SAMPLE EXAMINATION QUESTIONS FOR THE CHEMISTRY GLOBAL FINAL - CATEGORY 3 (GRADES 11-12)

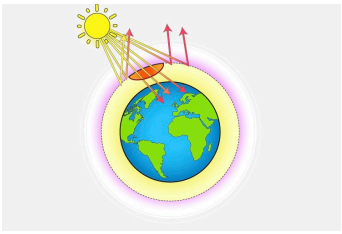
Q1. In a quantum mechanical model of an atom, the probability of finding an electron in a 2p orbital is highest in which region relative to the nucleus?
A) Spherical shell close to the nucleus
B) Circular orbit at a fixed distance
C) Dumbbell-shaped region along the x, y, or z-axis
D) Random points throughout the atom

Q2. Which of the following compounds exhibits optical isomerism due to the presence of two chiral centers?
A) 2-Chloropropane
B) 2,3-Dichlorobutane
C) 1-Chloropropane
D) 2-Chloro-2-methylpropane

Q3. Which molecule has the shortest bond length between the central atom and the ligand due to significant π-backbonding?
A) CO
B) BF_3
C) N_2
D) PF_5

Q4. A reaction has a rate law of rate = $k[A]^2[B]$. If the concentration of A is halved and B is doubled, the new rate compared to the original is:
A) 0.25 times
B) 0.5 times
C) 1 time
D) 2 times

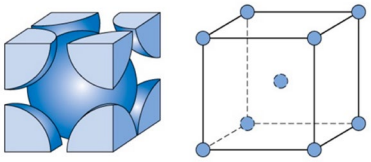
Q5. The depletion of the ozone layer is primarily caused by which compound released into the atmosphere?
A) Carbon dioxide
B) Chlorofluorocarbons (CFCs)
C) Methane
D) Nitrogen oxides



Q6. A complex $[Z(NH_3)_4Cl_2]^+$ has a coordination number of 6 and Z in +3 oxidation state. If NH_3 is a weak field ligand, how many unpaired electrons are possible?
A) 1
B) 2
C) 3

D) 4

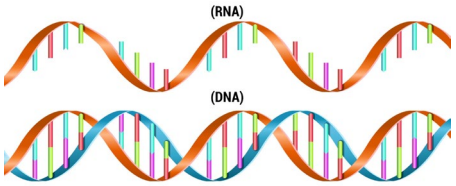
Q7. A body-centered cubic (BCC) unit cell has an atomic radius of 125 pm. What is the edge length of the unit cell?



A) 250 pm
B) 288 pm
C) 353 pm
D) 500 pm

Q8. A protein with 200 amino acids folds into a structure stabilized by 10 disulfide bonds. If each bond contributes 5 kcal/mol of stabilization energy, what is the total free energy change (ΔG) due to these bonds at 298 K, assuming no entropy change?
A) -50 kcal/mol
B) -25 kcal/mol
C) 0 kcal/mol
D) +50 kcal/mol

Q9. What is the primary reason that RNA molecules are typically single-stranded, while DNA forms a double helix, despite both containing similar phosphodiester backbones?



A) RNA lacks the thymine base found in DNA
B) RNA's 2'-hydroxyl group increases structural flexibility
C) DNA has a higher molecular weight than RNA
D) RNA nucleotides are less stable than DNA nucleotides

Q10. The standard electrode potential for Fe^{3+}/Fe^{2+} is +0.77 V. If the concentration of Fe^{2+} is 0.1 M and Fe^{3+} is 1 M at 298 K, what is the electrode potential?
A) +0.69 V
B) +0.77 V
C) +0.85 V
D) +0.93 V

Q11.A rare violet solid, insoluble in water but exhibiting exceptional solubility in dimethyl sulfoxide with a decomposition temperature exceeding 800°C, reacts with aqueous lead acetate to precipitate a yellow solid and, when subjected to fusion with sodium carbonate followed by acid extraction, releases a gas that forms a white precipitate with silver nitrate, so what is the most plausible chemical classification of this thermally stable and reactively distinctive unknown substance?
A) Iodine pentoxide
B) Potassium iodide
C) Silver bromide
D) Barium chromate

Q12. A reversible chemical reaction occurring within a closed system, where the enthalpy change is determined to be +75 kJ per mole of reactant and the entropy change is measured at +250 J per mole per Kelvin due to the formation of a highly disordered gaseous product,

requires an evaluation of the temperature range over which the reaction becomes spontaneous when coupled with an external pressure increase that further enhances the entropic contribution by favoring the gas phase, so at what temperature threshold does this spontaneity initiate?
A) 200 K
B) 300 K
C) 400 K
D) 500 K

Q13. In 400 g of water, sodium chloride with a mass of 46.8 g was dissolved. Inert electrodes were placed in the solution, and a constant electric current was passed, collecting chlorine gas with a volume of 2.24 L at STP. Determine the mass fraction of sodium chloride in the solution after electrolysis.
A) 10%
B) 23%
C) 18%
D) 8%

Q14. A mixture of iron(II) oxide and iron(III) oxide with a total mass of 8 g was dissolved in an excess of sulfuric acid. The resulting solution was reacted with a potassium permanganate ($KMnO_4$) solution with a mass fraction of 5%, having a mass of 31.6 g. Determine the mass of the iron(II) oxides in the initial mixture.
A) 4.4 g
B) 5.6 g
C) 3.6 g
D) 2.7 g

Q15. During the hydrolysis of an ester, acetic acid was formed, requiring 90.1 mL of a 10% sodium hydroxide solution (density 1.11 g/mL) for its neutralization. The vapors of the alcohol formed were passed over phosphorus(V) oxide, and the substance obtained from this process subsequently added bromine. A brominated derivative with a mass of 47 g was produced. Determine the mass of ester.
A) 10g
B) 26g
C) 22g
D) 35g

Q16. Two elements, located in the same period and the same group of the periodic table (in its short form), form a single stable binary compound with each other, where the mass fraction of one of the elements is 25.6%. This compound is highly soluble in water, and when gaseous ammonia is passed through its solution, a white precipitate forms, which gradually darkens in air. Identify the elements, determine the formula of the compound, and write the reaction equations.
Q17. Right-hand side with coefficients
Restore the left-hand side of the equations:
… + … = Li(HCOO)

… + … = $Al(OH)_3\downarrow + 3NaNO_3 + 3CO_2\uparrow$

… + … + … = $2MnSO_4 + K_2SO_4 + 8H_2O + 5O_2\uparrow$

… + … + … = $2Na_2CrO_4 + 3NaNO_2 + 2CO_2\uparrow$

… + … = $KCl + N_2\uparrow + 2H_2O$

Q18. A natural dipeptide with a mass of 17.4 g was subjected to complete hydrolysis using a sodium hydroxide solution (mass fraction of NaOH = 12%, density ρ = 1.2 g/mL). From the reaction products, 13.9 g of a salt of an optically active amino acid A was isolated, with a mass fraction of sodium in the salt equal to 16.55%.

1.Determine the composition of the dipeptide.

2.Provide the reaction equation for the interaction of this peptide with a dilute hydrochloric acid solution.

3.Provide the reaction equation for the alkaline hydrolysis of this dipeptide.

4.Calculate the volume of the sodium hydroxide solution required for the complete hydrolysis of this dipeptide.

5.Provide the projection formulas for the stereoisomers of the optically active amino acid.

Q19. The metal X is a trace element. However, its compounds—oxides and silicates—are widespread in nature. The metal does not react with water, acids, or bases, but it dissolves in aqua regia and hydrofluoric acid. The metal is pyrophoric, and upon combustion, it forms an oxide Y, in which the mass fraction of oxygen is 26.0%. The oxide Y is highly refractory and extremely hard, widely used in industry and medicine. When Y is fused with sodium hydroxide, a salt Z and water are formed. At high temperatures, the metal X reacts with sulfur to form an unstable sulfide E, where the mass fraction of the metal is the same as in the oxide.Determine the substances X, Y, Z, and E, and write their formulas in the answer.

Q20. You have at your disposal three types of fuel: gaseous hydrogen under a pressure of 10 atm and a temperature of 25°C (cost: 25 conventional units per cubic meter), gaseous methane under the same conditions (cost: 5 conventional units per cubic meter), and coal (cost: 3 conventional units per kilogram), which consists of pure graphite.

Questions:

1. Write the combustion equations for each substance and calculate the heat effect.
2. Determine which type of fuel provides the greatest energy during combustion:
   a) per unit volume;
   b) per unit mass;
   c) per conventional unit of cost.

Reference Data:

a) Standard molar enthalpies of formation (Q) (kJ/mol):

CH_4: 74.8

CO_2: 393.5

H_2O(liquid): 285.8

b) Density of graphite: 2.27 g/cm³

Answer key
1) C
2) B
3) A
4) B
5) B
6) C
7) B
8) A
9) B
10) A
11) B
12) B
13) D
14) C
15) C

Open ended problem's solutions

Q16.

Since the elements are in the same period and the same group of the periodic table, one of them belongs to the main subgroup, while the other is in a secondary subgroup, i.e., it is a d-metal. Based on its solubility in water, the substance is a halide, indicating that the metal is located in the secondary subgroup of the seventh group of the periodic table. Judging by its properties, this metal is manganese, and the substance is $MnBr_2$.Indeed, the mass fraction of manganese in it is calculated as 55 : 215 ≈ 0.256 = 25.6%.The elements are Mn and Br, and the substance is $MnBr_2$.

Reaction equations:

1. $MnBr_2 + 2NH_3 + 2H_2O \rightarrow Mn(OH)_2\downarrow + 2NH_4Br$
2. $2Mn(OH)_2 + O_2 \rightarrow 2MnO_2\downarrow + 2H_2O$

Q17.

Answer:

$LiH + CO_2 \rightarrow LiHCOO$ (the equation $LiOH + CO \rightarrow LiHCOO$ is also accepted)

$$Al(NO_3)_3 + 3NaHCO_3 \rightarrow Al(OH)_3\downarrow + 3NaNO_3 + 3CO_2\uparrow$$

$$5H_2O_2 + 2KMnO_4 + 3H_2SO_4 \rightarrow 2MnSO_4 + K_2SO_4 + 8H_2O + 5O_2\uparrow$$

$$Cr_2O_3 + 3NaNO_3 + 2Na_2CO_3 \rightarrow 2Na_2CrO_4 + 3NaNO_2 + 2CO_2\uparrow$$

$$NH_4Cl + KNO_2 \rightarrow KCl + N_2\uparrow + 2H_2O$$

Final Answers:

1. **Composition of dipeptide:** Val-Gly (valyl-glycine)
2. **Reaction with HCl:** $\text{Val-Gly} + \text{HCl} \rightarrow \text{Valine} + \text{Glycine} + \text{HCl}$
3. **Alkaline hydrolysis:**
   $\text{Val-Gly} + 2\text{NaOH} \rightarrow \text{Na-Valinate} + \text{Na-Glycinate} + 2\text{H}_2\text{O}$
4. **Volume of NaOH solution:** 55.6 mL
5. **Projection formulas:**
   - L-Valine: COOH | H-C-NH_2 | $CH(CH_3)_2$
   - D-Valine: COOH | NH_2-C-H | $CH(CH_3)_2$

Q18.

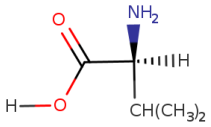
Q19.

X: Zr (zirconium)

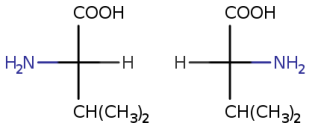
Y: ZrO_2 (zirconium dioxide)

Z: Na_2ZrO_3 (sodium zirconate)

E: ZrS (zirconium sulfide)



Fischer Projections



L-Valine D-Valine

Final Answers:

1. **Combustion equations and heat effects:**
   - $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}, \Delta H = -285.8\,\text{kJ/mol of H}_2$
   - $\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}, \Delta H = -890.3\,\text{kJ/mol of CH}_4$
   - $\text{C} + \text{O}_2 \rightarrow \text{CO}_2, \Delta H = -393.5\,\text{kJ/mol of C}$
2. **Greatest energy:**
   - a) Per unit volume: Graphite (74434145 kJ/m³)
   - b) Per unit mass: Hydrogen (142900 kJ/kg)
   - c) Per unit cost: Methane (72773 kJ/unit)

Q20.