



ACS USNCO
U.S. National Chemistry Olympiad

2020 U.S. NATIONAL CHEMISTRY OLYMPIAD LOCAL SECTION EXAM

Prepared by the American Chemical Society Chemistry Olympiad Examinations Task Force

OLYMPIAD EXAMINATIONS TASK FORCE

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

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																	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.**

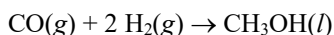
1. A 2.50 L sample of butane gas (C_4H_{10}), measured at 22.0 °C and 1.20 atm pressure, is combusted completely and the carbon dioxide gas collected at the same pressure and temperature. What volume of CO_2 is produced?

- (A) 2.50 L (B) 9.00 L
(C) 10.0 L (D) 22.5 L

2. How many hydrogen atoms are in 2.50 g of pharmacolite, $CaHAsO_4 \cdot 2H_2O$ ($M = 216.0$)?

- (A) 6.97×10^{21} (B) 2.09×10^{22}
(C) 2.79×10^{22} (D) 3.48×10^{22}

3. Methanol is produced industrially by catalytic hydrogenation of carbon monoxide according to the following equation:



If the yield of the reaction is 40%, what volume of CO (measured at STP) would be needed to produce 1.0×10^6 kg CH_3OH ?

- (A) 2.8×10^8 L (B) 7.0×10^8 L
(C) 1.7×10^9 L (D) 2.1×10^9 L

4. What volume of 18.0 M sulfuric acid must be diluted to 250.0 mL to afford a 0.55 M solution of sulfuric acid?

- (A) 3.1 mL (B) 4.5 mL (C) 7.6 mL (D) 31 mL

5. What is the concentration of H_2O_2 in a solution that is 30.0% by mass hydrogen peroxide and has a density of 1.11 g cm^{-3} ?

- (A) 9.79 M (B) 12.6 M
(C) 18.5 M (D) 32.6 M

6. A 5.00 g mixture of potassium sulfide and potassium chloride contains 2.80 g potassium. What percentage by mass of the mixture is potassium sulfide?

- (A) 13.8% (B) 19.2% (C) 44.0% (D) 96.1%

7. Which salt dissolves in water to give a pink solution?

- (A) $Co(CH_3COO)_2$ (B) $CuSO_4$
(C) $Fe(NO_3)_3$ (D) $ZnCl_2$

8. A student is using a buret for a titration. What initial buret reading should be recorded?



- (A) 6.6 mL (B) 7.4 mL
(C) 6.63 mL (D) 7.37 mL

9. A strip of metallic zinc is placed in a beaker containing dilute aqueous copper(II) nitrate. Which statement correctly describes what takes place?

- (A) No reaction takes place.
(B) The mass of the metal strip decreases as the zinc is oxidized.
(C) A white precipitate of $CuNO_3$ is formed.
(D) Bubbles of $NO(g)$ form as the nitrate ion is reduced.

10. Which element does NOT have multiple allotropes?

- (A) Carbon (B) Oxygen
(C) Fluorine (D) Phosphorus

11. Which reaction is not exothermic?

- (A) Dilution of concentrated hydrochloric acid in water.
(B) Dilution of concentrated sulfuric acid in water.
(C) Dissolution of solid sodium hydroxide in water.
(D) Dissolution of solid sodium bicarbonate in water.

12. The molar mass of a volatile organic liquid is measured by weighing the mass of an empty flask of known volume, adding some of the liquid, heating the flask in a water bath until the liquid has just vaporized completely, then sealing the flask, letting it cool, and remeasuring the mass of the flask with the remaining organic compound. Which error will lead to a calculated value of the molar mass that is lower than the theoretical value?

- (A) The flask is not sealed promptly after the last of the compound vaporizes.
 (B) The organic compound dimerizes to an appreciable extent in the gas phase.
 (C) The barometric pressure was assumed to be 1 atm but in fact was greater than 1 atm.
 (D) The volume of the flask used in the calculation is smaller than the true volume.

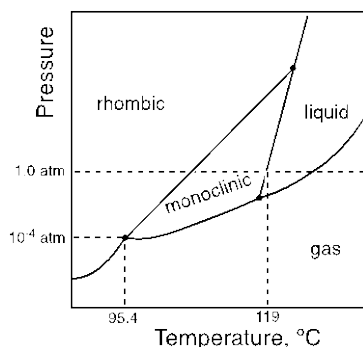
13. Which gas has an effusion rate closest to half that of oxygen gas at a given temperature?

- (A) H_2 (B) He (C) SO_2 (D) Xe

14. Which compound has the highest normal boiling point?

- (A) 1-butanol, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$
 (B) 2-butanol, $\text{CH}_3\text{CH}_2\text{CH}(\text{CH}_3)\text{OH}$
 (C) 2-methyl-1-propanol, $(\text{CH}_3)_2\text{CHCH}_2\text{OH}$
 (D) 2-methyl-2-propanol, $(\text{CH}_3)_3\text{COH}$

15. A portion of the phase diagram of elemental sulfur is shown below. Which statement about sulfur is correct?



- (A) Rhombic sulfur cannot be sublimed without first converting to monoclinic sulfur.
 (B) The conversion of rhombic sulfur to monoclinic sulfur is exothermic.
 (C) Rhombic sulfur is denser than monoclinic sulfur.
 (D) At atmospheric pressure, monoclinic sulfur cannot be in equilibrium with liquid sulfur.

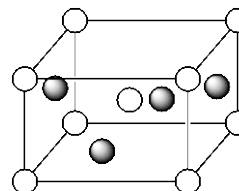
16. In which are the ionic compounds listed in order of increasing magnitude of their lattice energy?

- (A) $\text{CaO} < \text{RbI} < \text{LiF} < \text{LiI}$
 (B) $\text{RbI} < \text{CaO} < \text{LiI} < \text{LiF}$
 (C) $\text{LiI} < \text{LiF} < \text{CaO} < \text{RbI}$
 (D) $\text{RbI} < \text{LiI} < \text{LiF} < \text{CaO}$

17. Sodium halides crystallize in the rock salt structure, which has a cubic unit cell with four formula units per unit cell. A sodium halide has a density of 2.83 g cm^{-3} and a unit cell edge length of 462 pm. Which compound is it?

- (A) NaF (B) NaCl (C) NaBr (D) NaI

18. The tetragonal unit cell of white tin is shown below. Each circle represents a tin atom, with the gray circles sitting on the four vertical faces of the unit cell. How many tin atoms are contained in this unit cell?



- (A) 2 (B) 4 (C) 8 (D) 13

19. For which reaction is $\Delta H^\circ_{\text{rxn}}$ equal to ΔH°_f of $\text{CaSO}_3(s)$?

- (A) $\text{Ca}(s) + \frac{1}{8} \text{S}_8(s) + \frac{3}{2} \text{O}_2(g) \rightarrow \text{CaSO}_3(s)$
 (B) $8 \text{Ca}(s) + \text{S}_8(s) + 12 \text{O}_2(g) \rightarrow 8 \text{CaSO}_3(s)$
 (C) $8 \text{Ca}(s) + \text{S}_8(g) + 12 \text{O}_2(g) \rightarrow 8 \text{CaSO}_3(s)$
 (D) $\text{CaO}(s) + \text{SO}_2(g) \rightarrow \text{CaSO}_3(s)$

20. A 2.00 g sample of ice at 0.0°C is placed in 50.0 g of water initially at 25.0°C in an insulated container. What is the final temperature after the system has achieved equilibrium? (For ice, $\Delta H^\circ_{\text{fusion}} = 6.01 \text{ kJ mol}^{-1}$.)

- (A) 21.0°C (B) 21.8°C
 (C) 22.5°C (D) 24.0°C

21. Ethanol has a normal boiling point of 78.3°C and a standard heat of vaporization ($\Delta H^\circ_{\text{vap}}$) of 38.6 kJ mol^{-1} . What is the vapor pressure of ethanol at 45.0°C ?

- (A) 0.25 atm (B) 0.57 atm
 (C) 0.87 atm (D) 0.91 atm

22. If the average carbon-hydrogen bond dissociation enthalpy in ethane is 416 kJ mol^{-1} , what is the bond dissociation enthalpy of the carbon-carbon bond in ethane?

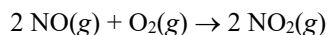
Species	ΔH°_f , kJ mol^{-1}
$\text{C}_2\text{H}_6(\text{g})$	-84.7
$\text{H}(\text{g})$	217.9
$\text{C}(\text{g})$	718.4

- (A) 164 kJ mol^{-1} (B) 333 kJ mol^{-1}
 (C) 386 kJ mol^{-1} (D) 404 kJ mol^{-1}
23. A reaction has $K_{\text{eq}} = 20$ at 298 K, and K_{eq} increases with increasing temperature between 298 K and 350 K. What may be concluded from these observations?

- I. $\Delta G^\circ_{\text{rxn}} < 0$ at 330 K
 II. $\Delta S^\circ_{\text{rxn}} > 0$ at 330 K

- (A) I only (B) II only
 (C) Both I and II (D) Neither I nor II
24. A sample of water in a movable piston is maintained at 100.0°C with an external pressure p . Which statement best describes the transformation of some of the liquid water into water vapor?

- (A) It is spontaneous if $p \geq 1 \text{ atm}$.
 (B) It is reversible if $p = 1 \text{ atm}$ and spontaneous if $p > 1 \text{ atm}$.
 (C) It is nonspontaneous if $p \geq 1 \text{ atm}$.
 (D) It is reversible if $p = 1 \text{ atm}$ and nonspontaneous if $p > 1 \text{ atm}$.
25. In a study of the reaction below, the concentration of $\text{O}_2(\text{g})$ is found to be decreasing by 0.042 M min^{-1} . At what rate is the concentration of nitrogen dioxide gas changing?



- (A) Increasing by 0.021 M min^{-1}
 (B) Increasing by 0.042 M min^{-1}
 (C) Increasing by 0.084 M min^{-1}
 (D) It cannot be determined without knowing the rate law for the reaction.
26. The rate constant for an elementary chemical reaction can be affected by which of the following?

- I. Reactant concentrations
 II. Product concentrations

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

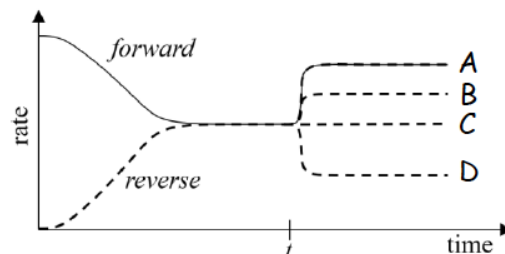
27. Sulfuryl chloride (SO_2Cl_2) decomposes via first-order kinetics. The half-life is 4.1 minutes at a certain temperature. How long does it take for 30% of the SO_2Cl_2 in a sample to decompose at this temperature?

- (A) 0.6 min (B) 2.1 min
 (C) 2.5 min (D) 7.1 min

28. The rate constant of a chemical reaction increases 26% when the temperature is raised from 50°C to 55°C . What is the activation energy of this reaction?

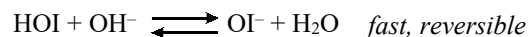
- (A) 1.1 kJ mol^{-1} (B) 18 kJ mol^{-1}
 (C) 41 kJ mol^{-1} (D) 220 kJ mol^{-1}

29. The graph below shows the forward and reverse rates for a reaction as a function of time. At time t , a catalyst is added to the system, and the forward reaction rate is observed to change as indicated by the solid curve. Which dashed curve best indicates how the reverse reaction rate changes?



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

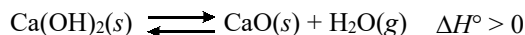
30. The following mechanism is proposed for the oxidation of I^- by OCl^- in aqueous solution:



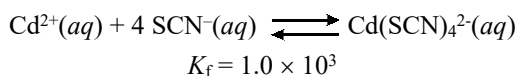
What reaction orders for OCl^- , I^- , and OH^- are consistent with this mechanism?

	Order in OCl^-	Order in I^-	Order in OH^-
(A)	1	1	1
(B)	1	1	0
(C)	1	0	0
(D)	1	1	-1

31. The endothermic reaction shown below is at equilibrium in a sealed flask, with significant amounts of both $\text{Ca(OH)}_2(s)$ and $\text{CaO}(s)$ present. Which action will increase the amount of $\text{Ca(OH)}_2(s)$ at equilibrium?

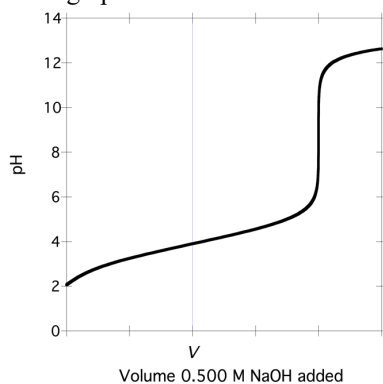


- (A) Crushing the $\text{Ca(OH)}_2(s)$ into smaller pieces
 (B) Decreasing the temperature of the flask
 (C) Adding more $\text{CaO}(s)$ to the flask
 (D) Adding $\text{N}_2(g)$ to the flask
32. A solution of ammonia, NH_3 , has $\text{pH} = 11.50$. What is the ammonia concentration? (The $\text{p}K_a$ of NH_4^+ is 9.24.)
- (A) $1.7 \times 10^{-5} \text{ M}$ (B) $3.2 \times 10^{-3} \text{ M}$
 (C) $5.5 \times 10^{-3} \text{ M}$ (D) 0.58 M
33. At equilibrium, a solution contains 0.50 mol each of $\text{Cd}^{2+}(aq)$, $\text{SCN}^-(aq)$, and $\text{Cd(SCN)}_4^{2-}(aq)$. What is the solution's volume?



- (A) 2.0 L (B) 2.2 L (C) 2.8 L (D) 8.0 L
34. Barium fluoride has $K_{sp} = 1.8 \times 10^{-7}$. What is the maximum fluoride ion concentration possible in a solution with $[\text{Ba}^{2+}] = 5.0 \times 10^{-4} \text{ M}$?
- (A) $3.6 \times 10^{-4} \text{ M}$ (B) $3.6 \times 10^{-3} \text{ M}$
 (C) $9.5 \times 10^{-3} \text{ M}$ (D) $1.9 \times 10^{-2} \text{ M}$

35. Trimesic acid is a triprotic acid with $\text{p}K_1 = 3.1$, $\text{p}K_2 = 3.9$, and $\text{p}K_3 = 4.7$. 100.0 mL of 0.100 M trimesic acid is titrated with 0.500 M $\text{NaOH}(aq)$ to give the graph below. What volume of $\text{NaOH}(aq)$ has been added at the point marked V on the graph?

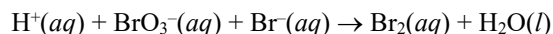


- (A) 5 mL (B) 10 mL (C) 20 mL (D) 30 mL

36. A solution containing $\text{Co(H}_2\text{O)}_6^{2+}(aq)$, $\text{CoCl}_4^{2-}(aq)$, and $\text{Cl}^-(aq)$ at equilibrium at room temperature is initially pink. When heated, the solution turns blue. Then, when $\text{Ag}^+(aq)$ is added, the solution turns back to pink. Which statements are correct?

- I. $\text{Co(H}_2\text{O)}_6^{2+}(aq)$ is pink.
 II. Formation of $\text{CoCl}_4^{2-}(aq)$ from $\text{Co(H}_2\text{O)}_6^{2+}(aq)$ and $\text{Cl}^-(aq)$ is exothermic.

- (A) I only (B) II only
 (C) Both I and II (D) Neither I nor II
37. What is the average oxidation state of tungsten in sodium phosphotungstate, $\text{Na}_3\text{PW}_{12}\text{O}_{40}$?
- (A) +6.00 (B) +6.17
 (C) +6.42 (D) +6.67
38. Bromate ion and bromide ion react to form bromine in acidic solution. When the reaction is balanced, which statement about $\text{H}^+(aq)$ is correct?



- (A) Its coefficient is twice the coefficient of $\text{Br}^-(aq)$.
 (B) Its coefficient is twice the coefficient of $\text{Br}_2(aq)$.
 (C) Its coefficient is twice the coefficient of $\text{BrO}_3^-(aq)$.
 (D) Its coefficient is the sum of the coefficients of $\text{BrO}_3^-(aq)$ and $\text{H}_2\text{O}(l)$.
39. Which reactions are spontaneous under standard conditions?

Half-Reaction	$E^\circ, \text{ V}$
$\text{Cu}^+(aq) + e^- \rightarrow \text{Cu}(s)$	+0.52
$\text{Co}^{2+}(aq) + 2 e^- \rightarrow \text{Co}(s)$	-0.28
$\text{In}^{3+}(aq) + 3 e^- \rightarrow \text{In}(s)$	-0.34

- I. $2 \text{Cu}^+(aq) + \text{Co}(s) \rightarrow \text{Co}^{2+}(aq) + 2 \text{Cu}(s)$
 II. $3 \text{Co}^{2+}(aq) + 2 \text{In}(s) \rightarrow 2 \text{In}^{3+}(aq) + 3 \text{Co}(s)$

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

40. An electrolytic cell consists of two copper electrodes immersed in a solution of copper(II) sulfate. What is the result of passing 0.35 A of current through this cell for 1300 s?

- (A) The mass of the anode increases by 0.15 g.
 (B) The mass of the anode increases by 0.30 g.
 (C) The mass of the anode decreases by 0.15 g.
 (D) The mass of the anode decreases by 0.30 g.

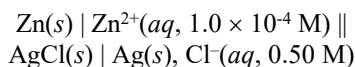
41. What is the change in standard free energy at 298 K for the conversion of ozone to molecular oxygen as shown in the equation below?



Half-Reaction	E° , V
$\text{O}_3(\text{g}) + 2 \text{H}^+(\text{aq}) + 2 e^- \rightarrow \text{O}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$	+2.08
$\text{O}_2(\text{g}) + 4 \text{H}^+(\text{aq}) + 4 e^- \rightarrow 2 \text{H}_2\text{O}(\text{l})$	+1.23

- (A) -164 kJ mol^{-1} (B) -328 kJ mol^{-1}
 (C) -401 kJ mol^{-1} (D) -492 kJ mol^{-1}

42. What is the cell potential of the following galvanic cell under the stated conditions at 298 K?



Half-Reaction	E° , V
$\text{Zn}^{2+}(\text{aq}) + 2 e^- \rightarrow \text{Zn}(\text{s})$	-0.762
$\text{AgCl}(\text{s}) + e^- \rightarrow \text{Ag}(\text{s}) + \text{Cl}^-(\text{aq})$	+0.222

- (A) +0.884 V (B) +0.984 V
 (C) +1.084 V (D) +1.120 V

43. For which element is the +2 oxidation state LEAST common?

- (A) Al (B) V (C) Fe (D) Sm

44. How many completely filled p orbitals are present in a ground state Cl atom?

- (A) 1 (B) 2 (C) 4 (D) 5

45. Which atom has the highest first ionization energy?

- (A) N (B) O (C) P (D) S

46. The electronegativity of gallium (1.8) is greater than that of aluminum (1.6). Which is the best explanation for this difference?

- (A) Ga is larger than Al, so its valence electrons experience less electron-electron repulsion.
 (B) Ga has more protons than Al, so its valence electrons are more attracted to the nucleus.
 (C) Ga has a filled $3d$ subshell, whose electrons incompletely screen the nucleus.
 (D) Ga experiences significant relativistic effects, which contract the valence orbitals.

47. Which set of quantum numbers could NOT correspond to an electron in a ground-state gas phase Pd atom?

- (A) $n = 2, l = 1, m_l = -1, m_s = 1/2$
 (B) $n = 3, l = 3, m_l = -1, m_s = -1/2$
 (C) $n = 4, l = 0, m_l = 0, m_s = -1/2$
 (D) $n = 4, l = 2, m_l = 2, m_s = 1/2$

48. A certain nuclide undergoes beta decay to form ^{70}Ge . If the same nuclide undergoes electron capture instead, what daughter nuclide forms?

- (A) ^{70}Zn (B) ^{70}Ga (C) ^{70}Ge (D) ^{70}As

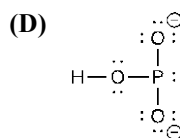
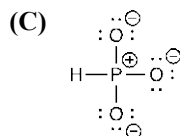
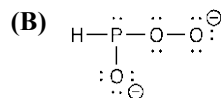
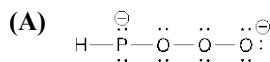
49. Which molecule is planar?

- (A) CF_4 (B) COF_2 (C) SF_4 (D) SOF_2

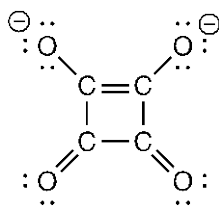
50. Which molecule has no unpaired electrons?

- (A) NO (B) O_2 (C) SO_2 (D) ClO_2

51. Phosphorous acid, H_3PO_3 , is a diprotic acid in aqueous solution ($\text{p}K_1 = 2.0$, $\text{p}K_2 = 6.6$). Which Lewis structure best represents HPO_3^{2-} ?

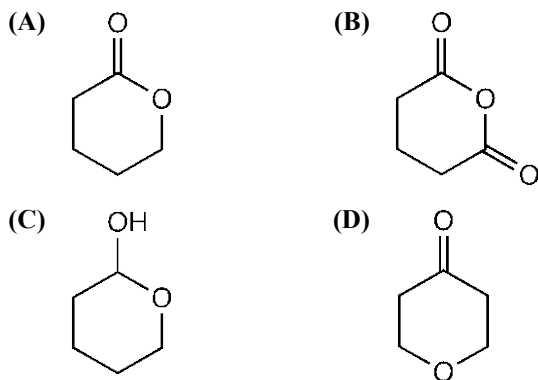


52. One Lewis structure of squarate ion, $C_4O_4^{2-}$, is shown below. Which statement best describes the bond distances in the squarate ion?

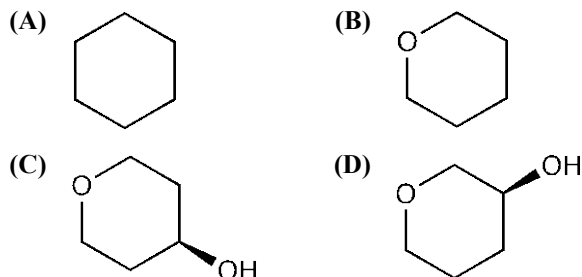


- (A) All carbon-carbon bond distances are the same, and all carbon-oxygen bond distances are the same.
 (B) There are two distinct carbon-carbon bond distances, but all carbon-oxygen bond distances are the same.
 (C) There are two distinct carbon-carbon bond distances, and two distinct carbon-oxygen bond distances.
 (D) There are three distinct carbon-carbon bond distances, and two distinct carbon-oxygen bond distances.
53. The bond distance in CO is 112.8 pm, while the bond distance in NO is 115 pm. Which is the best explanation for the shorter bond in CO?
- (A) Carbon has one fewer valence electron than nitrogen.
 (B) Carbon is less electronegative than nitrogen.
 (C) Carbon has a smaller atomic radius than nitrogen.
 (D) Carbon can form up to four bonds, while nitrogen can form only three.
54. How many stereoisomers does the square planar complex $Pt(NH_3)_2(Br)(Cl)$ have?
- (A) One (B) Two (C) Three (D) Four

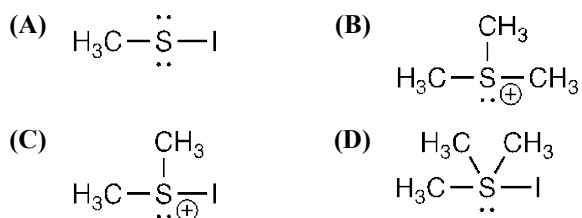
55. Which compound is an ester?



56. A pure substance is found to rotate the plane of plane-polarized light. Which compound is it?



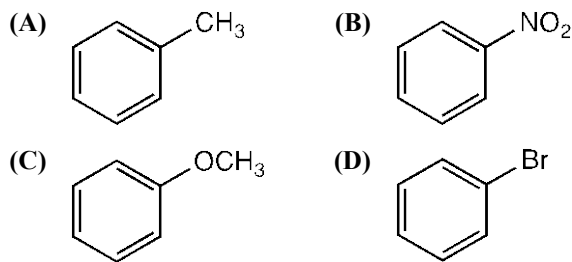
57. Which structure best represents the sulfur-containing species produced in the reaction of $(CH_3)_2S$ with CH_3I ?



58. How many distinct compounds have the formula C_5H_{12} ?

(A) One (B) Two (C) Three (D) Four

59. Which compound reacts the fastest in electrophilic aromatic substitution reactions (such as with Br_2 in the presence of $FeBr_3$)?



60. Which statement about unsaturated fats is NOT correct?

- (A) Unsaturated fats contain carbon-carbon double bonds.
 (B) Unsaturated fats generally have higher melting points than saturated fats with the same number of carbon atoms.
 (C) Unsaturated fats can be converted to saturated fats by treatment with H_2 in the presence of a metal catalyst.
 (D) Unsaturated fats must contain oxygen.

END OF TEST

Olympiad 2020
USNCO Local Section Exam
KEY

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