Harvard Undergraduate Science Olympiad India
2025 Final Round
9th-10th Grade
Chemistry Section: Exam

INSTRUCTIONS:

The HUSO India Final Round Chemistry section consists of two sections. Section I consists of multiple choice questions with only 1 correct answer. Section II consists of multiple choice questions with anywhere from 1 to 5 correct answers.

You may spend 1 hr on the Chemistry section. **You are allowed a non-programmable, non-graphing calculator. No additional notes or electronics are allowed.** The next page contains possibly useful reference information.

All answers must be bubbled on the provided on the answer sheet. Any writing on the exam booklet outside the designated boxes in the answer sheets will not be graded. You may write in this booklet, but **NO WRITING IN THIS BOOKLET WILL BE GRADED.**

For answers to be graded, you must fully darken in the corresponding bubbles on the answer sheet. Your bubble must have no white remaining to be properly scored. Poor bubbling will lead to your exam not being scored. Please write your full name, school name, and HUSO ID on the answer sheet. Bubble in the ID box the four digits of your ID following "25".

Grading:

- Section I: Single Select questions; +1 point per correct answer, -.25 points per incorrect answer, 0 points if question left blank.
- Section II: Multiple Select questions; +1 point per fully correct question (all correct choices selected AND no incorrect choices selected), 0 points otherwise. No negative points for incorrect answers.
- If there are ties, the higher Section II score wins.

Do your best! Embrace and conquer the challenge!

#	Section	Questions	% of Total
1	Single Select Questions	30	60
2	Multiple Select Questions	20	40
	Total	**50**	**100**

FOR REFERENCE:

STP: 0 ºC, 1 atm

Standard State (for thermodynamics): 25 ºC, 1 atm gas pressures, 1 M aqueous concentrations

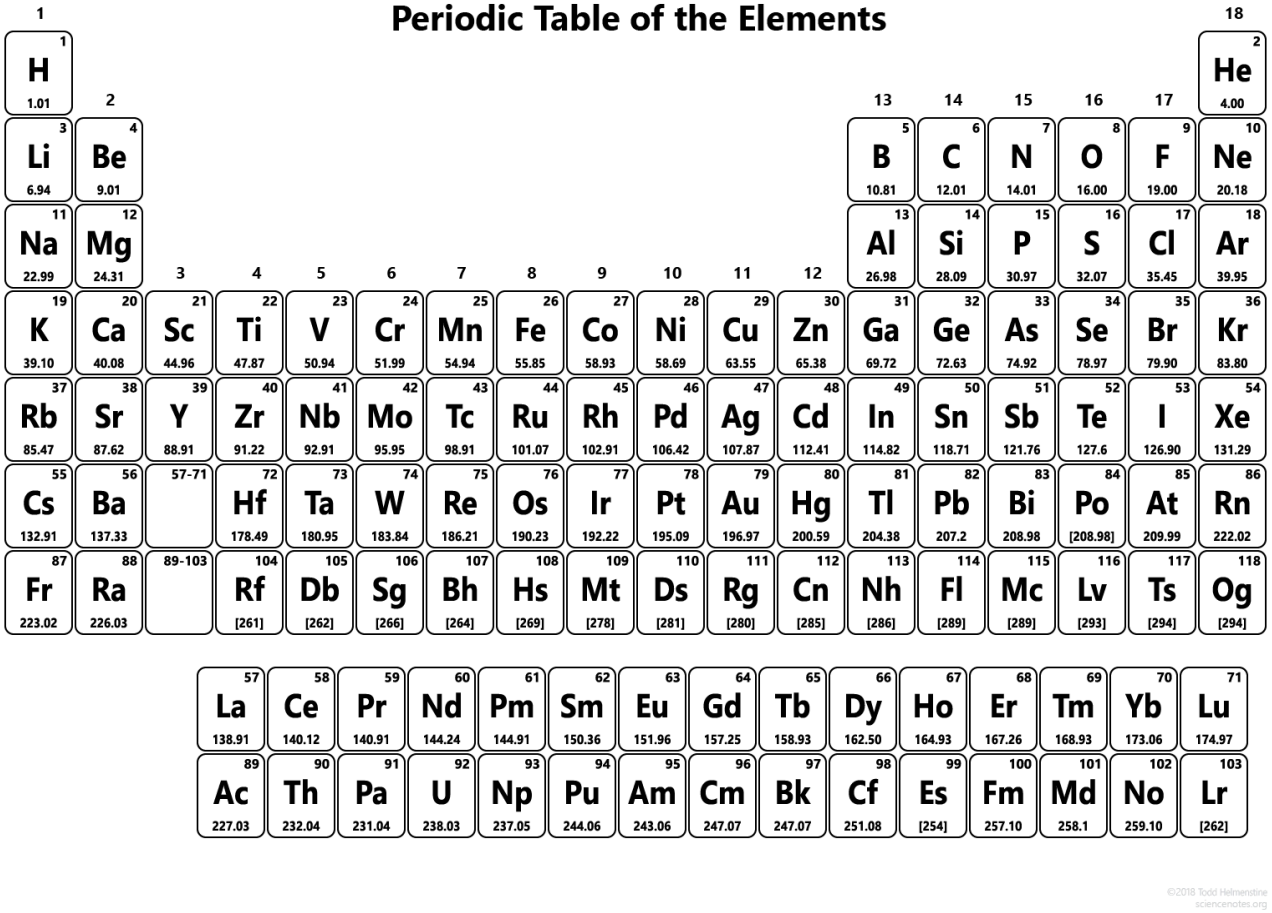
$R = 0.08206\ L \cdot atm/(mol \cdot K) = 8.314\ J/(mol \cdot K)$

$F = 96485\ C/(mol\ e^-)$

$h = 6.626 \cdot 10^{-34}\ J \cdot s$

$c = 2.998 \cdot 10^{8}\ m/s$

$N_A = 6.022 \cdot 10^{23}$



SECTION 1: Single Select Questions

60% of the Chemistry Section total

Instructions: Select the 1 best answer to each of the following questions. +1 point per correct answer, -.25 per incorrect answer, 0 points if question left blank.

1. Which of the following are present in atomic orbitals?
    a. Protons
    b. Neutrons
    c. Electrons
    d. Positrons
    e. Molecules

2. Which of the following atoms would react violently with water?
    a. Al
    b. Be
    c. Cu
    d. Ag
    e. Na

3. What is the name for a vertical column of elements on the periodic table?
    a. Period
    b. Group
    c. Diagonal
    d. Block
    e. Orbital

4. Which of the following atoms/ions is the most electronegative?
    a. Cl
    b. O
    c. O^{2-}
    d. S
    e. S^{2-}

5. Which of the following molecules are polar?
    a. CO_2
    b. CO
    c. Cl_2
    d. CH_4
    e. O_2

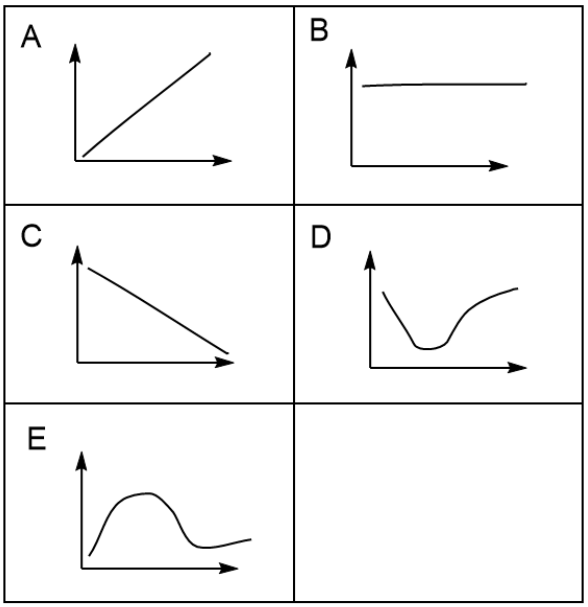
6. Which of the following best explains why the bond order of ozone is 1.5?
    a. The bonds between the atoms are polar.
    b. A pair of electrons is rapidly flipping between the two bond locations
    c. Ozone exists as an average of two equivalent lewis dot structures
    d. The central O atom is sp^2 hybridized
    e. Ozone exists in chemical equilibrium with O_2 in the atmosphere

7. How many nodes are observed in the wavefunction of a 4d orbital?
    a. 1
    b. 2
    c. 3
    d. 4
    e. 5

8. How many neutrons are present in an atom of $^{5}He^{2+}$?
    a. 1
    b. 2
    c. 3
    d. 4
    e. 5

9. When I balance the following equation, what do the coefficients sum to?
   __ $MgCl_2$ + __ NaOH → __ $Mg(OH)_2$ + __ NaCl
    a. 4
    b. 5
    c. 6
    d. 7
    e. 8

10. Which graph best shows the relationship between distance between nuclei (x-axis) and energy (y-axis) for a two-atom system forming a covalent bond?



11. What is the overall reaction order of the following reaction?

Overall reaction: $A + 2B \rightarrow C$

Experimental Data:

Initial concentration of A (mol/L)	Initial concentration of B (mol/L)	Initial Rate of Reaction (mol/(L*s))
0.35	0.25	0.63
0.80	0.25	1.45
1.75	0.65	8.25

a. 0
b. 1
c. 2
d. 3
e. 4

12. Completely combusting in excess oxygen 135.4 g of a compound consisting of only C, H, and O produces 54 g of water and 134.2 g of CO_2 as the only products. What is the empirical formula of the compound?
    a. CH_2O
    b. C_2H_5O
    c. CH_3O
    d. CH_2O_3
    e. CH_2O_2

13. I am given the following data:

Reaction	ΔH^o (kJ/mol)
H_2 (g) + Cl_2 (g) → 2 HCl (aq)	-334.4
Na (s) + ½ O_2 (g) + ½ H_2 (g) → NaOH (s)	-425.6

    What is the enthalpy change (ΔH^o) for the following reaction as shown below?
    HCl (aq) + NaOH (s) → Na (s) + ½ O_2 (g) + H_2 (g) + ½ Cl_2 (g)

    a. -760 kJ
    b. -167.2 kJ
    c. -91.2 kJ
    d. 592.8 kJ
    e. 760 kJ

14. I am told that the pKa of acetic acid is 4.76. I have a 2 M solution of acetic acid. What is its pH?
    a. 2.00
    b. 2.23
    c. 3.85
    d. 4.76
    e. 5.83

15. I am told that the Ksp of AgBr is 5.0×10^{-13}. What is the molar solubility of AgBr?
    a. 5.1×10^{-20} M
    b. 2.5×10^{-13} M
    c. 2.4×10^{-10} M
    d. 7.1×10^{-7} M
    e. 3.3×10^{-5} M

16. I am performing a titration of a solution of ammonia (NH_3) of unknown concentration. What standardized solution should I use as my titrant?
    a. Sodium Hydroxide
    b. Acetic Acid
    c. Potassium Permanganate
    d. Phenolphthalein
    e. Hydrochloric Acid

17. What is the lattice energy of $MgBr_2$ in kJ/mol? You are provided with the following data to use for the calculation.

Enthalpy	kJ/mol
Standard Enthalpy of Formation, $MgBr_2$	-518
Br_2 (l) → 2 Br (g)	224
Sublimation of Mg	150
1st Ionization Energy of Mg	736
2nd Ionization Energy of Mg	1450
1st Electron Affinity of Br	-342

    a. 1700
    b. 2000
    c. 2400
    d. 2700
    e. 3000

18. Ethan connected a palladium electrode to the negative terminal of a battery, and another palladium electrode to the positive terminal. He felt sleepy and dropped the two electrodes into an aqueous solution of F^-, OH^-, Na^+, and H^+. Which products form initially under standard conditions?
    a. H_2 and O_2
    b. H_2 and F_2
    c. Na and H_2
    d. Na and F_2
    e. Na and O_2

19. An acid solution with a mass percent concentration of 2.0% has a density of 0.997 g/cm^3 and a pH of 4.90. If we want the degree of dissociation of the acid to increase tenfold, then we must dilute the solution:
    a. 5 times
    b. 10 times
    c. 50 times
    d. 100 times
    e. The degree of association remains the same during dilution

20. Which of the following compounds has the lowest ionization energy?
    a. O_2
    b. O_2^+
    c. N_2
    d. N_2^+
    e. CO

21. Iron is known to be body centered cubic at room temperature. The unit cell of iron has an edge length 287 x 10^{-12} m. Calculate the density of iron at room temperature in g/cm^3 to the nearest whole number.
    a. 5
    b. 6
    c. 7
    d. 8
    e. 9

22. How many complex ion stereoisomers exist with the molecular formula $[Fe(NH_3)_2(H_2O)_3Cl]^{2+}$?
    a. 1
    b. 2
    c. 3
    d. 4
    e. 5

23. Which orbital type in the n=3 energy level has the best ability to shield outer-shell electrons?
    a. s
    b. p
    c. d
    d. f
    e. g

24. What is the oxidation state of Fe in $[Fe(NH_3)_3(H_2O)Br_2]^+$?
    a. -1
    b. 0
    c. +1
    d. +2
    e. +3

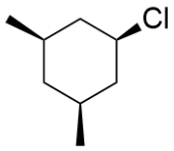
25. I have a balloon full of an equal concentration mixture of CO_2, N_2, O_2, and Ar gas. Assuming all gases are ideal, after 2 seconds which gas will have the highest concentration in the balloon?
    a. CO_2
    b. N_2
    c. O_2
    d. Ar
    e. By the ideal gas law, the gases will remain the same concentrations relative to each other.

26. The following reaction occurs in basic conditions. How many water molecules need to be added for the reaction to be balanced? (You should add water and hydroxide as needed to balance the reaction)

    $Se\ (s) + Cr(OH)_3\ (s) \rightarrow Cr\ (s) + SeO_3^{2-}\ (aq)$

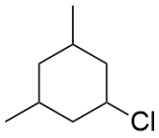
    a. 3
    b. 5
    c. 7
    d. 9
    e. 11

27. How many chiral centers does the following molecule have?



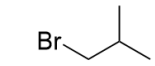
    a. 1
    b. 2
    c. 3
    d. 4
    e. 5

28. How many stereoisomers exist for the following structure?

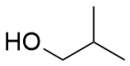


a. 1
b. 2
c. 3
d. 4
e. 5

29. Treating isobutyl bromide with NaOH would lead to which of the following products in highest yield?

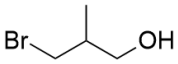


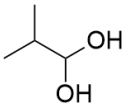
isobutyl bromide

A 

B 

C 

D 

E 

30. In an addition reaction between an amine and a ketone, classify the reagents as nucleophile and electrophile.
    a. Amine is nucleophile, ketone is nucleophile.
    b. Amine is electrophile, ketone is nucleophile.
    c. Amine is nucleophile, ketone is electrophile.
    d. Amine is electrophile, ketone is electrophile.
    e. None of the above

SECTION 2: Multiple Select Questions

40% of the Chemistry Section total

Instructions: Select ALL correct answers to each of the following questions (there is anywhere from 1 to 5 correct answers per question). +1 point per question where ALL correct answers are selected AND no incorrect answers are selected. 0 points otherwise.

31. Which of the following elements are halogens?
    a. I
    b. O
    c. F
    d. S
    e. He

32. Which of the following overall trends occur as you move towards the right in a period for the main group elements (ignore noble gases)?
    a. Increasing atomic mass
    b. Increasing electronegativity
    c. Increasing atomic radius
    d. Increasing number of valence electrons
    e. Decreasing 1st ionization energy

33. Which of the following statements are true about electrons?
    a. They are much smaller than protons and neutrons in terms of mass
    b. Each period of the periodic table has the same number of valence electrons
    c. Isotopes of the same element are atoms that vary in number of electrons
    d. Neutral atoms have the same number of protons and electrons
    e. Electrons orbit the nucleus in circular orbits

34. Which of the following atoms exist as diatomic gases in their standard states?
    a. H
    b. He
    c. N
    d. O
    e. P

35. Which of the following statements are true about ideal gases?
    a. Pressure is directly proportional to volume
    b. Pressure is directly proportional to number of moles
    c. Pressure is directly proportional to temperature (Kelvin)
    d. Pressure is inversely proportional to volume
    e. Pressure is inversely proportional to temperature (Kelvin)

36. Which of the following procedures are methods of qualitative analysis?
    a. Titration
    b. Flame test
    c. Combustion Analysis
    d. Observation of fizzing when reacting with HCl
    e. None of the above

37. Which of the following properties are generally true of ionic compounds?
    a. High melting point
    b. Conducts electricity as a solid
    c. Brittle (shatters with force)
    d. Ductile (can be made into a wire)
    e. Consists of a lattice of atoms/ions

38. Which of the following properties are generally true of metallic compounds?
    a. High melting point
    b. Conducts electricity as a solid
    c. Brittle (shatters with force)
    d. Ductile (can be made into a wire)
    e. Consists of a lattice of atoms/ions

39. Which of the following ions are colored in solutions?
    a. Na^{+}
    b. Cu^{2+}
    c. Fe^{3+}
    d. Cl^{-}
    e. NO_3^{-}

40. Which of the following processes are exothermic?
    a. Freezing
    b. Melting
    c. Vaporization
    d. Sublimation
    e. Breaking a bond

41. Which of the following compounds have trigonal pyramidal geometry?
    a. PCl_3
    b. H_2O
    c. $SOCl_2$
    d. CH_3Br
    e. XeO_3

42. Which of the following changes would increase the amount of Br^- obtained from the reaction below (assume solution in water is saturated in $PbBr_2$)?

    $PbBr_2\ (s) \rightleftharpoons Pb^{2+}\ (aq) + 2\ Br^-\ (aq)$

    a. Adding water
    b. Adding Pb^{2+}
    c. Adding iodide (I^-)
    d. Adding $PbBr_2$ solid
    e. None of the above

43. I am performing a titration of a solution of iron (II) chloride of unknown concentration. What standardized solutions would be useful as my titrant if I wanted to perform a redox titration?
    a. Sodium Hydroxide
    b. Acetic Acid
    c. Hydrochloric Acid
    d. Iron (III) chloride
    e. Potassium Permanganate

44. Which of the following are chemical changes?
    a. Evaporating off water from a salt solution
    b. Iron rusting
    c. Titrating acid and base
    d. Dilution of acid
    e. Melting ice

45. Which of the following statements are true about galvanic/voltaic cells?
    a. They produce a voltage
    b. They must be connected to a battery to operate
    c. Oxidation occurs at the cathode
    d. Both reduction and oxidation must occur in a galvanic cell
    e. A battery is composed of galvanic cells

46. Which of the following electronic transitions in a hydrogen atom emits visible light?
    a. 1s orbital to 2s orbital
    b. 3d orbital to 1s orbital
    c. 4d orbital to 2s orbital
    d. 2p orbital to 1s orbital
    e. 3s orbital to 2p orbital

47. Luke determines the amount of carbonate in a tablet of medicine by adding the medicine tablet into a solution of excess hydrochloric acid and providing gentle heat (50-60 ^{o}C) while stirring. Luke measured the initial mass of the beaker with acid and the initial mass of the tablet. After measuring the initial mass but before adding the tablet to the acid, he crushes the tablet with a mortar and pestle and then transfers it to the acid. He recorded the final mass of the beaker with acid and dissolved tablet after the total mass stops changing and the tablet stops fizzing. Which of the following issues would lead to him overestimating the amount of carbonate in the tablet?
    a. Some water evaporated during the heating process.
    b. The acid was not actually in excess.
    c. The acid was in high excess, but Luke used 7 M HCl instead of 6 M HCl which the procedure asked for.
    d. Luke took the final measurement while there was still some bubbling from the tablet.
    e. Some tablet remained on the mortar and pestle.

48. Alice, Bob, and Adelina are working together on an experiment to determine the molar mass of butane by collecting butane (C_4H_{10}) gas over water. Specifically, they are using a butane lighter and measure the difference between the initial and final mass of the lighter to determine the mass of butane used. Here was their experimental procedure:
    1) Take an initial mass of the lighter.
    2) Measure the volume of butane gas collected in a graduated cylinder partially submerged under water (by displacing water); use this volume to calculate the number of moles of butane gas used.
    3) Take a final mass of the lighter.

    Unfortunately, Adelina tells Alice and Bob that their experimental molar mass of butane is too high compared to the true molar mass. Which of the following reasons could explain why?
    a. They forgot to dry the lighter before measuring the final mass of the lighter.
    b. The team performed the experiment and calculations assuming the room pressure was 1.0 bar, but they did not realize the room pressure was actually 1.013 bar.
    c. The lighter contained some propane (C_3H_8) mixed in with the butane.
    d. The water was slightly acidic, with pH 6.5.
    e. The water was slightly basic, with pH 7.5.

49. Which of the following intermolecular forces can occur between two non-polar molecules?
    a. Dispersion
    b. Ion-ion
    c. Ion-dipole
    d. Dipole-induced dipole
    e. Dipole-dipole

50. Which of the following reagents is a strong oxidizing agent?
    a. H_2
    b. OsO_4
    c. CH_3MgBr
    d. $NaBH_4$
    e. NH_3