



ACS USNCO
U.S. National Chemistry Olympiad

2023 U.S. NATIONAL CHEMISTRY OLYMPIAD

NEW LOCAL SECTION EXAM

Prepared by the American Chemical Society Chemistry Olympiad Examinations Task Force

OLYMPIAD EXAMINATIONS TASK FORCE

Seth N. Brown, **Chair**, *University of Notre Dame*, Notre Dame, IN

Monica Marie Arroyo, *Pontifical Catholic University of Puerto Rico*, Ponce, PR

James Ayers, *Colorado Mesa University*, Grand Junction, CO

Jerry Bell, *Simmons University*, Boston, MA (retired)

Jesse Bernstein, *Miami Country Day School*, Miami, FL (retired)

Alan D. Crosby, *Newton South HS*, Newton, MA (retired)

Mark DeCamp, *University of Michigan*, Dearborn, MI (retired)

James Dohm, *ExxonMobil*, Houston, TX

Xu Duan, *Holton-Arms School*, Bethesda, MD

Kimberly Gardner, *United States Air Force Academy*, CO

Paul Groves, *South Pasadena HS*, South Pasadena, CA (retired)

John Kotz, *State University of New York*, Oneonta, NY (retired)

Sarah Leite, *Hopkins School*, New Haven, CT

Michael A. Morgan, *Francisco Bravo Medical Magnet HS*, Los Angeles, CA

Jane Nagurney, *Scranton Preparatory School*, Scranton, PA (retired)

DIRECTIONS TO THE EXAMINER

This test is designed to be taken with an answer sheet on which the student records his or her responses. All answers are to be marked on that sheet, not written in the booklet. Each student should be provided with an answer sheet and scratch paper, both of which must be turned in with the test booklet at the end of the examination. Local Sections may use an answer sheet of their own choice.

The full examination consists of 60 multiple-choice questions representing a fairly wide range of difficulty. A periodic table and other useful information are provided on page two of this exam booklet for student reference.

Only non-programmable calculators are to be used on the ACS Local Section exam. The use of a programmable calculator, cell phone, or any other device that can access the internet or make copies or photographs during the exam is grounds for disqualification.

Suggested Time: 60 questions—110 minutes

DIRECTIONS TO THE EXAMINEE

DO NOT TURN THE PAGE UNTIL DIRECTED TO DO SO.

This is a multiple-choice examination with four choices for each question. There is only one correct or best answer to each question. When you select your choice, blacken the corresponding space on the answer sheet with your pencil. Make a heavy full mark, but no stray marks. If you decide to change your answer, be certain to erase your original answer completely.

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

CONSTANTS
$R = 8.314 \text{ J mol}^{-1} \text{ K}^{-1}$
$R = 0.08314 \text{ L bar mol}^{-1} \text{ K}^{-1}$
$F = 96,500 \text{ C mol}^{-1}$
$F = 96,500 \text{ J V}^{-1} \text{ mol}^{-1}$
$N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$
$h = 6.626 \times 10^{-34} \text{ J s}$
$c = 2.998 \times 10^8 \text{ m s}^{-1}$
$0 \text{ }^\circ\text{C} = 273.15 \text{ K}$
$1 \text{ atm} = 1.013 \text{ bar} = 760 \text{ mm Hg}$
Specific heat capacity of $\text{H}_2\text{O} = 4.184 \text{ J g}^{-1} \text{ K}^{-1}$

EQUATIONS		
$E = E^\circ - \frac{RT}{nF} \ln Q$	$\ln K = \left(\frac{-\Delta H^\circ}{R} \right) \left(\frac{1}{T} \right) + \text{constant}$	$\ln \left(\frac{k_2}{k_1} \right) = \frac{E_a}{R} \left(\frac{1}{T_1} - \frac{1}{T_2} \right)$

PERIODIC TABLE OF THE ELEMENTS

1	PERIODIC TABLE OF THE ELEMENTS																18				
1A															3A	4A	5A	6A	7A	8A	
1 H 1.008	2 He 4.003															13 B 10.81	14 C 12.01	15 N 14.01	16 O 16.00	17 F 19.00	18 Ne 20.18
3 Li 6.941	4 Be 9.012															13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
11 Na 22.99	12 Mg 24.31	3 B	4 C	5 N	6 O	7 F	8 Ne	9 Na	10 Mg	11 Al	12 Si	13 P	14 S	15 Cl	16 Ar						
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)				

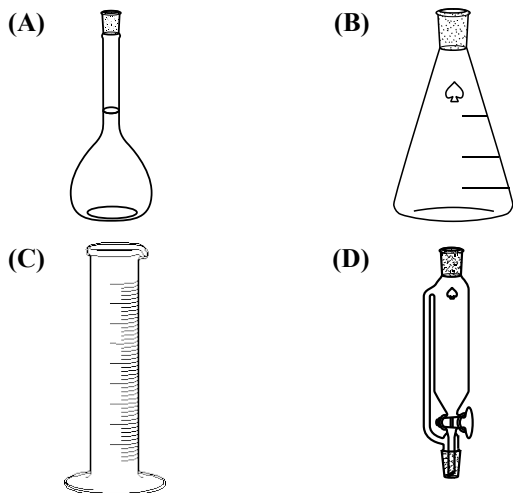
58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 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 soft, #2 pencil. 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. A 1.00-g sample of which compound will produce the greatest amount of carbon dioxide after complete combustion with excess oxygen?
(A) CH₄ (B) C₃H₆ (C) C₆H₁₄ (D) C₈H₁₈
2. Rhenium (Re) consists of two stable isotopes, ¹⁸⁵Re and ¹⁸⁷Re. The average atomic mass of Re is 186.2 amu. What is the mole percent of ¹⁸⁵Re in rhenium?
(A) 40% (B) 50%
(C) 60% (D) 62%
3. A 10.00 g sample of a soluble barium salt is treated with an excess of sodium sulfate to precipitate 8.93 g BaSO₄ (*M* = 233.4). Which barium salt is it?
(A) BaCl₂ (*M* = 208.2)
(B) Ba(O₂CH)₂ (*M* = 227.3)
(C) Ba(NO₃)₂ (*M* = 261.3)
(D) BaBr₂ (*M* = 297.1)
4. How much Sr(OH)₂ • 8 H₂O (*M* = 265.76) is needed to prepare 150.0 mL of solution in which [OH⁻] = 0.100 M?
(A) 1.99 g (B) 3.98 g
(C) 5.98 g (D) 7.98 g
5. Which procedure produces a 0.2 M solution of Na₂SO₄?
(A) Mixing 500 mL of 0.4 M NaOH with 500 mL of 0.2 M Na₂SO₄
(B) Mixing 300 mL of 1.2 M NaOH with 600 mL of 0.3 M H₂SO₄
(C) Dissolving 0.2 mol solid Na₂SO₄ in 500 mL water
(D) Diluting 400 mL of 0.3 M Na₂SO₄ to a final volume of 1.0 L
6. 10.0 g of an alkali metal chloride salt is dissolved in 90.0 g H₂O. This solution has a vapor pressure that is 3.2% lower than that of pure water at the same temperature. What is the salt?
(A) LiCl (B) NaCl (C) KCl (D) RbCl
7. What is the mobile phase in thin layer chromatography?
(A) A liquid solvent such as isopropanol
(B) A smooth solid surface such as a glass plate
(C) A coating on a solid surface such as silica gel
(D) A chamber such as a glass jar
8. Which is the strongest acid?
(A) HBrO
(B) HBrO₂
(C) HBrO₃
(D) HBrO₄
9. Which compound, when dissolved in water, will increase the electrical conductivity of water the least?
(A) SO₃ (B) H₂O₂
(C) MgCl₂ (D) NH₄Br
10. Which metal reacts most vigorously with water?
(A) Aluminum (Al) (B) Zinc (Zn)
(C) Cesium (Cs) (D) Mercury (Hg)
11. A student determines the acetic acid concentration of a sample of distilled vinegar by measuring 25.00 mL of the vinegar with a volumetric pipet, then titrating the sample with standardized sodium hydroxide solution using phenolphthalein as an indicator. Which error will give an acetic acid content for the vinegar that is too high?
(A) The titration flask has some distilled water in it when the acetic acid sample is added to it.
(B) The volumetric pipet has some distilled water in it when the acetic acid sample is measured with it.
(C) Some of the vinegar remains in the volumetric pipet rather than being dispensed into the titration flask.
(D) The endpoint is recorded when the solution turns dark red instead of faint pink.

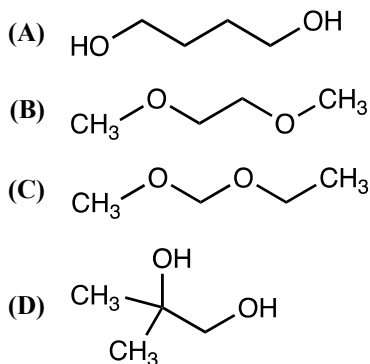
12. Which 50-mL container would be most suitable for measuring and dispensing 37 mL of an aqueous solution?



13. What is the partial pressure of Ar in a gaseous mixture of 3.25 g Ar and 2.28 g Kr in a 5.00 L container at 15.0 °C?

- (A) 0.0572 bar (B) 0.390 bar
(C) 0.412 bar (D) 0.447 bar

14. Which isomer of C₄H₁₀O₂ has the highest normal boiling point?

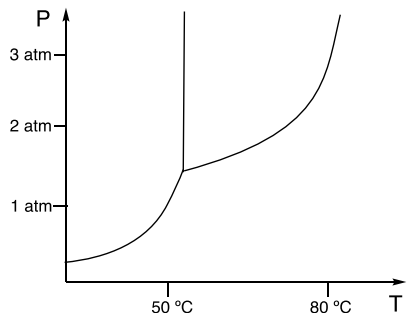


15. Which statements about the behavior of gaseous H₂ molecules in a container at 1 atm and 298 K are correct?

- I. All H₂ molecules are moving at the same speed.
 II. The H₂ molecules are colliding more frequently with the walls of the container than they would in the same container at 398 K.

- (A) I only (B) II only
(C) Both I and II (D) Neither I nor II

16. A portion of the phase diagram of uranium hexafluoride (UF₆) is shown below.



Which statements are correct?

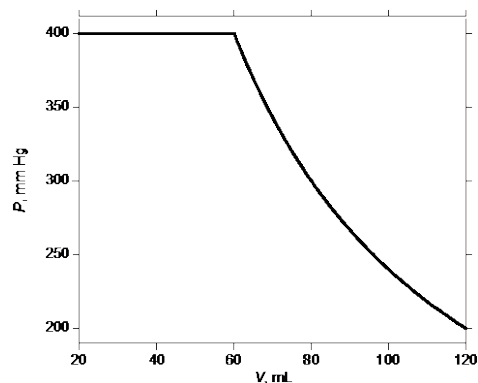
- I. UF₆ sublimes, rather than melts, at 1 atm pressure.
 II. At 2 atm and 45 °C, only solid UF₆ is present at equilibrium.

- (A) I only (B) II only
(C) Both I and II (D) Neither I nor II

17. How many nearest neighbors does each silicon atom have in a crystal of Si?

- (A) 4 (B) 6
(C) 8 (D) 12

18. A sample of methanol, CH₃OH, is introduced into an evacuated chamber with a movable piston. The pressure is measured as a function of the volume of the container while the temperature is maintained at 50 °C, and the graph below is obtained. Which statement best describes this system?



- (A) At volumes below 60 mL, methanol is only present in the liquid phase.
 (B) At volumes above 60 mL, methanol is only present in the gaseous phase.
 (C) If the process were repeated at 60 °C, the point at which the pressure begins to decrease would shift to higher volume.
 (D) If more methanol were added to the container, the pressure at V = 20 mL would increase.

19. The amount of energy released by a chemical process is always equal to that absorbed by the system and surroundings. This is a consequence of which law?

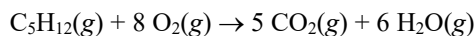
- (A) The Zeroth Law of Thermodynamics
 (B) The First Law of Thermodynamics
 (C) The Second Law of Thermodynamics
 (D) The Third Law of Thermodynamics

20. What is ΔG°_f of NO(g) at 298 K?

Substance	ΔH°_f , kJ mol ⁻¹	S° , J mol ⁻¹ K ⁻¹
N ₂ (g)	0	191.6
O ₂ (g)	0	205.2
NO(g)	90.3	210.8

- (A) 27.5 kJ mol⁻¹ (B) 86.6 kJ mol⁻¹
 (C) 145.7 kJ mol⁻¹ (D) 153.1 kJ mol⁻¹

21. Which statements about entropy, enthalpy, and energy are correct for the reaction below?



I. $\Delta S^\circ > 0$ II. $\Delta H^\circ > \Delta E^\circ$

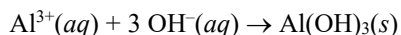
- (A) I only (B) II only
 (C) Both I and II (D) Neither I nor II

22. 4.00 mL of 2.00 M aqueous NaOH is added to 100.0 mL of 0.200 M aqueous NaHSO₄, all initially at 25.00 °C, in a well-insulated flask. Neglecting the effects of dilution, and assuming that volumes are additive and that all solutions have the same density and specific heat capacity as pure water, what is the final temperature of the mixture?

Species	ΔH°_f , kJ mol ⁻¹
OH ⁻ (aq)	-230
HSO ₄ ⁻ (aq)	-886
SO ₄ ²⁻ (aq)	-909
H ₂ O(l)	-286

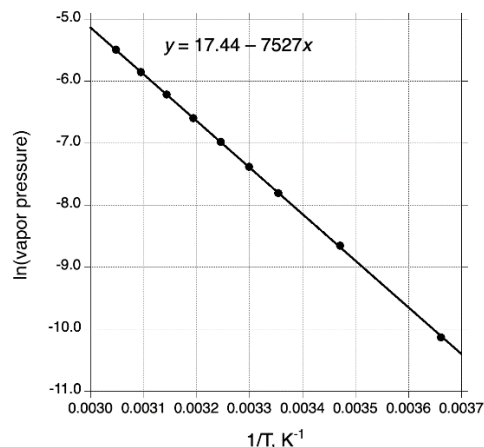
- (A) 25.18 °C (B) 26.06 °C
 (C) 26.45 °C (D) 28.63 °C

23. The K_{sp} of Al(OH)₃ is 2.0×10^{-31} at 298 K. What is ΔG° (at 298 K) for the precipitation of Al(OH)₃ according to the equation below?



- (A) -175 kJ mol⁻¹ (B) 14.7 kJ mol⁻¹
 (C) 70.6 kJ mol⁻¹ (D) 175 kJ mol⁻¹

24. The vapor pressure of solid I₂ is measured (in bar) over the temperature range 0–55 °C. The natural logarithms of these vapor pressures are plotted as a function of the reciprocal of the absolute temperature as shown below. What is the standard enthalpy of sublimation ($\Delta H^\circ_{\text{subl}}$) of I₂(s)?



- (A) 7.53 kJ mol⁻¹ (B) 17.4 kJ mol⁻¹
 (C) 19.4 kJ mol⁻¹ (D) 62.6 kJ mol⁻¹

25. *Tert*-butyl chloride reacts with hydroxide ion in a process that is first order in both *tert*-butyl chloride and hydroxide. If both reactants are doubled in concentration, how does the reaction rate change?

- (A) The rate does not change.
 (B) The rate doubles.
 (C) The rate quadruples.
 (D) The effect on the rate cannot be determined from the information given.

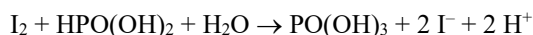
26. Under certain conditions, the rate of decomposition of hydrogen peroxide is first order in H₂O₂. It is observed that the concentration of H₂O₂ decreases by 1.00% in 300.0 s. What is the rate constant for the reaction?

- (A) $3.35 \times 10^{-5} \text{ s}^{-1}$ (B) $2.31 \times 10^{-3} \text{ s}^{-1}$
 (C) $3.33 \times 10^{-3} \text{ s}^{-1}$ (D) 300 s^{-1}

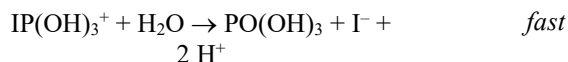
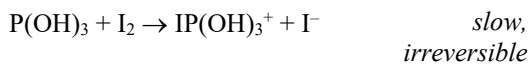
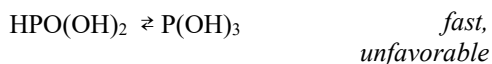
27. The pain reliever naproxen has a half-life of 12 h in the human body. A patient takes a 400 mg tablet of naproxen at 8 AM and a second 400 mg tablet at 8 PM (12 h after the first dose). How much naproxen remains in the patient's body at 8 AM the following day (12 h after the second dose)?

- (A) 50 mg (B) 100 mg
 (C) 200 mg (D) 300 mg

28. For the aqueous reaction



the following mechanism is proposed:



Which observation is consistent with this mechanism?

- (A) The reaction is first order in both $\text{HPO}(\text{OH})_2$ and I_2 .
(B) The reaction rate is independent of the I_2 concentration.
(C) The reaction goes faster as the concentration of H^+ is increased.
(D) The reaction goes slower as the concentration of I^- is increased.

29. In which ways may a catalyst increase the rate of a reaction?

- I. It may alter the rate law of the reaction.
II. It may make the overall reaction more exothermic.

- (A) I only (B) II only
(C) Both I and II (D) Neither I nor II
30. The rate constant of a chemical reaction increases by 63% when the temperature is raised from 40 °C to 45 °C. What is the activation energy of this reaction?
- (A) 1.5 kJ mol⁻¹ (B) 9.7 kJ mol⁻¹
(C) 76.5 kJ mol⁻¹ (D) 80.9 kJ mol⁻¹

31. What mass of lead(II) fluoride ($K_{\text{sp}} = 4.0 \times 10^{-8}$) will dissolve in 1.00 L of water?

- (A) 0.025 g (B) 0.049 g
(C) 0.087 g (D) 0.53 g

32. The K_{a} of the pyridinium ion, $\text{C}_5\text{H}_5\text{NH}^+$, is 5.9×10^{-6} . What is the pH of a 0.170 M solution of pyridine, $\text{C}_5\text{H}_5\text{N}$?

- (A) 3.00 (B) 4.77 (C) 8.77 (D) 9.23

33. Excess solid silver chloride is added to water and the mixture stirred until equilibrium is achieved. Addition of which substance will increase the concentration of chloride ion in this solution?

- (A) AgNO_3 (B) AgCl
(C) NH_3 (D) H_2O

Problems 34 and 35 are about the exothermic reaction of iodine with iodide ion shown below.



34. 1.0×10^{-4} mol I_2 and 4.0×10^{-3} mol KI are dissolved in water at 25 °C to give 100.0 mL of solution. What is the equilibrium concentration of I_2 in this solution?

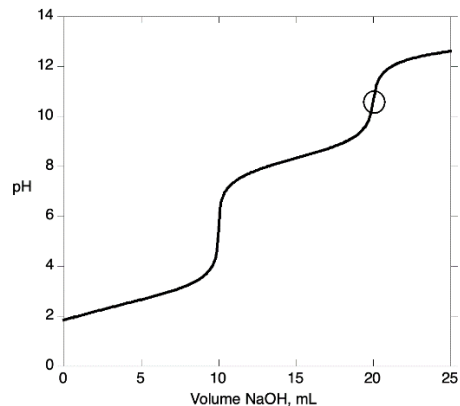
- (A) 1.3×10^{-6} M (B) 3.4×10^{-5} M
(C) 5.0×10^{-4} M (D) 5.3×10^{-3} M

35. Which changes will result in an increase in the number of moles of $\text{I}_2(\text{aq})$ present at equilibrium?

- I. Increasing the temperature
II. Replacing the KI with an equal mass of NaI

- (A) I only (B) II only
(C) Both I and II (D) Neither I nor II

36. A 0.100 M aqueous solution of H_2SeO_3 is titrated with 1.000 M NaOH solution. At the point marked with a circle on the titration curve, which species comprise at least 10% of the total selenium in solution?



- (A) H_2SeO_3 only (B) H_2SeO_3 and HSeO_3^-
(C) HSeO_3^- and SeO_3^{2-} (D) SeO_3^{2-} only

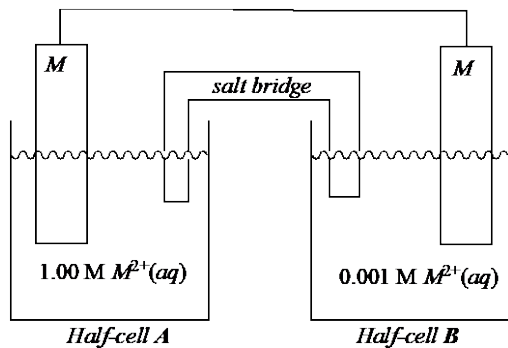
37. What is the average oxidation state of iron in riebeckite, $\text{Na}_2\text{Fe}_5\text{Si}_8\text{O}_{22}(\text{OH})_2$?

- (A) +2.0 (B) +2.4 (C) +3.0 (D) +5.6

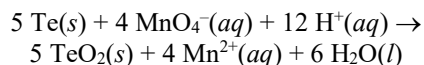
38. An electrolytic cell is operated for 3000 s using a current of 1.50 A. From which 1.0 M solution will the smallest mass of metal be deposited?

- (A) CdCl_2 (B) InBr_3
(C) TlNO_3 (D) $\text{Pb}(\text{NO}_3)_2$

39. A galvanic cell using an unknown metal M is arranged as shown below. What can be concluded about this cell?



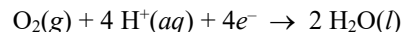
- (A) Half-cell A is the cathode.
 (B) Half-cell B is the cathode.
 (C) No current flows in the cell since the same metal is used in both half-cells.
 (D) Which cell is the cathode depends on the standard reduction potential of $M^{2+}(aq)$.
40. When manganese metal is placed in a solution containing silver(I) ion in acidic solution, metallic silver deposits on the manganese. Which half-reactions are taking place?
- I. $Ag^+(aq) + e^- \rightarrow Ag(s)$
 II. $Mn(s) + 4 H_2O(l) \rightarrow MnO_4^-(aq) + 8 H^+(aq) + 7 e^-$
- (A) I only (B) II only
 (C) Both I and II (D) Neither I nor II
41. What is E° for the following redox reaction?



Half-reaction	E°, V
$TeO_2(s) + 4 H^+(aq) + 4 e^- \rightarrow Te(s) + 2 H_2O(l)$	+0.59
$MnO_4^-(aq) + 8 H^+(aq) + 5 e^- \rightarrow Mn^{2+}(aq) + 4 H_2O$	+1.51

- (A) -3.09 V (B) 0.92 V
 (C) 3.09 V (D) 5.19 V

42. The reduction of O_2 to H_2O in acidic solution has a standard reduction potential of +1.23 V. What is the effect on the half-cell potential at 25 °C when the pH of the solution is decreased by one unit?



- (A) The half-cell potential decreases by 236 mV.
 (B) The half-cell potential increases by 236 mV.
 (C) The half-cell potential decreases by 59 mV.
 (D) The half-cell potential increases by 59 mV.
43. Which statement best describes the amount of energy released by gas-phase oxygen and sulfur atoms upon accepting an electron (electron affinities)?
- (A) O releases less energy than S because the smaller size of O causes greater electron-electron repulsion.
 (B) O releases less energy than S because O has a lower mass than S.
 (C) O releases more energy than S because the electron enters a $2p$ orbital in O but a $3p$ orbital in S.
 (D) O releases more energy than S because O has a larger effective nuclear charge Z_{eff} than S.
44. Which element has chemical properties most similar to those of S?
- (A) O (B) P (C) Cl (D) Se
45. What is the largest number of electrons that can have both a principal quantum number $n = 4$ and an orbital angular momentum quantum number $l = 2$ in a given atom?
- (A) 1 (B) 3 (C) 5 (D) 10
46. Which best represents the arrangement of electrons in a ground-state gas-phase Ni^{2+} ion?
- $4s$ $3d$
 $\uparrow\downarrow$ $\uparrow\downarrow \uparrow\downarrow \uparrow\downarrow \uparrow\downarrow () ()$
- (A) $[Ar] (\uparrow\downarrow) (\uparrow\downarrow)(\uparrow\downarrow)(\uparrow\downarrow)() ()$
 (B) $[Ar] (\uparrow\downarrow) (\uparrow\downarrow)(\uparrow) (\uparrow) (\uparrow) (\uparrow)$
 (C) $[Ar] () (\uparrow\downarrow)(\uparrow\downarrow)(\uparrow\downarrow)(\uparrow\downarrow)()$
 (D) $[Ar] () (\uparrow\downarrow)(\uparrow\downarrow)(\uparrow\downarrow)(\uparrow) (\uparrow)$
47. What is the wavelength of a photon whose energy is 334 kJ mol^{-1} ?
- (A) 222 nm (B) 358 nm
 (C) 590 nm (D) 2994 nm

48. What nuclide decays by alpha emission to form ^{219}Rn ?

- (A) ^{215}Po (B) ^{219}At (C) ^{219}Fr (D) ^{223}Ra

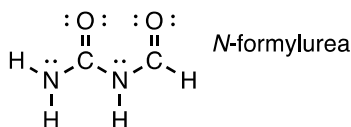
49. Which molecule has the strongest bond?

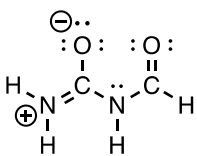
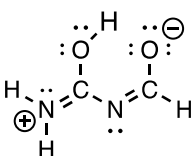
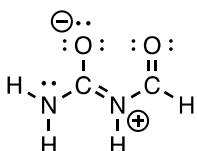
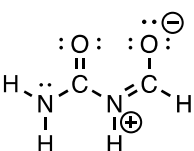
- (A) H_2 (B) N_2 (C) O_2 (D) F_2

50. What is the geometry of the iodate ion, IO_3^- ?

- (A) Trigonal pyramidal (B) Trigonal planar
(C) T-shaped (D) Zigzag

51. Which is NOT a valid resonance structure of *N*-formylurea?



- (A)  (B) 
- (C)  (D) 

52. Which molecule is best described as having a lone pair on nitrogen in an sp^2 -hybridized orbital?

- (A) NH_3 (B) HCN
(C) H_2CNH (D) H_3CNH_2

53. Nitric oxide, NO , has a smaller first ionization energy than either N atoms or O atoms. Which is the best explanation for this observation?

- (A) The electron that is ionized in NO occupies an antibonding orbital.
(B) NO forms a strong bond, which lowers the ionization energy.
(C) NO has a large dipole moment, which increases electron-electron repulsion.
(D) N atoms have a half-filled $2p$ subshell, while O is very electronegative. Both of these factors give the isolated atoms unusually high ionization energies.

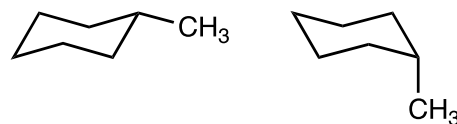
54. How many stereoisomers does the octahedral complex $\text{Co}(\text{NH}_3)_3(\text{CN})_3$ have?

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

55. How many stable isomers have the formula $\text{C}_2\text{H}_2\text{ClBr}$?

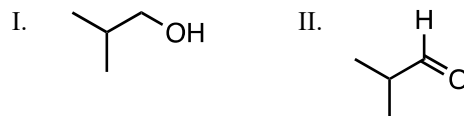
- (A) 1 (B) 2 (C) 3 (D) 4

56. Which best describes the relationship between the two structures shown below?



- (A) They are identical.
(B) They are enantiomers.
(C) They are in rapid equilibrium at room temperature and are present in equal quantities.
(D) They are in rapid equilibrium at room temperature and are present in unequal quantities.

57. Which compounds react readily with acidic dichromate solution ($\text{K}_2\text{Cr}_2\text{O}_7/\text{aqueous H}_2\text{SO}_4$)?



- (A) I only (B) II only
(C) Both I and II (D) Neither I nor II

58. In the reaction of sodium cyanide with 1-bromobutane in methanol solution, what is the principal role of the cyanide ion?

- (A) A Brønsted base
(B) A nucleophile
(C) An oxidant
(D) A solvent

59. The amino acid lysine has the side chain $\text{R} = \text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2$. A mutation of lysine to which amino acid is least likely to change the overall charge on a protein at $\text{pH} = 8.0$?

- (A) Arginine, $\text{R} = \text{CH}_2\text{CH}_2\text{CH}_2\text{NHC}(=\text{NH})\text{NH}_2$
(B) Glycine, $\text{R} = \text{H}$
(C) Methionine, $\text{R} = \text{CH}_2\text{CH}_2\text{SCH}_3$
(D) Serine, $\text{R} = \text{CH}_2\text{OH}$

60. What monosaccharide units are found in both starch and cellulose?

- (A) Arabinose
- (B) Fructose
- (C) Glucose
- (D) Ribose

END OF TEST

Olympiad 2023
USNCO Local Section Exam
KEY

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