ACS USNCO
U.S. National Chemistry Olympiad

2025 U.S. NATIONAL CHEMISTRY OLYMPIAD

NATIONAL EXAM PART I

Prepared by the American Chemical Society Chemistry Olympiad Examinations Task Force

OLYMPIAD EXAMINATIONS TASK FORCE

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DIRECTIONS TO THE EXAMINER

Part I of this test is designed to be taken with a Gradescope answer sheet on which the student records their responses. Only this Gradescope sheet is graded for a score on Part I. Testing materials, scratch paper, and the Gradescope sheet should be made available to the student only during the examination period. All testing materials including scratch paper should be turned in and kept secure until **April 14, 2025,** after which tests can be returned to students and their teachers for further study. Allow time for students to read the directions, ask questions, and fill in the requested information on the Gradescope sheet. The answer sheet must be completed using a dark pencil or dark pen. When the student has completed **Part I,** or after **one hour and thirty minutes** has elapsed, the student must turn in the Gradescope sheet, Part I of the testing materials, and all scratch paper.

There are three parts to the National Chemistry Olympiad Examination. You have the option of administering the three parts in any order, and you are free to schedule rest breaks between parts.

Part I	**60 questions**	**single answer, multiple-choice**	**1 hour, 30 minutes**
Part II	**8 questions**	**problem-solving, explanations**	**1 hour, 45 minutes**
Part III	**2 lab problems**	**laboratory practical**	**1 hour, 30 minutes**

A periodic table and other useful information are provided on page 2 for student reference.

Only non-programmable calculators that do not have any on-board memory space (accessed through a mini-USB or other linkage) are to be used on the ACS Local Section Exam and on the National Exam, if used. The use of an unacceptable calculator, cell phone, or any other device that can access the internet, make copies or photographs, or has access to stored information during the exam is grounds for disqualification.

DIRECTIONS TO THE EXAMINEE – DO NOT TURN THE PAGE UNTIL DIRECTED TO DO SO.

Answers to questions in Part I must be entered on a Gradescope answer sheet to be scored. Be sure to write your name and assigned USNCO ID number on the answer sheet. **Make a record of this ID number because you will use the same number on Parts II and III.** Each item in **Part I** consists of a question or an incomplete statement that is followed by four possible choices. Select the single choice that best answers the question or completes the statement. Then use a pencil or pen to blacken the space on your answer sheet next to the same letter as your choice. You may write on the examination, but the test booklet will not be used for grading. Scores are based on the number of correct responses. When you complete Part I (or at the end of one hour and 30 minutes), you must turn in all testing materials, scratch paper, and your Gradescope answer sheet.

ABBREVIATIONS AND SYMBOLS					
amount of substance	n	Faraday constant	F	molar mass	M
ampere	A	free energy	G	mole	mol
atmosphere	atm	frequency	ν	Planck's constant	h
atomic mass unit	u	gas constant	R	pressure	P
Avogadro constant	N_A	gram	g	rate constant	k
Celsius temperature	°C	hour	h	reaction quotient	Q
centi– prefix	c	joule	J	second	s
coulomb	C	kelvin	K	speed of light	c
density	d	kilo– prefix	k	temperature, K	T
electromotive force	E	liter	L	time	t
energy of activation	E_a	measure of pressure	mm Hg	vapor pressure	VP
enthalpy	H	milli– prefix	m	volt	V
entropy	S	molal	m	volume	V
equilibrium constant	K	molar	M	year	y

CONSTANTS

$R = 8.314 \text{ J mol}^{-1} \text{ K}^{-1}$

$R = 0.08314 \text{ L bar mol}^{-1} \text{ K}^{-1}$

$F = 96{,}500 \text{ C mol}^{-1}$

$F = 96{,}500 \text{ J V}^{-1} \text{ mol}^{-1}$

$N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$

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

$c = 2.998 \times 10^{8} \text{ m s}^{-1}$

$0 \text{ °C} = 273.15 \text{ K}$

1 atm = 1.013 bar = 760 mm Hg

Specific heat capacity of H_2O = $4.184 \text{ J g}^{-1} \text{ K}^{-1}$

EQUATIONS

$$E = E^{o} - \frac{RT}{nF} \ln Q$$

$$\ln K = \left(\frac{-\Delta H^{o}}{R} \right) \left(\frac{1}{T} \right) + \text{constant}$$

$$\ln \left(\frac{k_2}{k_1} \right) = \frac{E_a}{R} \left(\frac{1}{T_1} - \frac{1}{T_2} \right)$$

PERIODIC TABLE OF THE ELEMENTS

1 1A																	18 8A
1 **H** 1.008	2 **2A**											13 **3A**	14 **4A**	15 **5A**	16 **6A**	17 **7A**	2 **He** 4.003
3 **Li** 6.941	4 **Be** 9.012											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.31	3 **3B**	4 **4B**	5 **5B**	6 **6B**	7 **7B**	8 **8B**	9 **8B**	10 **8B**	11 **1B**	12 **2B**	13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.88	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.39	31 **Ga** 69.72	32 **Ge** 72.61	33 **As** 74.92	34 **Se** 78.97	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.95	43 **Tc** (98)	44 **Ru** 101.1	45 **Rh** 102.9	46 **Pd** 106.4	47 **Ag** 107.9	48 **Cd** 112.4	49 **In** 114.8	50 **Sn** 118.7	51 **Sb** 121.8	52 **Te** 127.6	53 **I** 126.9	54 **Xe** 131.3
55 **Cs** 132.9	56 **Ba** 137.3	57 **La** 138.9	72 **Hf** 178.5	73 **Ta** 180.9	74 **W** 183.8	75 **Re** 186.2	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.1	79 **Au** 197.0	80 **Hg** 200.6	81 **Tl** 204.4	82 **Pb** 207.2	83 **Bi** 209.0	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89 **Ac** (227)	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (263)	107 **Bh** (262)	108 **Hs** (265)	109 **Mt** (266)	110 **Ds** (281)	111 **Rg** (272)	112 **Cn** (285)	113 **Nh** (286)	114 **Fl** (289)	115 **Mc** (289)	116 **Lv** (293)	117 **Ts** (294)	118 **Og** (294)

58 **Ce** 140.1	59 **Pr** 140.9	60 **Nd** 144.2	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 152.0	64 **Gd** 157.3	65 **Tb** 158.9	66 **Dy** 162.5	67 **Ho** 164.9	68 **Er** 167.3	69 **Tm** 168.9	70 **Yb** 173.0	71 **Lu** 175.0
90 **Th** 232.0	91 **Pa** 231.0	92 **U** 238.0	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** **(262)**

DIRECTIONS

- When you have selected your answer to each question, blacken the corresponding space on the answer sheet using a dark pencil or pen. Make a heavy, full mark, but no stray marks. If you decide to change an answer, erase the unwanted mark very carefully.
- There is only one correct answer to each question. Any questions for which more than one response has been blackened **will not be counted**.
- Your score is based solely on the number of questions you answer correctly. **It is to your advantage to answer every question.**

1. Adipic acid, $C_6H_{10}O_4$ (M = 146.15), is prepared by the partial oxidation of cyclohexane, C_6H_{12} (M = 84.16), according to the following balanced reaction:

$$2\ C_6H_{12}(l) + 5\ O_2(g) \rightarrow 2\ C_6H_{10}O_4(s) + 2\ H_2O(l)$$

A sample of 25.0 g cyclohexane reacts with excess oxygen to give 33.5 g of adipic acid. What is the yield of the reaction?

(A) 38.6% **(B)** 39.9% **(C)** 48.9% **(D)** 77.2%

2. When a 1.000 g sample of $CoCO_3$ is heated under vacuum, it forms 0.630 g of an oxide of cobalt. When this sample is exposed to air, it forms a second oxide of cobalt, and attains a mass of 0.675 g. What are the formulas of the first and second oxide of cobalt, respectively?

(A) CoO, Co_2O_3 **(B)** CoO, Co_3O_4

(C) Co_2O_3, Co_3O_4 **(D)** Co_3O_4, Co_2O_3

3. A white, crystalline solid contains only the elements C, H, N, and O. Complete combustion of a 1.000 g sample gives 1.831 g CO_2 (M = 44.01) and 0.750 g H_2O (M = 18.02). What is its molecular formula?

(A) C_3H_6NO **(B)** $C_4H_4NO_2$

(C) $C_6H_{12}N_2O_2$ **(D)** $C_8H_8N_2O_4$

4. 10.0 mL of 0.100 M $CaCl_2$ is mixed with 10.0 mL of 0.050 M $AgNO_3$. What is the concentration of chloride ion in the final solution?

(A) 0.025 M **(B)** 0.075 M

(C) 0.100 M **(D)** 0.200 M

5. A metal sulfate decahydrate contains 31.48% water by mass. What is the metal?

(A) Na **(B)** Cr **(C)** Rh **(D)** Au

6. Which procedures will result in a 1.000 m solution of sodium acetate?

I. Adding 1.000 mol sodium acetate trihydrate to a 1.000-liter volumetric flask, adding deionized water to dissolve, and then filling to the mark

II. Mixing 1.000 mol sodium hydroxide with 1.000 mol acetic acid and 1.000 kg deionized water

(A) I only **(B)** II only

(C) Both I and II **(D)** Neither I nor II

7. A white solid is either sodium carbonate or sodium sulfate. Which procedure will best distinguish between the two?

(A) Adding 1.0 M hydrochloric acid to the two solids

(B) Adding 1.0 M barium nitrate to solutions made from the two solids

(C) Adding 1.0 M potassium bromide to solutions made from the two solids

(D) Measuring the conductivity of solutions made from the two solids

8. A colorimeter contains four LEDs. Which one would give the best results in determining the concentration of a substance that forms a blue solution?

(A) Violet (430 nm) **(B)** Blue (470 nm)

(C) Green (565 nm) **(D)** Red (635 nm)

9. A student wishes to determine the number of colored dyes present in the ink of a black felt-tip marker. Which technique would be most suitable?

(A) Paper chromatography

(B) Gas chromatography

(C) Nuclear magnetic resonance spectroscopy

(D) Ultraviolet-visible spectroscopy

10. A solution of a metal chloride gives a red flame test. Which metal is it?

(A) Na **(B)** K **(C)** Cu **(D)** Sr

11. Exposure of an aqueous solution of which ion to oxygen gas will cause a color change?

(A) Cr^{2+} **(B)** $Cr_2O_7^{2-}$

(C) $Fe(C_2O_4)_3^{3-}$ **(D)** $Fe(CN)_6^{3-}$

12. A student determines the rate constant for the reaction of iodide with hydrogen peroxide in strongly acidic solution (Rate = $k[H_2O_2][I^-][H^+]$) by mixing 1.00 mL aliquots of solutions of known concentrations of potassium iodide, ascorbic acid, and hydrochloric acid with four drops of starch solution, then adding 1.00 mL of hydrogen peroxide solution and recording the time required for the solution to turn blue. A student uses half the stipulated amount of one of the solutions but does not realize it. Underdosing of which solutions will cause the value of the rate constant to be too high?

I. Hydrochloric acid II. Ascorbic acid

(A) I only **(B)** II only

(C) Both I and II **(D)** Neither I nor II

13. 8.82 g of Br_2 is placed in an evacuated 1.00 L flask and heated to 58.8 °C, the normal boiling point of bromine. How much liquid bromine remains at equilibrium?

(A) 0.00 g **(B)** 2.95 g

(C) 3.63 g **(D)** 5.87 g

14. The normal boiling point of dichloromethane (CH_2Cl_2) is 40 °C, while the normal boiling point of chloroform ($CHCl_3$) is 61 °C. An increase in which type of intermolecular forces is most responsible for this increase in boiling point?

(A) London dispersion forces

(B) Dipole-dipole interactions

(C) Ion-dipole interactions

(D) Hydrogen bonding

15. Which has the highest melting point?

(A) K_2O **(B)** CaO

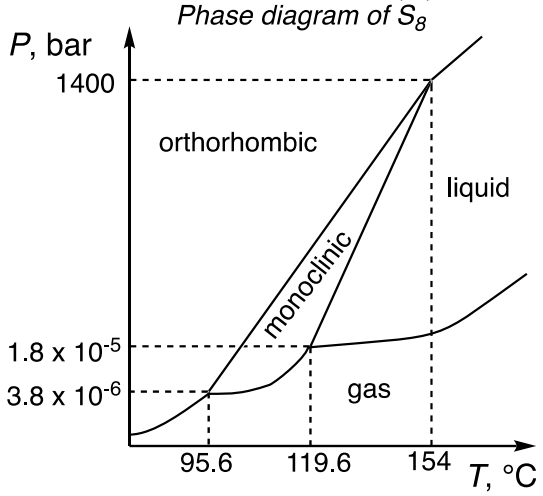
(C) Cu_2O **(D)** GeO_2

16. Platinum crystallizes in a face-centered cubic unit cell. The atomic radius of platinum is 139 pm. What is the density of solid platinum?

(A) 5.33 g cm^{-3} **(B)** 7.54 g cm^{-3}

(C) 18.6 g cm^{-3} **(D)** 21.3 g cm^{-3}

17. Which statement about elemental sulfur (S_8) is correct?



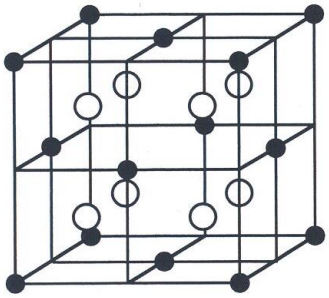
(A) Monoclinic sulfur sublimes at 1 bar pressure.

(B) Monoclinic sulfur is denser than orthorhombic sulfur.

(C) Monoclinic sulfur is not thermodynamically stable above 119.6 °C.

(D) Monoclinic sulfur transforms exothermically into orthorhombic sulfur.

18. The unit cell of solid fluorite, CaF_2, is shown below. Which statement about fluorite is correct?



(A) Fluorite has a primitive cubic unit cell.

(B) The larger open circles represent the Ca atoms and the smaller filled circles represent the F atoms.

(C) The larger open circles' nearest neighbors consist of six of the other larger open circles arranged in an octahedron.

(D) The smaller closed circles' nearest neighbors consist of eight of the larger open circles arranged in a cube.

Questions 19 and 20 use the following thermodynamic data:

Substance	$\Delta H°_f$, kJ mol^{-1}	$\Delta G°_f$ (298 K), kJ mol^{-1}	$S°$, J mol^{-1} K^{-1}
$Cl_2(g)$	0	0	223.1
$PCl_3(g)$	–287.0	–267.8	311.8
$PCl_5(g)$	–374.9		364.4

19. What is K_p for the gas-phase reaction of PCl_3 with Cl_2 at 450 K?

$$PCl_3(g) + Cl_2(g) \rightarrow PCl_5(g) \qquad K_p = ???$$

(A) 19.8 **(B)** 2.02×10^4

(C) 3.17×10^6 **(D)** 1.60×10^{10}

20. What is $\Delta G°_f$ of PCl_5 at 298 K?

(A) –266.3 kJ mol^{-1} **(B)** –304.9 kJ mol^{-1}

(C) –355.7 kJ mol^{-1} **(D)** –374.9 kJ mol^{-1}

21. Which quantities are independent of the path taken, given the same initial and final state?

I. The work done by the reaction of a mole of gaseous propane with excess gaseous oxygen to form carbon dioxide and water vapor at a constant pressure of 1.0 atm

II. The heat absorbed by the expansion of a mole of carbon dioxide from a pressure of 4.0 atm to a pressure of 1.0 atm

(A) I only **(B)** II only

(C) Both I and II **(D)** Neither I nor II

22. The standard enthalpy of combustion of propene, $C_3H_6(g)$, is –1926 kJ mol^{-1}. Given the tabulated bond dissociation enthalpies (BDEs), what is the bond dissociation enthalpy of a C=C bond?

$$C_3H_6(g) + 4.5\ O_2(g) \rightarrow 3\ CO_2(g) + 3\ H_2O(g)$$
$$\Delta H°_{rxn} = -1926 \text{ kJ mol}^{-1}$$

Bond	BDE, kJ mol^{-1}	Bond	BDE, kJ mol^{-1}
C–H	415	C–O	350
O–H	464	C=O	804
O–O	140	C–C	345
O=O	498	C=C	**???**

(A) 476 kJ mol^{-1} **(B)** 606 kJ mol^{-1}

(C) 690 kJ mol^{-1} **(D)** 715 kJ mol^{-1}

23. Which reaction has $\Delta S° > 0$?

(A) $Ga(l) \rightarrow Ga(s)$

(B) $C_{60}(s) \rightarrow 60\ C(s, \text{graphite})$

(C) $CaCO_3(s) \rightarrow Ca^{2+}(aq) + CO_3^{2-}(aq)$

(D) $NH_4^+(aq) + OH^-(aq) \rightarrow NH_3(aq) + H_2O(l)$

24. A sample of 10.0 g ammonium nitrate (M = 80.1) is added to 100.0 g water in a well-insulated container. The solid and liquid are both initially at 22.0 °C, and the temperature of the solution after the ammonium nitrate has dissolved is 15.1 °C. What is the enthalpy of solution of ammonium nitrate? You may assume that the specific heat capacity of the solution is the same as that of pure water, 4.184 J g^{-1} K^{-1}.

$$NH_4NO_3(s) \rightarrow NH_4^+(aq) + NO_3^-(aq) \quad \Delta H°_{soln} = ???$$

(A) –3.2 kJ mol^{-1} **(B)** 3.2 kJ mol^{-1}

(C) 5.5 kJ mol^{-1} **(D)** 25 kJ mol^{-1}

25. The rate law for the oxidation of iodide to iodine by hydrogen peroxide in weakly acidic solution is studied by allowing the reaction to proceed in the presence of a fixed amount of sodium thiosulfate (which rapidly reduces iodine to iodide) and measuring the time t to the first appearance of a blue color due to the starch-iodine complex. The following data are obtained on solutions made with the indicated volumes of reactant solutions and enough water to give a total volume of 10.0 mL. What are the reaction orders in H_2O_2, I^-, and H^+?

$$H_2O_2(aq) + 2\ I^-(aq) + 2\ H^+(aq) \rightarrow I_2(aq) + 2\ H_2O(l)$$

Run	CH_3COOH, mL	NaOH, mL	KI, mL	H_2O_2, mL	t, s
1	2.0	1.0	2.0	2.0	68.2
2	4.0	1.0	2.0	2.0	68.9
3	2.0	1.0	4.0	2.0	33.2
4	2.0	1.0	2.0	4.0	32.9

	Order in H_2O_2	Order in I^-	Order in H^+
(A)	0	1	1
(B)	1	1	0
(C)	1	1	1
(D)	1	2	2

26. The oxidation of cyanide ion to cyanate ion by hypoiodite is proposed to take place by the following mechanism. If the pH is greater than either the pK_a of HOI or of HCN, what is the rate law?

$$OI^- + H^+ \rightleftharpoons HOI \qquad \textit{fast}$$
$$CN^- + HOI \rightleftharpoons ICN + OH^- \qquad \textit{fast, unfavorable}$$
$$ICN + OH^- \rightarrow HOCN + I^- \qquad \textit{slow}$$
$$HOCN + OH^- \rightarrow OCN^- + H_2O \qquad \textit{fast}$$

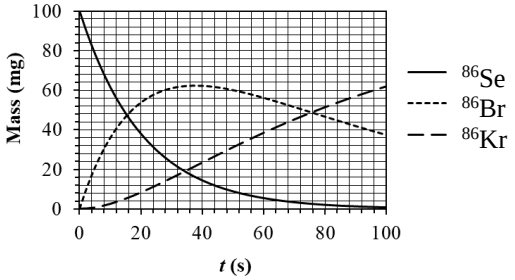
(A) Rate = $k[CN^-][OI^-]$

(B) Rate = $k[CN^-][OI^-][H^+]$

(C) Rate = $k[CN^-][OI^-][OH^-]$

(D) Rate = $k[CN^-][OI^-][OH^-]^2$

27. ^{86}Se undergoes β^- decay to ^{86}Br with a half-life of 14.3 s. ^{86}Br then undergoes β^- decay to ^{86}Kr, a stable product. 0.100 g ^{86}Se was placed in a sealed vessel, and the masses of all three species were recorded over time as shown below. What is the half-life of ^{86}Br?



(A) 55 s

(B) 70. s

(C) 85 s

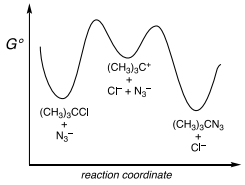
(D) It cannot be determined from the information given.

28. A reactant **R** undergoes independent, irreversible first-order reactions to form two products, **X** and **Y**. The reaction to form **X** has an activation energy that is 20.0 kJ mol^{-1} higher than the activation energy of the reaction to form **Y**. At 50.0 °C, the yield of **X** is 50.0%. What is the yield of **X** at 70.0 °C?

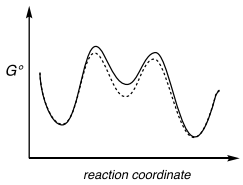
(A) 32.5% **(B)** 39.4%

(C) 60.6% **(D)** 77.0%

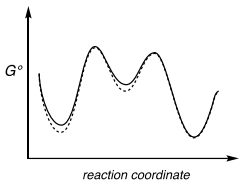
29. The reaction of *tert*-butyl chloride, $(CH_3)_3CCl$, with azide ion takes place via the carbocation intermediate $(CH_3)_3C^+$ as shown on the reaction coordinate diagram below. The reaction proceeds faster in solvents of high polarity (such as water) than in less polar solvents (such as ethanol). The solid line represents the reaction coordinate in 80% water/20% ethanol. Which dashed line best represents the reaction coordinate in 20% water/80% ethanol?



(A)



(B)



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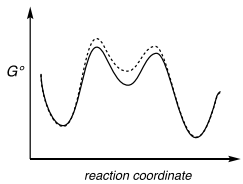
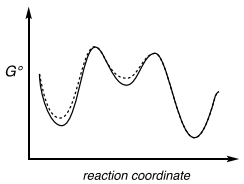


(D)



30. The reaction of hydroxide ion with methyl iodide takes place in a single elementary step. The reaction is faster when the carbon-12 isotope is present than when carbon-14 is present ($k_{^{12}C}/k_{^{14}C} = 1.088$). What is the principal reason for the difference in rates?

$$CH_3I + OH^- \rightarrow CH_3OH + I^-$$

(A) The carbon nucleus is less stable in $^{14}CH_3I$.

(B) The vibrational energies are lower in $^{14}CH_3I$.

(C) The molecule is less sterically hindered in $^{14}CH_3I$.

(D) The carbon-iodine bond dissociation enthalpy is smaller in $^{14}CH_3I$.

31. Given the equilibrium constants:

$$Ag^+(aq) + Cl^-(aq) \rightleftharpoons AgCl(s) \qquad K_1$$

$$2\ Ag^+(aq) + CrO_4^{2-}(aq) \rightleftharpoons Ag_2CrO_4(s) \qquad K_2$$

What is the equilibrium constant for the following reaction?

$$2\ AgCl(s) + CrO_4^{2-}(aq) \rightleftharpoons Ag_2CrO_4(s) + 2\ Cl^-(aq)$$

(A) $\dfrac{K_1}{K_2}$ **(B)** $\dfrac{K_1}{K_2^2}$

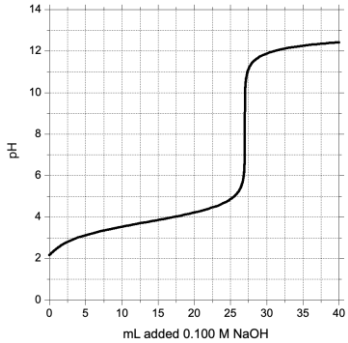
(C) $\dfrac{K_2^2}{K_1}$ **(D)** $\dfrac{K_2}{K_1^2}$

32. A solution of allylamine, $C_3H_5NH_2$, is 3.61% ionized and has a pH = 11.12. What is the pK_a of the allylammonium ion, $C_3H_5NH_3^+$?

(A) 3.77 **(B)** 9.69

(C) 10.23 **(D)** 12.56

33. A solution of formic acid, HCOOH, is titrated with 0.1000 M NaOH and the data below are obtained.



At the point where 15.0 mL of NaOH have been added, what are the relative concentrations of HCOOH, $HCOO^-$, and Na^+?

(A) $[HCOO^-] > [Na^+] > [HCOOH]$

(B) $[Na^+] > [HCOO^-] > [HCOOH]$

(C) $[HCOOH] > [Na^+] > [HCOO^-]$

(D) $[HCOOH] > [HCOO^-] > [Na^+]$

34. At high temperatures, solid calcium carbonate (M = 100.09) is in equilibrium with solid calcium oxide and carbon dioxide gas.

$$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$$

Into an evacuated 30.0 L chamber maintained at 1200 K is introduced 3.0 g solid $CaCO_3$. After the system is allowed sufficient time to equilibrate, the pressure is 0.10 bar. What will the total pressure be at equilibrium if an additional 3.0 g $CaCO_3$ is added to the chamber?

(A) 0.10 bar

(B) 0.14 bar

(C) 0.20 bar

(D) It cannot be determined from the information given.

35. At a certain temperature, the reaction below has K_p = 3.75. Initially, all four gases are in a rigid container, each with a partial pressure of 0.60 bar. What will the partial pressure of $SO_2(g)$ be once the system achieves equilibrium?

$$SO_2(g) + NO_2(g) \rightleftharpoons SO_3(g) + NO(g) \qquad K_p = 3.75$$

(A) 0.19 bar **(B)** 0.25 bar

(C) 0.35 bar **(D)** 0.41 bar

36. Cadmium iodate, $Cd(IO_3)_2$, has $K_{sp} = 2.5 \times 10^{-8}$. Iodide ion forms a complex ion CdI_4^{2-} with $K_f = 1.3 \times 10^6$. What is the minimum amount of iodide ion that would need to be added to dissolve 0.100 mol $Cd(IO_3)_2$ in 1.00 L of solution?

(A) 0.40 mol **(B)** 0.59 mol

(C) 0.62 mol **(D)** 0.99 mol

37. What is the average oxidation state of molybdenum in the phosphomolybdate ion $PMo_{12}O_{40}^{3-}$?

(A) +6.00 **(B)** +6.17

(C) +6.42 **(D)** +6.50

38. For a voltaic cell $Zn|Zn^{+2}(1.0\ M)\|Ag^+(1.0\ M)|Ag$, which is correct?

(A) The zinc electrode is the anode.

(B) The concentration of Ag^+ increases as the cell operates.

(C) The mass of the zinc electrode increases as the cell operates.

(D) Electrons flow through the external circuit from the silver electrode to the zinc electrode.

39. A 1.000 g sample of a gold compound is electrolyzed exhaustively to deposit all the gold present on the cathode. This requires 4700 s of electrolysis with a constant current of 0.130 A. What is the compound?

(A) $LiAuCl_2$ (M = 274.8) **(B)** $LiAuCl_4$ (M = 345.7)

(C) $CsAuCl_2$ (M = 400.8) **(D)** $CsAuCl_4$ (M = 471.7)

40. Which factors contribute to inefficiencies in silicon-based photovoltaic devices in harvesting the energy of light from the sun?

I. Photons with energies less than the band gap of silicon are not absorbed by the device.

II. Energy is lost as heat when photons with energies greater than the band gap of silicon are absorbed by the device.

(A) I only **(B)** II only

(C) Both I and II **(D)** Neither I nor II

41. The standard reduction potential $E°$ for the reduction of permanganate to manganese(II) in acidic solution is 1.51 V at 298 K. What is the value of E for the half-reaction at 298 K at the given concentrations?

$$MnO_4^-(aq, 0.0100\ M) + 8\ H^+(aq, 0.200\ M) + 5\ e^- \rightarrow Mn^{2+}(aq, 0.0200\ M) + 4\ H_2O(l)$$

(A) 1.16 V **(B)** 1.44 V

(C) 1.50 V **(D)** 1.51 V

42. What is the standard reduction potential $E°$ for the reduction of hydrogen selenate to hydrogen selenide?

$$HSeO_4^-(aq) + 9\ H^+(aq) + 8\ e^- \rightarrow H_2Se(aq) + 4\ H_2O(l)$$
$$E° = ???$$

Half-reaction	$E°$, V
$HSeO_4^-(aq) + 3\ H^+(aq) + 2\ e^- \rightarrow H_2SeO_3(aq) + H_2O(l)$	1.15
$H_2SeO_3(aq) + 4\ H^+(aq) + 4\ e^- \rightarrow Se(s) + 3\ H_2O(l)$	0.74
$Se(s) + 2\ H^+(aq) + 2\ e^- \rightarrow H_2Se(aq)$	–0.11

(A) 0.30 V **(B)** 0.63 V

(C) 0.71 V **(D)** 1.78 V

43. In what group is the atom with the following ionization energies?

IE_1, kJ mol^{-1}	IE_2, kJ mol^{-1}	IE_3, kJ mol^{-1}	IE_4, kJ mol^{-1}
738	1450	7730	10500

(A) Group 1 **(B)** Group 2

(C) Group 3 **(D)** Group 13

44. In a ground-state gas-phase Sb atom, how many electrons have the quantum numbers $n = 5$, $l = 1$, and $m_l = 0$?

(A) 1 **(B)** 2 **(C)** 3 **(D)** 6

45. Two atomic orbitals have the same number of radial nodes and the same magnetic quantum number m_l. Which other quantum numbers must these orbitals have in common?

I. The principal quantum number n

II. The angular momentum quantum number l

(A) I only **(B)** II only

(C) Both I and II **(D)** Neither I nor II

46. The *p* block elements in the third row of the periodic table (Al–Cl) release more energy when an electron is added to the gas phase atoms than do their lighter congeners (B–F). Which is the best explanation for this phenomenon?

(A) The heavier elements have more protons in their nuclei and have a greater electrostatic attraction to the electrons.

(B) The heavier elements have more neutrons in their nuclei and have a greater gravitational attraction to the electrons.

(C) The 3*p* orbitals are larger and have less electron-electron repulsion.

(D) The 3*p* orbitals have more nodes and accept electrons at lower energy.

47. Which elements are closest in electronegativity?

(A) C and Al **(B)** O and Cl

(C) N and P **(D)** P and As

48. By what mode does ^{212}Po undergo radioactive decay?

(A) α decay **(B)** β^- decay

(C) Positron emission **(D)** Spontaneous fission

49. Which species has a square planar geometry?

(A) BH_4^- **(B)** SF_4

(C) $ZnCl_4^{2-}$ **(D)** $AuCl_4^-$

50. Which isomer of CNO^- is most stable?

(A) Linear CNO^- **(B)** Linear NCO^-

(C) Linear CON^- **(D)** Cyclic CNO^-

51. How many stereoisomers of octahedral $Co(en)_2Cl_2^+$ are possible (en = ethylenediamine, $H_2NCH_2CH_2NH_2$)?

(A) 1 **(B)** 2 **(C)** 3 **(D)** 4

52. Which statement most accurately describes the bonding in the acetyl cation, CH_3CO^+?

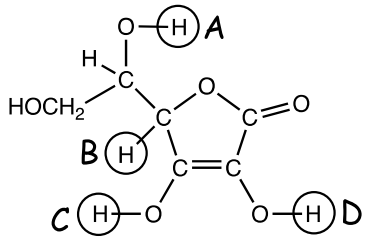
(A) The species has five σ bonds and two π bonds.

(B) The carbon-oxygen bond has a bond order of 2.

(C) The carbon bonded to oxygen has a bent geometry.

(D) The most significant resonance structure has a formal positive charge on carbon.

53. Which of the labeled protons in ascorbic acid is the most acidic?



(A) A **(B)** B **(C)** C **(D)** D

54. Which statements about the gas-phase molecule NF are correct?

I. It has two unpaired electrons in its lowest-energy state.

II. It has a smaller ionization energy than atomic N.

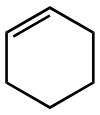
(A) I only **(B)** II only

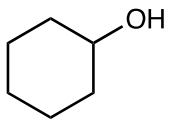
(C) Both I and II **(D)** Neither I nor II

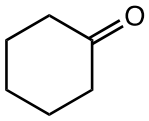
55. How many stable isomers of C_4H_8 are there?

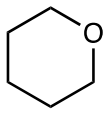
(A) 3 **(B)** 4 **(C)** 5 **(D)** 6

56. Which compound absorbs infrared radiation strongly at 1715 cm^{-1}?

(A) 

(B) 

(C) 

(D) 

57. An unknown alcohol is thought to be either 2-pentanol or 3-pentanol. Which instrumental method would most effectively distinguish between these two possibilities?

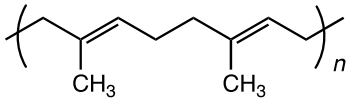
(A) Mass spectrometry

(B) Infrared spectroscopy

(C) Ultraviolet spectroscopy

(D) ^{13}C NMR spectroscopy

58. The structure of gutta percha, a naturally occurring polymer, is shown below. Which compound is the monomeric building block of gutta percha?



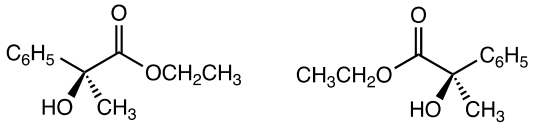
(A) 2-methyl-1-butene

(B) 3-methyl-1-butene

(C) 2-methyl-1,3-butadiene

(D) 3-methyl-1,2-butadiene

59. In the presence of which catalysts will the two esters below hydrolyze at different rates from each other?



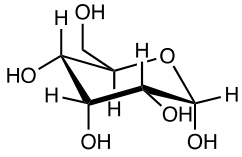
I. H_2SO_4 II. Pig liver esterase

(A) I only **(B)** II only

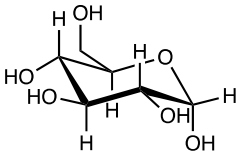
(C) Both I and II **(D)** Neither I nor II

60. Which structure does not readily produce D-glucose when dissolved in acidic solution?

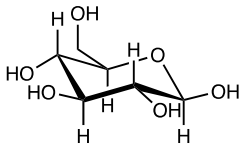
(A)



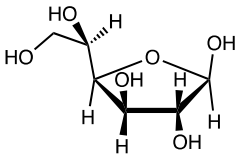
(B)



(C)



(D)



END OF TEST

Olympiad 2025

USNCO National Exam

KEY

Number	Answer	Correct %		Number	Answer	Correct %
1.	D	93%		31.	D	91%
2.	B	54%		32.	B	48%
3.	C	40%		33.	A	25%
4.	B	54%		34.	D	14%
5.	B	42%		35.	D	57%
6.	D	17%		36.	D	16%
7.	A	48%		37.	A	42%
8.	D	71%		38.	A	77%
9.	A	91%		39.	D	47%
10.	D	71%		40.	C	53%
11.	A	47%		41.	B	54%
12.	B	25%		42.	B	40%
13.	B	43%		43.	B	74%
14.	A	43%		44.	A	51%
15.	B	37%		45.	D	35%
16.	D	35%		46.	C	50%
17.	D	70%		47.	D	27%
18.	D	39%		48.	A	51%
19.	A	41%		49.	D	32%
20.	B	43%		50.	B	60%
21.	A	27%		51.	C	43%
22.	B	59%		52.	A	37%
23.	D	11%		53.	C	20%
24.	D	53%		54.	C	41%
25.	B	73%		55.	D	11%
26.	B	62%		56.	C	51%
27.	A	32%		57.	D	39%
28.	C	58%		58.	C	39%
29.	C	49%		59.	B	40%
30.	B	36%		60.	A	18%