ACS USNCO
U.S. National Chemistry Olympiad

2022 U.S. NATIONAL CHEMISTRY OLYMPIAD

LOCAL SECTION EXAM

Prepared by the American Chemical Society Chemistry Olympiad Examinations Task Force

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	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		

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 °C = 273.15 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

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

PERIODIC TABLE OF THE ELEMENTS

1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1 **H** 1.008																	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											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 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. Which potassium salt is 28.9% chlorine by mass?

(A) KCl **(B)** KClO **(C)** $KClO_2$ **(D)** $KClO_3$

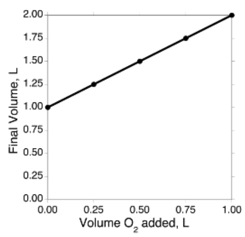
2. How many sulfur atoms are in 3.00 g of iron pyrite, FeS_2 (M = 120.0)?

(A) 7.53×10^{21} **(B)** 1.51×10^{22}

(C) 3.01×10^{22} **(D)** 6.02×10^{23}

3. A gas mixture contains 50 mol% H_2 and 50 mol% He. 1.00-L samples of this gas mixture are mixed with variable volumes of O_2 (at 0 °C and 1 atm). A spark is introduced to allow the mixture to undergo complete combustion. The final volume is measured at 0 °C and 1 atm. Which graph best depicts the final volume as a function of the volume of added O_2?

(A)



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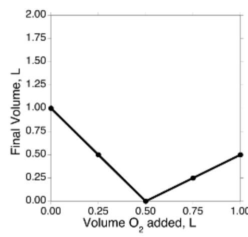

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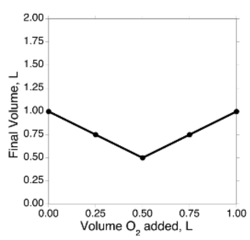

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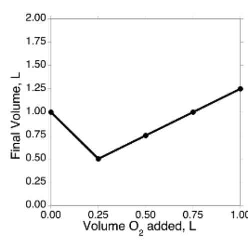


4. What is the concentration of nitrate ions in 40.0 mL of a 0.25 M solution of copper(II) nitrate?

(A) 0.010 M **(B)** 0.020 M

(C) 0.050 M **(D)** 0.50 M

5. 1.000 g of a transition metal carbonate, MCO_3, is heated to produce the metal oxide and 0.383 g of carbon dioxide (M = 44.01). What is the identity of the metal M?

(A) Mn **(B)** Ni **(C)** Cu **(D)** Zn

6. 14.0 mL of 0.53 M barium nitrate solution and 16.0 mL of 0.44 M sodium sulfate solution are mixed. Which ion is LEAST abundant in solution?

(A) Ba^{2+} **(B)** NO_3^- **(C)** Na^+ **(D)** SO_4^{2-}

7. Which salt gives a colorless aqueous solution?

(A) $NaClO_4$ **(B)** K_2CrO_4

(C) $Ni(NO_3)_2$ **(D)** $CuSO_4$

8. 100 mL of a 1.0 M solution of hydrochloric acid is gradually added to a stirred mixture containing 0.01 mol calcium hydroxide, 100 mL water, and a small amount of phenolphthalein. What changes are observed?

I. The mixture changes from colorless to pink.
II. The mixture changes from cloudy to clear.

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

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

9. Below is shown a section of a buret filled with titrant before beginning a titration. What initial volume should be recorded?

(A) 1.20 mL **(B)** 1.26 mL

(C) 2.74 mL **(D)** 2.80 mL

10. Titration with aqueous triiodide solution to a starch endpoint would be LEAST suitable for which determination?

(A) Analysis of nickel content in a Ni/Co alloy

(B) Determination of ascorbic acid in a vitamin C tablet

(C) Measurement of sulfite concentration in a white wine

(D) Determination of waters of hydration in a sodium thiosulfate sample

11. Which liquid will NOT react with metallic sodium?

(A) Water **(B)** Mineral oil
(C) Ethanol **(D)** Carbon tetrachloride

12. The molar enthalpy of solution of a salt that dissolves endothermically in water is measured in a coffee-cup calorimeter by weighing a known amount of distilled water into the cup and measuring its temperature, then adding a known mass of the salt to the water and measuring the temperature after the salt dissolves. If some water is initially present in the cup before the weighed amount of water is added, what is the effect on the experiment?

(A) Calculated $\Delta H°_{soln}$ > True $\Delta H°_{soln}$

(B) Calculated $\Delta H°_{soln}$ = True $\Delta H°_{soln}$

(C) Calculated $\Delta H°_{soln}$ < True $\Delta H°_{soln}$

(D) The reaction will be calculated to be exothermic even though it is actually endothermic.

13. When liquid water converts to solid ice at 0 °C and 1 atm pressure, which of the following changes takes place?

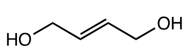
(A) Heat flows out of the system.

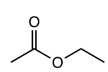
(B) The volume of the system decreases.

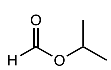
(C) The vapor pressure of water increases.

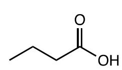
(D) The hydrogen bonds become weaker.

14. Which isomer of $C_4H_8O_2$ has the greatest solubility in water?

(A) 

(B) 

(C) 

(D) 

15. Which compound has the lowest normal boiling point?

(A) HF **(B)** HCl **(C)** HBr **(D)** HI

16. A sealed container contains a gaseous sample at 300.0 K consisting of either pure ethane (C_2H_6), pure neon (Ne), or a mixture of the two. The pressure inside the container at this temperature is 1.00 atm. When the container is cooled to 150.0 K, the pressure is 0.37 atm. What is the composition of the sample? (The vapor pressure of C_2H_6 at 150 K is 0.10 atm; the critical temperature of Ne is 44 K.)

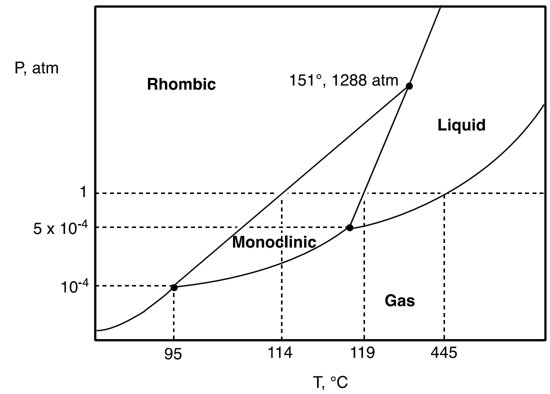
(A) Pure ethane

(B) Pure neon

(C) A mixture of ethane and neon.

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

17. Which statement about sulfur, whose phase diagram is shown below, is correct?



(A) Monoclinic sulfur sublimes at 1 atm pressure while rhombic sulfur does not.

(B) Rhombic sulfur is less dense than monoclinic sulfur.

(C) At temperatures above 119 °C, monoclinic sulfur cannot exist at equilibrium.

(D) The conversion of rhombic sulfur to monoclinic sulfur is endothermic.

18. Aluminum crystallizes in a face-centered cubic unit cell with an edge length of 405 pm. What is its density?

(A) 0.674 g cm^{-3} **(B)** 1.35 g cm^{-3}
(C) 2.70 g cm^{-3} **(D)** 5.40 g cm^{-3}

19. A container with 100.0 g of ice at 0 °C is placed in a humid room whose temperature is 40 °C. The ice melts as water vapor condenses into the container. Assuming that all the heat transferred to the container comes from condensation, how much water will have condensed in the container once all the ice is melted and has reached 40 °C? The heat of fusion of ice is 334 J g^{-1} and the heat of vaporization of water is 2260 J g^{-1}.

(A) 13.8 g **(B)** 14.8 g **(C)** 22.2 g **(D)** 677 g

20. The standard enthalpy of formation of hematite, $Fe_2O_3(s)$, is –825.5 kJ mol^{-1}. What is the standard enthalpy of reaction for the reduction of hematite with carbon monoxide to give metallic iron as shown below?

$CO(g) + \frac{1}{2} O_2(g) \rightarrow CO_2(g)$	$\Delta H°_{rxn}$ = –283.0 kJ mol^{-1}
$Fe_2O_3(s) + 3\,CO(g) \rightarrow 2\,Fe(s) + 3\,CO_2(g)$	$\Delta H°_{rxn}$ = ???

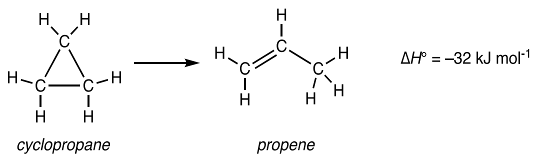
(A) –23.5 kJ mol^{-1} **(B)** –542.5 kJ mol^{-1}
(C) –849.0 kJ mol^{-1} **(D)** –1674.5 kJ mol^{-1}

21. Which of the following equations correctly describe the change in internal energy, ΔE, of a reaction taking place in a bomb calorimeter?

I. $\Delta E = q$
II. $\Delta E = \Delta H - V\Delta P$

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

22. Cyclopropane isomerizes exothermically to propene as shown.



The C–C single bond in propene has an estimated bond dissociation enthalpy (BDE) of 345 kJ mol^{-1}, while the C=C double bond in propene has a BDE of 611 kJ mol^{-1}. Assuming that the C–H bonds in propene and cyclopropane all have the same BDE, what is the estimated BDE of a C–C single bond in cyclopropane?

(A) 308 kJ mol^{-1} **(B)** 329 kJ mol^{-1}
(C) 423 kJ mol^{-1} **(D)** 924 kJ mol^{-1}

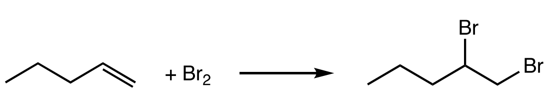
23. Two reactions have similar $\Delta H°_{rxn}$ values ($\Delta H°_{rxn\,(1)} \approx \Delta H°_{rxn\,(2)}$), but reaction (1) has a much smaller standard entropy change than reaction (2) ($\Delta S°_{rxn\,(1)} << \Delta S°_{rxn\,(2)}$). At 298 K, which statements about these two reactions must be correct?

I. Reaction (1) must have a larger equilibrium constant ($K_{eq\,(1)} > K_{eq\,(2)}$).
II. Reaction (1) must have a larger Arrhenius prefactor ($A_{(1)} > A_{(2)}$).

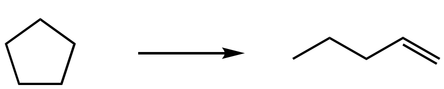
(A) I only **(B)** II only
(C) Both I and II **(D)** Neither I nor II

24. Which reaction has $\Delta S°_{rxn} > 0$? All reactants and products are liquids.

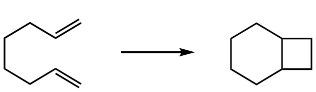
(A)



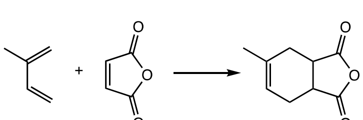
(B)



(C)



(D)



25. Dichromate ion is reduced by chloride ion according to the equation below. If [Cl⁻] is decreasing at a rate of 0.37 mol L^{-1} min^{-1}, how is the concentration of $Cr^{3+}(aq)$ changing?

$$14\ H^+(aq) + Cr_2O_7^{2-}(aq) + 6\ Cl^-(aq) \rightarrow 2\ Cr^{3+}(aq) + 3\ Cl_2(aq) + 7\ H_2O(l)$$

(A) Increasing by 0.12 mol L^{-1} min^{-1}
(B) Increasing by 1.11 mol L^{-1} min^{-1}
(C) Decreasing by 0.12 mol L^{-1} min^{-1}
(D) Decreasing by 1.11 mol L^{-1} min^{-1}

26. The isotope cobalt-57 has a half-life of 272 d. How long will it take a sample of ^{57}Co to decay to 38% of its original activity?

(A) 103 d **(B)** 337 d **(C)** 188 d **(D)** 380 d

27. Which statement best describes the variation of the rate constant of a reaction with temperature?

(A) The rate constant does not change with temperature because it is an unvarying characteristic of the specific reaction.
(B) The rate constant typically decreases with increasing temperature because fewer molecules are able to adopt the required orientation at higher temperature.
(C) The rate constant typically increases with increasing temperature because increasing the temperature increases the fraction of collisions that result in reaction.
(D) The rate constant typically increases with increasing temperature because most reactions become more favorable as the temperature increases.

28. A mechanism for the reaction of nitric oxide with hydrogen to form water and nitrogen gas is proposed below. What rate law is predicted by this mechanism?

$2\ NO(g) \rightleftarrows N_2O_2(g)$	*fast, unfavorable equilibrium*
$N_2O_2(g) + H_2(g) \rightarrow N_2O(g) + H_2O(g)$	*slow, irreversible*
$N_2O(g) + H_2(g) \rightarrow H_2O(g) + N_2(g)$	*fast, irreversible*

(A) Rate = $k[NO]^2$
(B) Rate = $k[NO]^2[H_2]$
(C) Rate = $k[NO]^2[H_2]^2$
(D) Rate = $k\dfrac{[NO]^2[H_2]^2}{[N_2O][H_2O]}$

29. An irreversible reaction A + B → C is carried out under various conditions, but always with $[B]_0 >> [A]_0$. Plots of 1/[A] as a function of time for each reaction are linear, and the slopes of these plots do not depend on the initial concentration of B. What is the rate law for the reaction under these conditions?

(A) Rate = k[A] **(B)** Rate = k[A][B]
(C) Rate = $k[A]^2$ **(D)** Rate = $k[A]^2[B]$

30. The reaction of $H_2(g)$ with $C_2H_4(g)$ to form $C_2H_6(g)$ is catalyzed by metallic platinum. Which statement most accurately describes the impact of changing the catalyst in this reaction?

(A) The rate of the reaction would not change if a greater mass of catalyst were used because the platinum is a solid so its concentration is a fixed number.

(B) The rate of the reaction would increase if more finely divided platinum were used because the reaction depends on the surface area of the catalyst.

(C) The $\Delta H°$ for the reaction would become more negative if a greater mass of catalyst were used because the catalyst adsorbs the reactants exothermically.

(D) The $\Delta S°$ for the reaction would become more negative if more finely divided platinum were used because the catalyst absorbs gas-phase reactants to form ordered surface species.

31. Lead(II) iodide has a solubility product constant of 1.4 × 10^{-8}. What is the concentration of I^- in a saturated solution of PbI_2?

(A) 1.2×10^{-4} M **(B)** 2.4×10^{-4} M
(C) 1.5×10^{-3} M **(D)** 3.0×10^{-3} M

32. Sodium bicarbonate decomposes at high temperatures according to the following equation:

$$2\ NaHCO_3(s) \leftrightarrows Na_2CO_3(s) + CO_2(g) + H_2O(g)$$

At a certain temperature, 50.0 g of $NaHCO_3$ is allowed to react in a 3.0 L evacuated vessel. At equilibrium, the total pressure is 6.25 atm, with some of both solids still present. If 100.0 g of $NaHCO_3$ is allowed to react in the same vessel at the same temperature, what will the pressure be at equilibrium?

(A) 6.25 atm **(B)** 8.84 atm
(C) 12.5 atm **(D)** 25.0 atm

33. In a solution prepared by dissolving 0.1 mol $NaNO_2$ in 1.0 L pure water, which species has the lowest concentration?

(A) Na^+ **(B)** NO_2^- **(C)** HNO_2 **(D)** H_3O^+

34. A saturated solution of which silver salt has the highest concentration of Ag^+?

(A) AgCl, $K_{sp} = 1.8 \times 10^{-10}$

(B) Ag_2CrO_4, $K_{sp} = 1.1 \times 10^{-12}$

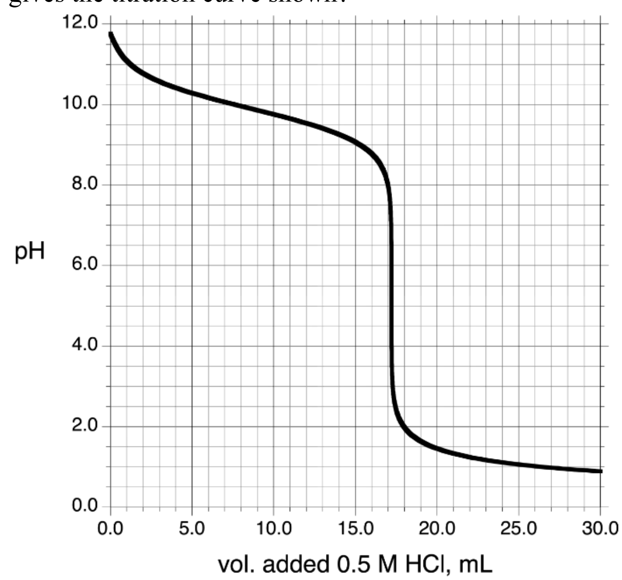
(C) AgBr, $K_{sp} = 5.0 \times 10^{-13}$

(D) Ag_2SO_3, $K_{sp} = 1.5 \times 10^{-14}$

35. What is the pH of a 0.10 M solution of NH_4F? The K_a of NH_4^+ is 5.6×10^{-10} and the K_a of HF is 6.8×10^{-4}.

(A) 2.08 **(B)** 5.12 **(C)** 6.21 **(D)** 8.08

36. 1.000 g of which salt, when titrated with 0.500 M HCl, gives the titration curve shown?



(A) Potassium cyanide, KCN (M = 65.12, pK_a of HCN = 9.2)

(B) Sodium nitrite, $NaNO_2$ (M = 69.00, pK_a of HNO_2 = 3.4)

(C) Potassium phenoxide, $K(C_6H_5O)$ (M = 116.20, pK_a of C_6H_5OH = 9.9)

(D) Sodium pivalate, $Na(C_4H_9COO)$ (M = 124.11, pK_a of C_4H_9COOH = 4.9)

37. Romanèchite has the formula $Ba_2Mn_5O_{10} \cdot 2H_2O$. What is the average oxidation state of manganese in romanèchite?

(A) +2.0 **(B)** +3.2 **(C)** +3.6 **(D)** +4.0

38. Which element is being reduced in the following equation?

$$3\ Cu(s) + 8\ HNO_3(aq) \rightarrow$$
$$2\ NO(g) + 3\ Cu(NO_3)_2(aq) + 4\ H_2O(l)$$

(A) Cu **(B)** H **(C)** N **(D)** O

39. A galvanic cell is constructed under standard conditions using cobalt in cobalt(II) nitrate solution and indium in indium(III) nitrate solution. Which statements about this cell are correct?

Half-reaction	$E°$, V
$Co^{2+}(aq) + 2e^- \rightarrow Co(s)$	–0.28
$In^{3+}(aq) + 3e^- \rightarrow In(s)$	–0.34

I. The standard cell potential is 0.46 V.
II. Indium is the anode.

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

40. Molten sodium chloride is electrolyzed for 10.0 minutes with a constant current of 10.0 A. What mass of sodium metal is produced?

(A) 1.43 g **(B)** 2.20 g **(C)** 3.63 g **(D)** 4.41 g

41. The standard cell potential of a galvanic cell based on the reaction below is 1.10 V. Which concentrations would result in the largest measured voltage?

$$Cu^{2+}(aq) + Zn(s) \rightarrow Zn^{2+}(aq) + Cu(s)$$

(A) $[Cu^{2+}] = 1.0$ M and $[Zn^{2+}] = 1.0$ M
(B) $[Cu^{2+}] = 3.0$ M and $[Zn^{2+}] = 1.0$ M
(C) $[Cu^{2+}] = 1.0$ M and $[Zn^{2+}] = 3.0$ M
(D) $[Cu^{2+}] = 3.0$ M and $[Zn^{2+}] = 3.0$ M

42. The standard reduction potential of oxygen under acidic conditions at 298 K is +1.23 V. What is the standard reduction potential for the four-electron reduction of $O_2(g)$ under basic conditions?

(A) 1.23 V **(B)** 1.02 V **(C)** 0.83 V **(D)** 0.40 V

43. Photons of what wavelength of light have an energy of 1.00×10^3 kJ mol^{-1}?

(A) 2.00×10^{31} m **(B)** 1.20×10^{-7} m
(C) 1.20×10^{-4} m **(D)** 8.36×10^{6} m

44. In which set are all three species isoelectronic?

(A) H^+, Li^+, Na^+ **(B)** C, N^-, O^{2-}
(C) Se^{2-}, Br^-, Rb^+ **(D)** I, Xe, Cs

45. Which change in principal quantum number n involves the greatest change in energy?

(A) $n = 1 \rightarrow n = 2$ in H **(B)** $n = 2 \rightarrow n = 3$ in He^+
(C) $n = 3 \rightarrow n = 4$ in Li^{2+} **(D)** $n = 4 \rightarrow n = 5$ in Be^{3+}

46. Which gas-phase ion has the greatest number of unpaired electrons in its ground state?

(A) Fe^{3+} **(B)** Co^{3+} **(C)** Ni^{3+} **(D)** Cu^{3+}

47. Which principle restricts the occupancy of an atomic orbital to no more than two electrons?

(A) The principle of conservation of energy
(B) The principle of conservation of angular momentum
(C) The Pauli exclusion principle
(D) The Heisenberg uncertainty principle

48. When copper-64 decays by positron emission, what daughter nuclide is formed?

(A) ^{64}Ni **(B)** ^{65}Ni **(C)** ^{64}Zn **(D)** ^{65}Zn

49. Which molecule has a nonzero dipole moment?

(A) CF_4 **(B)** C_2F_4 **(C)** SF_4 **(D)** SF_6

50. How many π bonds are in cyanogen, NCCN?

(A) 2 **(B)** 4 **(C)** 6 **(D)** 7

51. In azomethane, H_3CNNCH_3, what are the molecular geometries around the carbon and nitrogen atoms, respectively?

(A) Tetrahedral at carbon, bent at nitrogen
(B) Tetrahedral at carbon, linear at nitrogen
(C) Square planar at carbon, bent at nitrogen
(D) Square planar at carbon, linear at nitrogen

52. What is the bond order of O_2^+?

(A) 1.0 **(B)** 1.5 **(C)** 2.0 **(D)** 2.5

53. Which is the best explanation for phosphorus favoring formation of P_4 over P_2 molecules, while nitrogen forms only N_2 molecules?

(A) Phosphorus-phosphorus π bonds are weaker than nitrogen-nitrogen π bonds.

(B) Phosphorus can have an expanded octet while nitrogen cannot.

(C) The nonbonding electrons on phosphorus occupy an unhybridized *s* orbital while the nonbonding electrons on nitrogen occupy hybrid orbitals.

(D) The larger size of phosphorus allows the bonding electrons to be closer together.

54. In the octahedral complex $Co(NH_2CH_2CO_2)_3$, each glycinate ion $NH_2CH_2CO_2^-$ binds to cobalt through its nitrogen atom and one of its oxygen atoms. How many stereoisomers of $Co(NH_2CH_2CO_2)_3$ are possible?

(A) 2 **(B)** 4 **(C)** 6 **(D)** 8

55. A molecule has the formula $C_5H_{10}O$. Which functional groups might it contain?

I. Alcohol
II. Ketone

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

(C) Either I or II **(D)** Neither I nor II

56. How many distinct branched alkanes are there with the formula C_6H_{14}?

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

57. Which cycloalkane in its most stable conformation has average internal C–C–C bond angles most different from the value given?

(A) Cyclopropane, 60°

(B) Cyclobutane, 90°

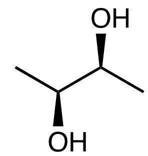
(C) Cyclopentane, 108°

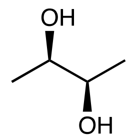
(D) Cyclohexane, 120°

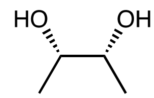
58. Which gas is most reactive toward 1-hexene?

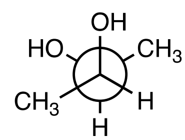
(A) N_2 **(B)** O_3 **(C)** N_2O **(D)** NH_3

59. Which structure depicts the enantiomer of the diol shown?



(A) 

(B) 

(C) 

(D) The diol shown is achiral and does not have an enantiomer.

60. Which biomolecule does NOT contain C=O double bonds?

(A) Sucrose (a carbohydrate)

(B) Glyceryl trioleate (a lipid)

(C) Phenylalanine tRNA (a nucleic acid)

(D) Trypsin (a protein)

END OF TEST

Olympiad 2022
USNCO Local Section Exam
KEY

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