \rightarrow 2\ NH_3(g)$ $\quad \Delta H° = -92.22\ kJ$

III) $N_2(g) + 4\ H_2(g) + Cl_2(g) \rightarrow 2\ NH_4Cl(s)$ $\quad \Delta H° = -628.86\ kJ$

Based on Hess's law and the manipulation of thermochemical equations, the value of X used to determine the enthalpy change for the synthesis of 2.00 mol of hydrogen chloride gas, in kJ, is:

a) – 905.7
b) – 352.0
c) – 176.0
d) + 268.2
e) + 536.4

Question 30: Consider the standard enthalpies of formation (298 K, 1 atm) given below:

(I) $N_2(g) + 3\ H_2(g) \rightarrow 2\ NH_3(g)$ $\quad \Delta H_1 = -92\ kJ$

(II) $H_2(g) + ½\ O_2(g) \rightarrow H_2O(l)$ $\quad \Delta H_2 = -286\ kJ$

Using Hess's law, calculate the enthalpy change for the reaction below:

$$4\ NH_3(g) + 3\ O_2(g) \rightarrow 2\ N_2(g) + 6\ H_2O(l)$$

a) – 414 kJ
b) – 752 kJ
c) – 1240 kJ
d) – 1532 kJ
e) – 1630 kJ

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Question 31: Analyze the following compounds:

$K_4\underline{P_2}O_7$; $Na\underline{Au}Cl_4$, $Ba_2\underline{Xe}O_6$; $Ca(\underline{Cl}O_2)_2$

The oxidation state of the highlighted element (underlined and in italics) in each of the following compounds is, respectively:

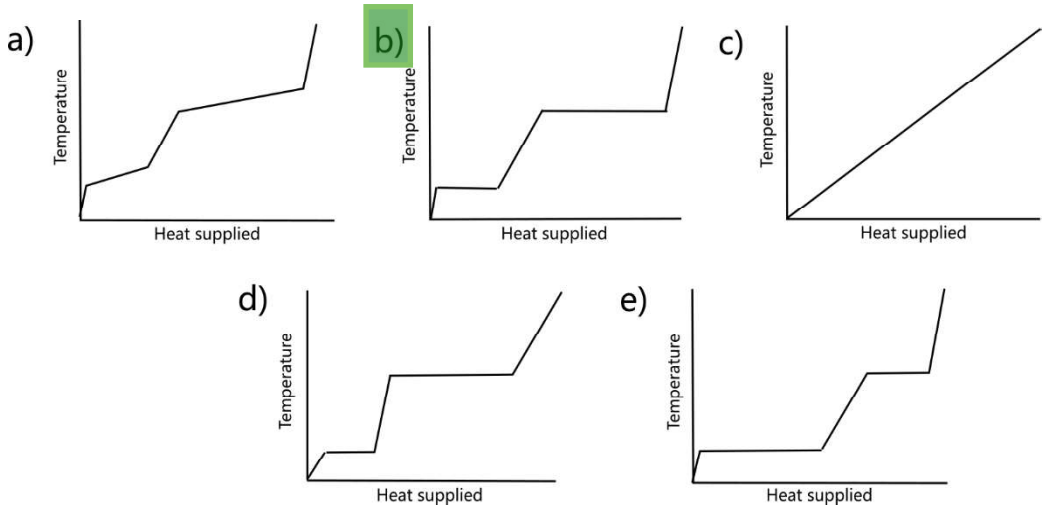
a) +5; +3; +10; +3
b) +5; +2; +10: +3
c) +10; +3; +8; +1
d) +5; +3; +8; +3
e) +10; +2; +6; +2

Question 32: Consider the galvanic cell represented by Zn(s) | Zn^{2+}(aq, 1,0 mol L^{-1}) || Cu^{2+}(aq, 1,0 mol L^{-1}) | Cu(s)
Given the following standard reduction potentials:
$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$ $E° = -0.76$ V
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ $E° = +0.34$ V

Select the **correct** statement regarding the operation of this galvanic cell under standard conditions.

a) Zinc acts as the cathode, undergoing reduction, while copper acts as the anode, undergoing oxidation.
b) Metallic copper is oxidized to Cu^{2+}, while Zn^{2+} is reduced to metallic zinc.
c) The overall cell reaction is nonspontaneous because zinc has a lower standard reduction potential than copper.
d) The standard cell potential is +1.10 V, with zinc serving as the anode and copper as the cathode.
e) Electrons flow through the external circuit from the copper electrode to the zinc electrode.

Question 33: A compound exhibits the following properties: specific heat capacities of 2 J g^{-1} K^{-1} for the solid, 6 J g^{-1} K^{-1} for the liquid, and 2 J g^{-1} K^{-1} for the gas; ΔH fusion = 0.3 kJ g^{-1}; and ΔH vaporization = 0.6 kJ g^{-1}. The solid form of this substance, initially at a temperature below its melting point, was heated until the gaseous phase reached a temperature above its boiling point. Which of the following heating curves best represents this process?



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Question 34: The determination of the concentration of $Fe^{2+}(aq)$ can be carried out by titration with potassium dichromate in an acidic medium. The overall chemical equation and the value of the standard potential ($\Delta E°$) of the corresponding reaction are given below:

$Cr_2O_7^{2-}(aq) + 6\ Fe^{2+}(aq) + 14\ H^+(aq) \rightarrow$
$2\ Cr^{3+}(aq) + 6\ Fe^{3+}(aq) + 7\ H_2O(l)$ $\quad \Delta E° = 0.559$ V

Assume that, except for $H^+(aq)$, all other chemical species are in their standard states at 298 K. Using the approximation of 0.0592 V for the Nernst equation constant at this temperature, select the alternative that gives the **approximate electromotive force (ΔE)** of this reaction when the system **has pH = 3.**

a) + 0.559 V
b) + 0.414 V
c) + 0.145 V
d) + 0.973 V
e) – 0.145 V

Question 35: An electrochemical cell is formed by two half-cells connected by a salt bridge. The platinum cathode (inert) is immersed in a solution containing iodine (I_2) at 0.024 mol L^{-1} and iodide at 0.053 mol L^{-1}. The anode, also platinum, is immersed in a saturated silver chromate solution in equilibrium with its solid phase. What must be the **concentration of chromate ion** for the cell to be **at equilibrium**?

$I_2(aq) + 2\ e^- \leftrightharpoons 2\ I^-(aq)$ $\quad E° = 0.536$ V
$Ag_2CrO_4(s) + 2e^- \leftrightharpoons 2\ Ag(s) + CrO_4^{2-}(aq)$ $\quad E° = 0.449$ V

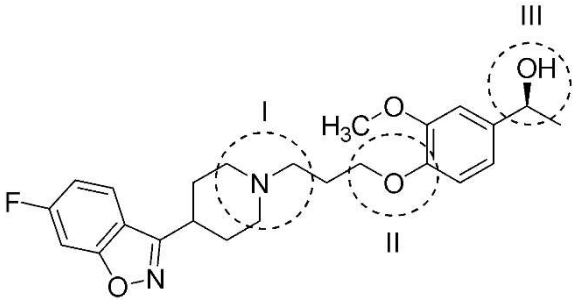
$$E = E° - \frac{0.0592}{n} \log Q$$

where Q is the reaction quotient.

Assume that no other equilibria or activity effects influence the system.

a) 0.135 mmol L^{-1}
b) 2.50 mmol L^{-1}
c) 240 mmol L^{-1}
d) 395 mmol L^{-1}
e) 746 mmol L^{-1}

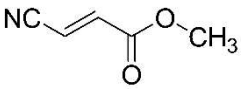
Question 36: Milsoperidone, whose structure is shown below, is an antipsychotic drug used in the treatment of schizophrenia and bipolar disorder.



The functional groups highlighted in the structure of milsoperidone are:

a) I: amine; II: ether; III: alcohol.
b) I: amide; II: ester; III: alcohol.
c) I: amine; II: ester; III: phenol.
d) I: amide; II: alcohol; III: phenol.
e) I: amine; II: ester; III: phenol.

Question 37: Given the structural representation of an organic compound:



It is correct to state that in the given structure:

a) There is no carbon atom with sp hybridization.
b) It contains an ether functional group and has the molecular formula $C_4H_5NO_2$.
c) There is only one carbon atom with sp^3 hybridization.
d) It contains an amine functional group and has the molecular formula $C_4H_5NO_2$.
e) There are only two carbon atoms with sp^2 hybridization.

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Question 38: Isomerism is a common phenomenon in organic chemistry in which molecules with the same molecular formula exhibit different physical and chemical properties. Regarding the isomerism of but-2-ene and its derivatives, select the **correct** alternative:

a) But-2-ene exhibits constitutional isomerism with methylpropene.
b) Cis-but-2-ene and trans-but-2-ene have the same boiling point because they are isomers.
c) Trans-but-2-ene is a polar molecule, whereas cis-but-2-ene is nonpolar.
d) The conversion between cis and trans isomers occurs freely at room temperature due to rotation around the double bond.
e) But-2-ene contains a chiral (asymmetric) carbon atom in its structure.

Question 39: Select the correct alternative that contains compounds in which functional groups corresponding to both organic functions can be identified: a primary alcohol and an aryl halide.

a) 1-chloro-2-hydroxybenzene and 2-methyl-3-pentanol.
b) 2-methyl-1-propanol and p-hydroxytoluene.
c) 3,5-dihydroxy-4-octanone and octanal.
d) 2,4-dimethyl-1-hexanol and 2-methyl-2-butanol.
e) 1-bromo-2-(hydroxymethyl)benzene and 2,3-dimethylpentan-1-ol.

Question 40: According to IUPAC rules, indicate the name, among those listed below, that corresponds to a carbon chain with 5 carbon atoms, a double bond at carbon 2, and a methyl group at carbon 4.

a) 2-methylpent-3-ene
b) Isopentene
c) 4-methylpent-2-ene
d) 2-methylpent-2-ene
e) 4-methylpent-3-ene

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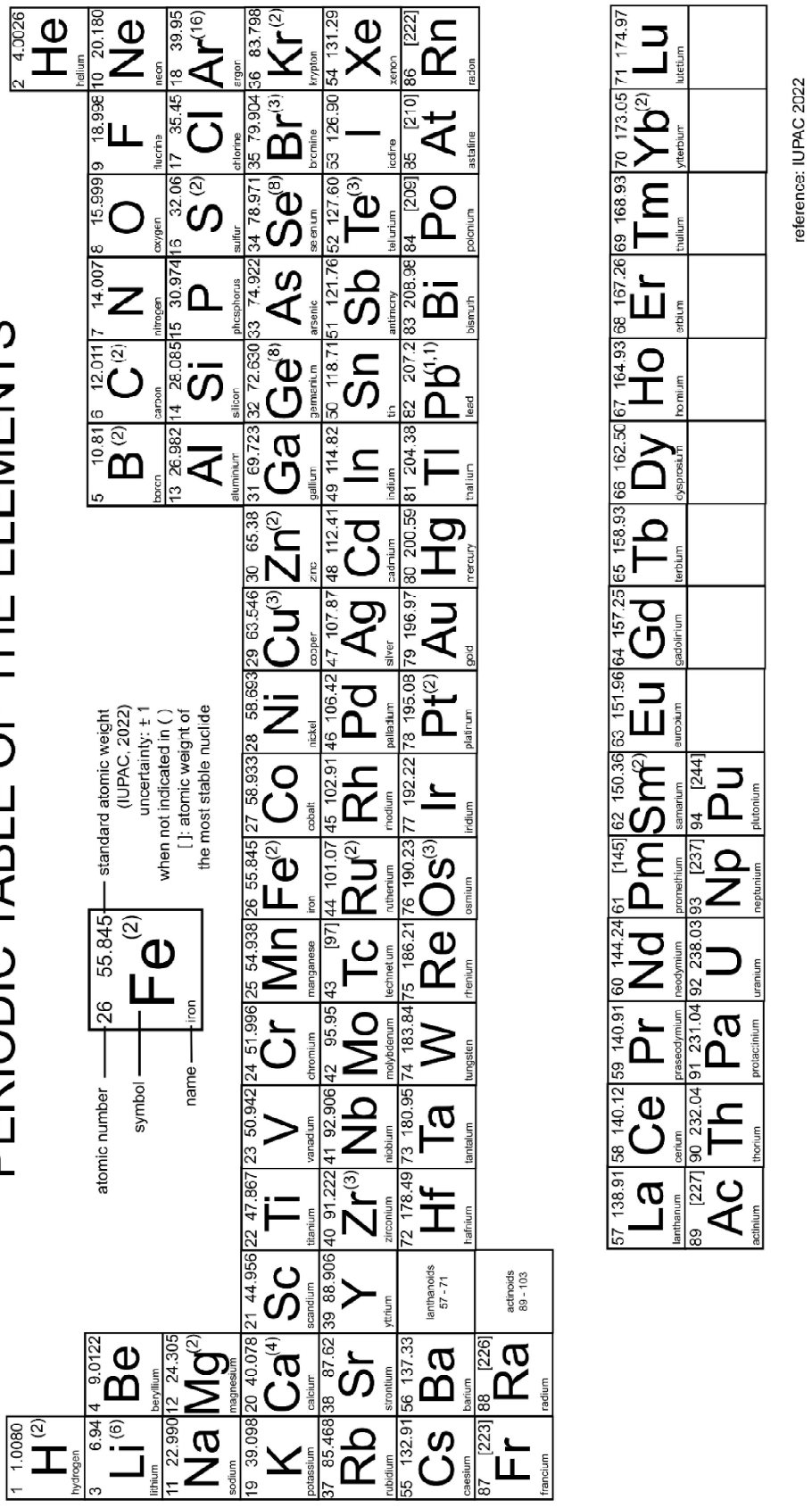

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SCRATCH WORK (for notes and calculations)