Harvard Undergraduate Science Olympiad Dubai 2026

Chemistry, 9-10th Grade

Number of Problems: 30 Questions

Instructions: This test consists of two sections:

- *Section A: 20 multiple choice questions, 1 point each.*
- *Section B: 10 short answer questions, 2 point each.*

For the multiple choice questions, select the correct answer and fill in the corresponding bubble on the answer sheet.

For the short answer questions, write the correct answer in the corresponding box on the answer sheet. Round numerical solutions to a reasonable number of significant figures.

Only responses on the answer sheet will be graded. You can use this test packet as scratch paper, but no points will be awarded for any work shown.

To determine tiesbreakers, we will compare scores on the last problem; if still tied, compare the second-to-last; continue backward until the score differs.

You are allowed with you a pencil or pen, erasers, and a non-programmable, scientific calculator. Any other electronic devices or notes are strictly prohibited. You have 60 minutes to complete this exam. Good luck!

Multiple Choice Questions (20 total)

1. Which of the following elements has the largest atomic radius?
   A. Lithium (Li)
   B. Carbon (C)
   C. Potassium (K)
   D. Fluorine (F)
   E. Neon (Ne)

2. During a beta-minus (β^-) radioactive decay, which of the following particles is emitted from the nucleus?
   A. An alpha particle (helium-4 nucleus)
   B. A positron (positively charged electron)
   C. A neutron
   D. A gamma ray (high-energy photon)
   E. An electron (beta particle)

3. Which of the following molecules is polar (i.e., has an overall dipole moment)?
   A. NH_3 (ammonia)
   B. CO_2 (carbon dioxide)
   C. CH_4 (methane)
   D. CCl_4 (carbon tetrachloride)
   E. BF_3 (boron trifluoride)

4. Consider the equilibrium: $N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g) + \text{heat}$. According to Le Châtelier's principle, what will happen if the temperature of this system is increased?
   A. The equilibrium will shift toward the products (to the right)
   B. The equilibrium will shift toward the reactants (to the left)
   C. The position of equilibrium will not change with temperature
   D. The equilibrium constant K will increase at the higher temperature
   E. The reaction will proceed to completion (all reactants converted to products)

5. Which of the following aqueous solutions is expected to have the lowest freezing point? (Assume ideal behavior and complete dissociation of ionic compounds.)
   A. Pure water
   B. 0.10 M glucose (a non-electrolyte sugar solution)
   C. 0.10 M NaCl (sodium chloride solution)
   D. 0.10 M $CaCl_2$ (calcium chloride solution)
   E. 0.05 M NaCl (sodium chloride solution)

6. For a typical chemical reaction, which of the following changes will **not** result in an increased reaction rate?

A. Increasing the concentration of reactants

B. Increasing the reaction temperature

C. Adding a suitable catalyst

D. Lowering the reaction temperature

E. Grinding a solid reactant into a fine powder (increasing surface area)

7. Which pair of aqueous solutions, when mixed, will produce a precipitate due to an insoluble product?

A. Na_2CO_3 (aq) + KCl (aq)

B. $NaNO_3$ (aq) + KBr (aq)

C. $Pb(NO_3)_2$ (aq) + K_2SO_4 (aq)

D. $Cu(NO_3)_2$ (aq) + NaCl (aq)

E. $CaCl_2$ (aq) + KNO_3 (aq)

8. Which of the following oxides will form an acidic solution when added to water?

A. CaO (s)

B. Na_2O (s)

C. Al_2O_3 (s)

D. CO_2 (g)

E. CO (g)

9. Which of the processes below involves an increase in entropy ($\Delta S > 0$)?

A. $2\,NH_3(g) \rightarrow N_2(g) + 3\,H_2(g)$

B. $H_2O(l) \rightarrow H_2O(s)$

C. $CO_2(g) \rightarrow CO_2(s)$

D. Compressing an ideal gas into a smaller volume (constant T)

E. $N_2(g) + 3\,H_2(g) \rightarrow 2\,NH_3(g)$

10. Which piece of laboratory equipment is most suitable for accurately measuring out **25.00 mL** of a liquid sample?

A. 50 mL beaker

B. 100 mL graduated cylinder

C. 50 mL Erlenmeyer flask

D. 50 mL burette

E. 25 mL volumetric pipette

11. Which of the following species is **diamagnetic** (all electrons paired, no unpaired electrons)?

A. O (oxygen atom)

B. Cl (chlorine atom)

C. Fe^{3+} ion

D. C (carbon atom)

E. Ca^{2+} ion

12. Which of these ligands can attach to a metal ion through two donor atoms (i.e., is **bidentate**)?

A. NH_3 (ammonia)

B. Ethylenediamine, $H_2NCH_2CH_2NH_2$

C. Cl^- (chloride)

D. CN^- (cyanide)

E. H_2O (water)

13. Which of the following ionic compounds is expected to have the highest lattice energy (strongest ionic bonding)?

A. NaCl

B. Al_2O_3

C. KBr

D. MgO

E. LiF

14. Which statement about ideal gases is **correct** according to the kinetic molecular theory?

A. Gas particles exert strong attractive forces on one another.

B. The volume of gas molecules is significant compared to the container volume.

C. All gas molecules have the same speed at a given temperature.

D. Collisions between gas molecules are perfectly elastic (no net energy loss).

E. Gas pressure results from particles sticking to the container walls.

15. For the titration of a weak acid with a strong base, which of the following indicators would be most appropriate?

A. Methyl orange (pH range approx. 3.1–4.4)

B. Bromothymol blue (pH range approx. 6.0–7.6)

C. Phenolphthalein (pH range approx. 8.3–10.0)

D. Litmus (color change around pH 7)

E. Methyl red (pH range approx. 4.4–6.2)

16. Which of the following salts will produce a **basic** (pH $>$ 7) solution when dissolved in water?

A. Sodium chloride, NaCl

B. Ammonium chloride, NH_4Cl

C. Potassium nitrate, KNO_3

D. Lithium bromide, LiBr

E. Sodium acetate, CH_3COONa

17. Which of the following is the correct IUPAC name for the molecule with structure $CH_3CH(CH_3)CH_2CH_3$?

A. 2-methylbutane

B. 3-methylbutane

C. pentane

D. isopentane (common name)

E. butane

18. When ethene (C_2H_4) reacts with bromine (Br_2) to yield 1,2-dibromoethane ($C_2H_4Br_2$), which type of reaction is occurring?

A. Substitution

B. Elimination

C. Addition

D. Polymerization

E. Combustion

19. Which of the following compounds is the **most acidic** (has the lowest pK_a)?

A. Ethanol, CH_3CH_2OH

B. Acetic acid, CH_3COOH

C. Phenol, C_6H_5OH

D. Water, H_2O

E. Acetylene, C_2H_2

20. If the standard Gibbs free energy change ΔG° for a reaction is negative (at 25 °C), which of the following must be true about the equilibrium constant K (at 25 °C)?

A. $K > 1$

B. $K < 1$

C. $K = 1$

D. $K < 0$

E. $K = 0$

Short Answer Questions (10 total)

1. A 0.500 mol sample of an ideal gas is confined in a 10.0 L container at 300 K. Use the ideal gas equation $PV = nRT$ to calculate the pressure of the gas in atmospheres (use $R = 0.08206\ \text{L} \cdot \text{atm}/(\text{mol} \cdot \text{K})$).

2. Determine the molecular geometry (VSEPR shape) of sulfur hexafluoride, SF_6.

3. In a laboratory experiment, a student measures the density of a liquid to be 0.78 g/mL. The true accepted density of the liquid is 0.85 g/mL. Calculate the percent error of the student's measurement.

4. What volume (in mL) of 0.250 M NaOH solution is required to completely neutralize 50.0 mL of 0.100 M HCl?

5. For the reaction $H_2(g) + I_2(g) \rightleftharpoons 2, HI(g)$, the equilibrium concentrations at a certain temperature are $[H_2] = 0.200$ M, $[I_2] = 0.200$ M, and $[HI] = 1.200$ M. Calculate the equilibrium constant K_c for this reaction.

6. A buffer solution is made using acetic acid and sodium acetate. The buffer contains 0.10 M acetic acid (CH_3COOH) and 0.20 M acetate ions (CH_3COO^-). Given the acid dissociation constant K_a of acetic acid is 1.8×10^{-5} ($pK_a \approx 4.76$), calculate the pH of the buffer.

7. A certain chemical reaction has $\Delta H^\circ = +50.0$ kJ and $\Delta S^\circ = +120$ J/K. Calculate ΔG° for this reaction at 298 K, and state whether the reaction is spontaneous at 298 K. (Pay attention to units when calculating ΔG°.)

8. The solubility product constant K_{sp} of silver sulfate (Ag_2SO_4) at a certain temperature is 1.2×10^{-5}. Write the dissolution equation for Ag_2SO_4 in water, and calculate the molar solubility of Ag_2SO_4 in pure water at this temperature.

9. The half-life of a certain first-order reaction is 15.0 minutes. Calculate the rate constant k for this reaction (include units in your answer).

10. What is the major organic product when 2-methyl-2-butene is treated with HBr? (Provide the name or clearly drawn structure of the product.)