



ACS USNCO
U.S. National Chemistry Olympiad

2021 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>	molar mass	<i>M</i>
ampere	<i>A</i>	free energy	<i>G</i>	mole	mol
atmosphere	atm	frequency	ν	Planck's constant	<i>h</i>
atomic mass unit	<i>u</i>	gas constant	<i>R</i>	pressure	<i>P</i>
Avogadro constant	N_A	gram	<i>g</i>	rate constant	<i>k</i>
Celsius temperature	°C	hour	<i>h</i>	reaction quotient	<i>Q</i>
centi- prefix	<i>c</i>	joule	<i>J</i>	second	<i>s</i>
coulomb	<i>C</i>	kelvin	<i>K</i>	speed of light	<i>c</i>
density	<i>d</i>	kilo- prefix	<i>k</i>	temperature, K	<i>T</i>
electromotive force	<i>E</i>	liter	<i>L</i>	time	<i>t</i>
energy of activation	E_a	measure of pressure mm Hg		vapor pressure	VP
enthalpy	<i>H</i>	milli- prefix	<i>m</i>	volt	<i>V</i>
entropy	<i>S</i>	molal	<i>m</i>	volume	<i>V</i>
equilibrium constant	<i>K</i>	molar	<i>M</i>	year	<i>y</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	13 B 10.81	14 C 12.01	15 N 14.01	16 O 16.00	17 F 19.00	18 Ne 20.18										
11 Na 22.99	12 Mg 24.31	3 B	4 C	5 N	6 O	7 F	8 Ne	9 Al 26.98	10 Si 28.09	11 P 30.97	12 S 32.07	13 Cl 35.45	14 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)

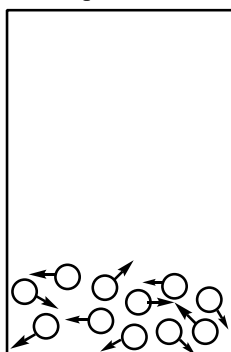
58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 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.**

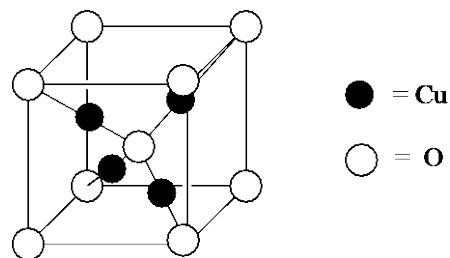
1. At 120 °C and 1 atm pressure, 1.00 L of methane, CH₄, reacts completely with excess oxygen to form carbon dioxide and water. What volumes of the two products are produced at this pressure and temperature?
(A) 1.00 L CO₂ and 2.00 L H₂O
(B) 1.00 L CO₂ and 4.00 L H₂O
(C) 2.00 L CO₂ and 2.00 L H₂O
(D) 2.00 L CO₂ and 4.00 L H₂O
2. Polypropylene is made by polymerizing propene, C₃H₆ (*M* = 42.1). How many molecules of propene must be polymerized to make 3.50 g polypropylene?
(A) 1.43×10^{22} (B) 5.01×10^{22}
(C) 6.02×10^{23} (D) 2.11×10^{24}
3. An organic compound contains only carbon, hydrogen, nitrogen, and oxygen. It is 61.71% C, 4.03% H, and 16.00% N by mass. What is its empirical formula?
(A) C₅H₄NO (B) C₉H₇N₂O₂
(C) C₁₀H₈N₂O (D) C₁₁H₈NO₂
4. 100.0 mL of 0.500 M CaBr₂ and 50.0 mL of 1.00 M NaBr are mixed. What is the concentration of bromide ion in the resulting solution?
(A) 0.500 M (B) 0.667 M
(C) 0.750 M (D) 1.00 M
5. 1.00 g of hydrated potassium carbonate, K₂CO₃·*n*H₂O, is heated to 250 °C to give 0.836 g anhydrous K₂CO₃. What is the value of *n*?
(A) 0.16 (B) 1.0 (C) 1.5 (D) 2.0
6. The concentration of an aqueous solution of a nonvolatile, monoprotic acid is measured first by freezing point depression and then by boiling point elevation. The solution is found to be 0.93 *m* by freezing point depression and to be 0.82 *m* by boiling point elevation. Which is the best explanation for this discrepancy?
(A) Ionization of the acid is markedly exothermic.
(B) The solute associates partially into dimers at lower temperatures.
(C) The volume of the solution is greater at higher temperatures.
(D) The boiling point elevation constant for water is smaller than its freezing point depression constant.
7. When substances are separated by fractional distillation, which property is least typical of the substance that distills first?
(A) Highest molar mass
(B) Weakest intermolecular forces
(C) Greatest vapor pressure
(D) Lowest boiling point
8. Which element is most abundant (by mass) in the Earth's crust?
(A) Carbon (B) Oxygen
(C) Magnesium (D) Silicon
9. Which gas has the highest molar solubility in water at 25 °C and 1 atm?
(A) CO₂ (B) NH₃ (C) O₂ (D) H₂S
10. Which compound is colorless?
(A) NaMnO₄ (B) CrAsO₄
(C) RbIO₄ (D) BaCrO₄

11. Chlorine gas is bubbled into a colorless aqueous solution of sodium iodide. Which is the best description of what takes place?
- (A) A precipitate of white NaCl forms.
 (B) A precipitate of metallic Na forms.
 (C) The solution turns pale green as the chlorine dissolves.
 (D) The solution turns yellow-brown as iodide reacts with the chlorine.
12. A student determines the number of moles of water in a hydrated metal oxide by weighing a clean, dry crucible and lid while the crucible is empty, then reweighing the crucible and lid with a sample of the hydrate, heating the crucible and lid with a Bunsen burner and then reweighing the crucible and lid with the sample after cooling to room temperature. Which error will result in too high a value for the amount of water of hydration?
- (A) The heating is conducted only once instead of the three times recommended by the procedure.
 (B) The lid is left off the crucible when it is weighed with the hydrated oxide.
 (C) The metal oxide reacts partially with oxygen in the air, forming a compound in a higher oxidation state.
 (D) Some of the heated oxide is spilled from the crucible before it can be weighed.
13. The diagram is a microscopic view of a snapshot of a substance at equilibrium, with the circles representing molecules and the arrows the molecules' velocities. What state of matter is depicted?



- (A) Solid (B) Liquid (C) Gas (D) Plasma
14. The vapor density of which fluorocarbon is 6.17 g L^{-1} at $23 \text{ }^\circ\text{C}$ and 1.00 atm ?
- (A) C_3F_6 (B) C_3F_8 (C) C_4F_6 (D) C_4F_8

15. What is the principal intermolecular force that must be overcome when *n*-hexane (C_6H_{14} , bp = $69 \text{ }^\circ\text{C}$) is vaporized?
- (A) Hydrogen bonding
 (B) Covalent bonding between carbon atoms
 (C) Dipole-dipole forces
 (D) London dispersion forces
16. The melting point of water decreases with increasing pressure. Which is the best explanation for this observation?
- (A) Liquid water is denser than solid water at $0 \text{ }^\circ\text{C}$.
 (B) Melting of ice is endothermic at $0 \text{ }^\circ\text{C}$.
 (C) The vapor pressure of liquid water is lower than the vapor pressure of solid water at $0 \text{ }^\circ\text{C}$.
 (D) Solid and liquid water cannot coexist at equilibrium at $0 \text{ }^\circ\text{C}$ at pressures different from 1 atm .
17. A cylinder containing a mixture of CO and CO_2 has a pressure of 2.00 atm at $93 \text{ }^\circ\text{C}$ (366 K). The cylinder is then cooled to $-90 \text{ }^\circ\text{C}$ (183 K), where CO is still a gas but CO_2 is a solid with a vapor pressure of 0.25 atm . The pressure in the cylinder at this temperature is 0.90 atm . What is the mole fraction of CO_2 in the cylinder?
- (A) 0.10
 (B) 0.28
 (C) 0.35
 (D) It cannot be determined from the information given.
18. A mineral containing only copper and oxygen adopts the cubic unit cell shown below. What is the formula of this mineral?



- (A) Cu_2O (B) CuO (C) Cu_3O_2 (D) Cu_4O_9
19. Burning 48.0 g of graphite in excess oxygen under standard conditions releases 1574.0 kJ of heat. What is ΔH°_f of $\text{CO}_2(\text{g})$?
- (A) 1574 kJ mol^{-1} (B) $-1574 \text{ kJ mol}^{-1}$
 (C) -394 kJ mol^{-1} (D) 32.8 kJ mol^{-1}

20. Two metal samples, labeled A and B, absorb the same amount of heat. Sample A has a mass of 10.0 g, and its temperature increases by 38 °C. Sample B has a mass of 20.0 g, and its temperature increases by 23 °C. Which sample has the greater specific heat capacity?

- (A) Sample A
 (B) Sample B
 (C) Both samples have the same specific heat capacity.
 (D) It is impossible to determine from the information given.

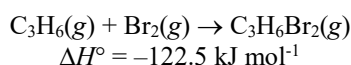
21. A reaction has $\Delta S^\circ > 0$ and $\Delta H^\circ > 0$. Which statement about this reaction must be correct?

- (A) If carried out in a well-insulated flask, the temperature of the reaction mixture will decrease.
 (B) It will occur spontaneously at 298 K and 1 atm pressure.
 (C) As the temperature is raised, K_{eq} for this reaction decreases.
 (D) The reaction has more moles of products than it has moles of reactants.

22. What is the boiling point of water in a pressure cooker with a pressure of 2.00 atm? (The enthalpy of vaporization of water is 40.7 kJ mol⁻¹.)

- (A) 101 °C (B) 121 °C (C) 141 °C (D) 200 °C

23. The gas-phase bromination of propene has a standard enthalpy of reaction of -122.5 kJ mol⁻¹.



Substance	ΔH°_f , kJ mol ⁻¹
C ₃ H ₆ (g)	20.4
Br ₂ (g)	30.9

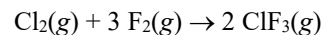
What is the standard enthalpy of formation of C₃H₆Br₂(g)?

- (A) -71.2 kJ mol⁻¹ (B) -102.1 kJ mol⁻¹
 (C) -142.9 kJ mol⁻¹ (D) -173.8 kJ mol⁻¹

24. Titanium has a normal melting point of 1668 °C and a molar enthalpy of fusion of 14.15 kJ mol⁻¹. The standard molar entropy of liquid titanium is 97.53 J mol⁻¹ K⁻¹ at 1668 °C. What is the standard molar entropy of solid titanium at this temperature?

- (A) 89.05 J mol⁻¹ K⁻¹ (B) 90.24 J mol⁻¹ K⁻¹
 (C) 97.52 J mol⁻¹ K⁻¹ (D) 104.82 J mol⁻¹ K⁻¹

25. In the reaction



the rate of disappearance of F₂(g) is 1.0 M s⁻¹. What is the rate of appearance of ClF₃(g)?

- (A) 0.33 M s⁻¹ (B) 0.67 M s⁻¹
 (C) 1.0 M s⁻¹ (D) 1.5 M s⁻¹

26. When the rate of the reversible reaction $\text{A} + \text{B} \rightleftharpoons \text{C}$ is studied under a certain set of conditions, it is found that the rate of the forward reaction is $k_f[\text{A}]$. What can be concluded about the rate law for the reverse reaction under these conditions?

- (A) Rate = $k_r[\text{C}]$
 (B) Rate = $k_r \frac{[\text{C}]}{[\text{B}]}$
 (C) The rate law of the reverse reaction cannot be determined from the information given.
 (D) An error must have been made, since if the reaction is reversible, the forward rate law must be Rate = $k_f[\text{A}][\text{B}]$.

27. A substance A decomposes irreversibly to form B. A plot of ln([A]) as a function of time from the beginning of the reaction until A is 97% consumed is a straight line with a negative slope. What is the reaction order in A?

- (A) Zero order (B) First order
 (C) Second order (D) Third order

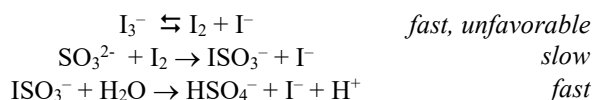
28. Which statement about catalysis is correct?

- (A) If a catalyst increases the forward rate of a reaction by a factor of two, it must increase the rate of the reverse reaction by a factor of two.
 (B) If a catalyst increases the rate of formation of a product by a factor of two, it must increase the rate of formation of the mirror image of the product by a factor of two.
 (C) A catalyst must be in the same phase as the reactants and products of the reaction.
 (D) A catalyzed reaction must proceed by the same mechanism as the uncatalyzed reaction, but with a lower activation energy.

29. The isotope ²²⁶Ra has a half-life for radioactive decay of 1600 y. How long will it take the amount of ²²⁶Ra in a sample of ²²⁶RaCl₂ to decrease by 25%?

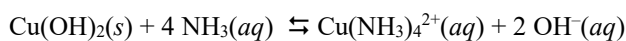
- (A) 660 y (B) 800 y (C) 1200 y (D) 1600 y

30. The oxidation of sulfite ion by triiodide ion is proposed to take place by the following mechanism:



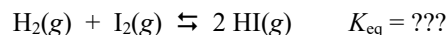
What rate law is predicted by this mechanism?

- (A) Rate = $k[\text{I}_3^-]$
 (B) Rate = $k[\text{I}_3^-][\text{SO}_3^{2-}]$
 (C) Rate = $\frac{k[\text{I}_3^-][\text{SO}_3^{2-}]}{[\text{I}^-]}$
 (D) Rate = $\frac{k[\text{I}_3^-][\text{SO}_3^{2-}]}{[\text{H}^+]}$
31. What is the correct equilibrium expression for the given reaction?



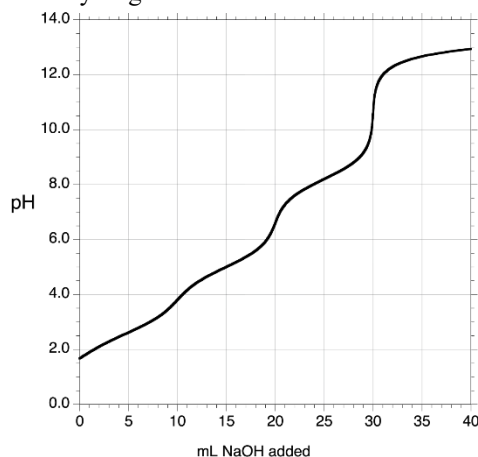
- (A) $K_{\text{eq}} = \frac{[\text{Cu}(\text{NH}_3)_4^{2+}][\text{OH}^-]}{[\text{NH}_3]}$
 (B) $K_{\text{eq}} = \frac{[\text{Cu}(\text{NH}_3)_4^{2+}][2 \text{OH}^-]}{[4 \text{NH}_3]}$
 (C) $K_{\text{eq}} = \frac{[\text{Cu}(\text{NH}_3)_4^{2+}][\text{OH}^-]^2}{[\text{NH}_3]^4}$
 (D) $K_{\text{eq}} = \frac{[\text{Cu}(\text{NH}_3)_4^{2+}][2 \text{OH}^-]^2}{[4 \text{NH}_3]^4}$
32. 0.100 mol of HF ($K_a = 6.6 \times 10^{-4}$) is added to water to make 1.00 L of solution. Which statement is correct at equilibrium?
- (A) $[\text{H}_3\text{O}^+] = [\text{HF}]$ (B) $[\text{H}_3\text{O}^+] = 0.100 \text{ M}$
 (C) $[\text{HF}] > [\text{F}^-]$ (D) $[\text{H}_3\text{O}^+] > [\text{HF}]$
33. What is the solubility of silver oxalate, $\text{Ag}_2\text{C}_2\text{O}_4$ ($K_{\text{sp}} = 3.5 \times 10^{-11}$), in a 0.050 M sodium oxalate solution?
- (A) $1.4 \times 10^{-8} \text{ M}$ (B) $5.9 \times 10^{-6} \text{ M}$
 (C) $1.3 \times 10^{-5} \text{ M}$ (D) $2.1 \times 10^{-4} \text{ M}$
34. A pure sample of a monoprotic acid is dissolved in water. The sample is titrated with sodium hydroxide solution. At the point where 20.0 mL of the NaOH solution has been added, the pH is 4.15. The phenolphthalein endpoint of the titration is observed when 50.0 mL of NaOH have been added. What is the $\text{p}K_a$ of the acid?
- (A) 4.15 (B) 4.33 (C) 4.55 (D) 5.19

35. Consider the reaction:



Into a 1.00 L vessel, 1.00 mol $\text{H}_2(\text{g})$ and 1.00 mol $\text{I}_2(\text{g})$ are placed at a high temperature. When the reaction mixture stops changing, it is found that 79.0% of the $\text{H}_2(\text{g})$ has reacted. What is the equilibrium constant for this reaction at this temperature?

- (A) 14.2 (B) 17.9 (C) 35.8 (D) 56.6
36. A triprotic acid is titrated with sodium hydroxide to give the titration curve below. What are the $\text{p}K_a$ values of the three acidic hydrogens?

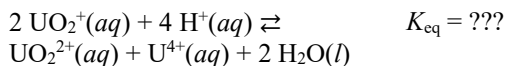


- (A) 2.6, 5.0, 8.2 (B) 3.8, 6.6, 10.6
 (C) 3.8, 8.2, 12.7 (D) 5.0, 8.2, 12.7
37. What is the average oxidation state of tin in the mineral abhurite, $\text{Sn}_{21}\text{Cl}_{16}(\text{OH})_{14}\text{O}_6$?
- (A) +1.71 (B) +2.00 (C) +2.76 (D) +3.43
38. If used in an electrochemical cell, which of the following half-reactions would require an inert electrode?
- I. $2 \text{Cl}^-(\text{aq}) \rightleftharpoons \text{Cl}_2(\text{g}) + 2 e^-$
 II. $\text{Fe}(\text{CN})_6^{3-}(\text{aq}) + e^- \rightleftharpoons \text{Fe}(\text{CN})_6^{4-}(\text{aq})$
- (A) I only (B) II only
 (C) Both I and II (D) Neither I nor II
39. Chromium is electroplated industrially by the electrolysis of solutions of $\text{K}_2\text{Cr}_2\text{O}_7$. How much time would be required to deposit 1.00 kg of Cr using a current of 200.0 A?
- (A) 2.58 h (B) 7.74 h (C) 15.5 h (D) 31.0 h

40. What is the standard reduction potential of $\text{Cr}^{3+}(\text{aq})$ to form metallic chromium?

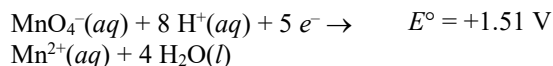
Half-reaction	E° , V
$\text{Cr}^{3+}(\text{aq}) + e^- \rightarrow \text{Cr}^{2+}(\text{aq})$	-0.41
$\text{Cr}^{2+}(\text{aq}) + 2e^- \rightarrow \text{Cr}(s)$	-0.91
$\text{Cr}^{3+}(\text{aq}) + 3e^- \rightarrow \text{Cr}(s)$???

- (A) -0.74 V (B) -1.32 V
(C) -1.73 V (D) -2.23 V
41. What is the equilibrium constant at 298 K for the disproportionation of uranium(V) in acidic solution as shown below?



Half-reaction	E° , V
$\text{UO}_2^{2+}(\text{aq}) + e^- \rightarrow \text{UO}_2^+(\text{aq})$	+0.16
$\text{UO}_2^+(\text{aq}) + 4 \text{H}^+(\text{aq}) + e^- \rightarrow \text{U}^{4+}(\text{aq}) + 2 \text{H}_2\text{O}(l)$	+0.27

- (A) 1.9×10^{-4} (B) 73
(C) 5300 (D) 1.9×10^7
42. The standard reduction potential E° for the reduction of permanganate in acidic solution is +1.51 V. What is the reduction potential for this half-reaction at pH = 5.00?



- (A) +1.50 V (B) +1.42 V
(C) +1.04 V (D) -0.85 V
43. Which is a possible set of quantum numbers n, l, m_l, m_s for a valence electron of sulfur (S)?
- (A) 3, 2, 2, $1/2$ (B) 3, 1, -1, $1/2$
(C) 2, 1, 0, $1/2$ (D) 3, 2, 0, $-1/2$
44. Which period 3 element has these successive ionization energies (in kJ mol^{-1})?

IE_1	IE_2	IE_3	IE_4
786.5	1577.1	3231.6	4355.5
IE_5	IE_6	IE_7	
16091	19805	23780	

- (A) Al (B) Si (C) P (D) S

45. Which is the ground-state electron configuration of gas-phase Co^{2+} ?

- (A) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^7$
(B) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^5$
(C) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 4d^5$
(D) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^7$

46. A fluorescent dye absorbs a photon of light of 485 nm and emits a photon of light at 540 nm. How much energy is lost as heat?

- (A) 4.17×10^{-20} J (B) 3.68×10^{-19} J
(C) 4.10×10^{-19} J (D) 3.06×10^{-18} J

47. Which gas-phase atom releases the most energy when an electron is added to it?

- (A) Na (B) Cl (C) K (D) Br

48. The isotope ^{44}Ti undergoes electron capture. Which daughter isotope is produced?

- (A) ^{40}K (B) ^{40}Ca (C) ^{44}Sc (D) ^{44}V

49. Which species has the strongest carbon-oxygen bond?

- (A) CO (B) CO_2
(C) CH_2O (D) CH_3OH

50. Which molecule has a nonzero dipole moment?

- (A) O_2 (B) O_3 (C) S_8 (D) SO_3

51. Which statement best describes the structure and bonding in nitromethane, $\text{H}_3\text{C}-\text{NO}_2$?

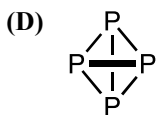
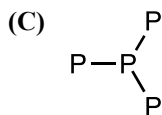
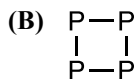
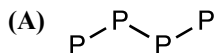
- (A) Each of the three bonds to nitrogen is a different length.
(B) The molecule is Lewis acidic because the nitrogen does not obey the octet rule.
(C) The molecule is Lewis basic because the nitrogen has a lone pair.
(D) The nitrogen atom has a trigonal planar geometry.

52. Which statements about the superoxide ion, O_2^- , are correct?

- I. It has a bond order of 2.0.
II. It has exactly one unpaired electron.

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

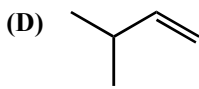
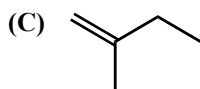
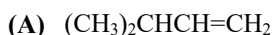
53. Which structure best depicts the three-dimensional shape of the P_4 molecule?



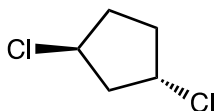
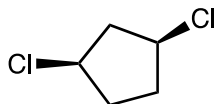
54. How many isomers are there of the octahedral coordination complex $Co(NH_3)_3Cl_3$?

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

55. Which is NOT a valid representation of 3-methyl-1-butene?



56. What is the relationship between the two compounds shown?



- (A) Identical (B) Structural isomers
(C) Geometric isomers (D) Mirror image isomers

57. An amine with the formula $C_4H_{11}N$ will have which of these properties?

- (A) Unpleasant odor
(B) Boiling point greater than $100\text{ }^\circ\text{C}$
(C) Absorption of light with $\lambda > 450\text{ nm}$
(D) Water solubility less than 10 g/L

58. Which combination of reactants and catalyst will produce methyl propanoate, $CH_3CH_2COOCH_3$, upon heating?

- (A) CH_3CH_2OH and CH_3COOH with catalytic $NaOH$
(B) CH_3CH_2OH and CH_3COOH with catalytic H_2SO_4
(C) CH_3OH and CH_3CH_2COOH with catalytic $NaOH$
(D) CH_3OH and CH_3CH_2COOH with catalytic H_2SO_4

59. Which conformation of cyclohexane (C_6H_{12}) is most stable?



60. Which element is NOT present in DNA?

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

END OF TEST

Olympiad 2021
USNCO Local Section Exam
KEY

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