2018 U. S. NATIONAL CHEMISTRY OLYMPIAD

NATIONAL EXAM PART I

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

James Ayers, *Colorado Mesa University*, Grand Junction, CO
Mark DeCamp, *University of Michigan*, Dearborn, MI (retired)
Marian DeWane, *Centennial High School*, Boise, ID
Xu Duan, *Holton-Arms School*, Bethesda, MD
Valerie Ferguson, *Moore HS*, Moore, OK
Julie Furstenau, *Thomas B. Doherty HS*, Colorado Springs, CO
Kimberly Gardner, *United States Air Force Academy*, CO
Paul Groves, *South Pasadena HS*, South Pasadena, CA
Nicolas Hamel, *Clackamas Community College*, Oregon City, OR
David W. Hostage, *Taft School*, Watertown, CT
John Kotz, *State University of New York*, Oneonta, NY (retired)
Jane Nagurney, *Scranton Preparatory School*, Scranton, PA
Sheila Nguyen, *Cypress College*, Cypress, CA
Ronald Ragsdale, *University of Utah*, Salt Lake City, UT (retired)

DIRECTIONS TO THE EXAMINER – PART I

The USNCO Subcommittee continues conducting a survey in an effort to determine the impact of the Olympiad program on students. At the end of the exam there are four questions, which should be answered on the same Scantron sheet students use for the exam. These questions may be administered after the 90 minutes allotted for the exam, each student should be encouraged to answer these questions.

Part I of this test is designed to be taken with a Scantron answer sheet on which the student records his or her responses. Only this Scantron sheet is graded for a score on Part I. Testing materials, scratch paper, and the Scantron sheet should be made available to the student *only* during the examination period. All testing materials including scratch paper should be turned in and kept secure until **April 23, 2018**, after which tests can be returned to students and their teachers for further study.
Allow time for students to read the directions, ask questions, and fill in the requested information on the Scantron sheet. The answer sheet must be completed using a pencil, not pen. When the student has completed **Part I**, or after **one hour and thirty minutes** has elapsed, the student must turn in the Scantron sheet, Part I of the testing materials, and all scratch paper.
There are three parts to the National Chemistry Olympiad Examination. You have the option of administering the three parts in any order, and you are free to schedule rest breaks between parts.

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

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

Students should be permitted to use non-programmable calculators. The use of a programmable calculator, cell phone, watch, or any other device that can access the internet or make copies or photographs during the exam is grounds for disqualification.

DIRECTIONS TO THE EXAMINEE – DO NOT TURN THE PAGE UNTIL DIRECTED TO DO SO. Answers to questions in Part I must be entered on a Scantron answer sheet to be scored. Be sure to write your name on the answer sheet, an ID number is already entered for you. **Make a record of this ID number because you will use the same number on Parts II and III.** Each item in **Part I** consists of a question or an incomplete statement that is followed by four possible choices. Select the single choice that best answers the question or completes the statement. Then use a pencil to blacken the space on your answer sheet next to the same letter as your choice. You may write on the examination, but the test booklet will not be used for grading. Scores are based on the number of correct responses. When you complete **Part I** (or at the end of one hour and 30 minutes), you must turn in all testing materials, scratch paper, and your Scantron answer sheet. **Do not forget to turn in your U.S. citizenship/Green Card Holder statement before leaving the testing site today.**

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
$R = 8.314$ J mol^{-1} K^{-1}
$R = 0.08314$ L bar mol^{-1} K^{-1}
$F = 96{,}500$ C mol^{-1}
$F = 96{,}500$ J V^{-1} mol^{-1}
$N_A = 6.022 \times 10^{23}$ mol^{-1}
$h = 6.626 \times 10^{-34}$ J s
$c = 2.998 \times 10^{8}$ m s^{-1}
0 °C = 273.15 K
1 atm = 1.013 bar = 760 mm Hg
Specific heat capacity of H_2O = 4.184 J g^{-1} K^{-1}

EQUATIONS

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

PERIODIC TABLE OF THE ELEMENTS

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

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

DIRECTIONS

- When you have selected your answer to each question, blacken the corresponding space on the answer sheet using a 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. Upon heating in a stream of hydrogen gas, 0.688 g of a manganese oxide is reduced to metallic manganese and forms 0.235 g water. What is the formula of the oxide?

(A) MnO **(B)** Mn_2O_3 **(C)** Mn_3O_4 **(D)** MnO_2

2. Which 1.00 g sample of an element contains the greatest number of molecules?

(A) Buckminsterfullerene, C_{60}

(B) Ozone, O_3

(C) White phosphorus, P_4

(D) Sulfur, S_8

3. Hydrogen gas reacts with 5.00 L of nitrogen gas under constant temperature and pressure conditions to form 10.0 L of ammonia gas. What is the minimum volume of hydrogen gas required to produce this amount of ammonia?

(A) 5.00 L **(B)** 7.50 L **(C)** 15.0 L **(D)** 30.0 L

4. Phosphoric acid can be manufactured according to the following reaction:

$$Ca_3(PO_4)_2 + 3\ SiO_2 + 5\ C + 5\ O_2 + 3\ H_2O \rightarrow 3\ CaSiO_3 + 5\ CO_2 + 2\ H_3PO_4$$

If *equal masses* of calcium phosphate (M = 310.) and silica (M = 60.0) are reacted with excess carbon, oxygen, and water to produce 1.00×10^3 kg phosphoric acid (M = 98.0), what mass of calcium phosphate was used, assuming 100% yield?

(A) 610. kg **(B)** 800. kg

(C) 920. kg **(D)** 1580 kg

5. After mixing 30.0 mL of 0.30 M $Ca(NO_3)_2$ solution and 15.0 mL of 0.60 M NaF solution, which ions are present in solution at concentrations of at least 0.10 M?

I. Ca^{2+} II. F^-

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

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

6. A salt whose formula is $Na_2S_xO_y$ is 47.5% sulfur by mass. What is the value of x in the formula?

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

7. Which salt is diamagnetic?

(A) $K_2[NO(SO_3)_2]$ **(B)** $K_4[Fe(CN)_6]$

(C) $Ce_2(SO_4)_3$ **(D)** $Hg[Co(SCN)_4]$

8. Which titration would NOT require the addition of an indicator?

(A) Determination of oxalate ion by titration with permanganate ion in acidic solution

(B) Determination of chloride ion by titration with silver ion

(C) Determination of acetic acid by titration with sodium hydroxide

(D) Determination of ammonia by titration with hydrochloric acid

9. A 1 mL sample of a 0.1 M solution of a divalent metal ion is pale pink. To it is added 1 mL of concentrated HCl, which causes a color change to bright blue. What is the metal ion?

(A) Ca^{2+} **(B)** Mn^{2+} **(C)** Co^{2+} **(D)** Cu^{2+}

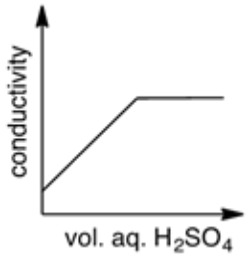
10. A copper-nickel alloy is analyzed by dissolving it in 8 M nitric acid, diluting the solution with water, and then adding 1 mL of this diluted solution to an excess of aqueous potassium iodide. What are the principal forms of copper and nickel in this final mixture?

(A) $Cu^{2+}(aq)$, $Ni^{3+}(aq)$ **(B)** $CuI_2(s)$, $NiI_2(s)$

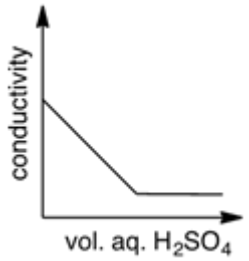
(C) $CuI(s)$, $Ni^{2+}(aq)$ **(D)** $Cu^{+}(aq)$, $Ni(s)$

11. A dilute solution of sulfuric acid is titrated into a solution of barium hydroxide and the conductivity of the solution is measured as a function of the added volume of sulfuric acid. Which graph represents the results of this experiment?

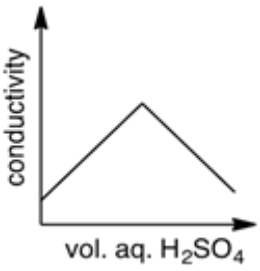
(A)



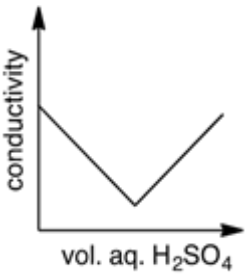
(B)



(C)



(D)



12. Which is the best way to prepare 500 mL of a 2.00 M solution of aqueous H_2SO_4 from deionized water (M = 18.02, density = 1.00 g mL^{-1}) and concentrated H_2SO_4 (M = 98.08, density = 1.84 g mL^{-1})?

(A) Weigh 98.1 g concentrated sulfuric acid into a 500-mL beaker, then slowly add deionized water to the beaker, with occasional swirling, until the liquid reaches the 500 mL mark.

(B) Weigh 98.1 g concentrated sulfuric acid into a 500-mL volumetric flask, slowly add deionized water to the mark, and mix.

(C) Weigh 98.1 g concentrated sulfuric acid into a 100-mL beaker, then slowly pour the H_2SO_4 into a 500-mL beaker with about 250 mL deionized water in it. Pour this solution into a 500-mL volumetric flask and fill to the mark with deionized water and mix.

(D) Weigh 446.6 g deionized water into a 500-mL volumetric flask, fill to the mark with concentrated sulfuric acid, and mix.

13. A substance has a density of 2.38 g mL^{-1} and is not significantly compressible. The substance is most likely in which physical state?

(A) Solid

(B) Liquid

(C) Gas

(D) Solid or liquid; there is not enough information given to distinguish between the two

14. Carbon tetrachloride, CCl_4, has a higher normal boiling point than chloroform, $CHCl_3$ (77 ºC vs. 61 ºC). Differences in which interactions contribute the most to this difference in boiling point?

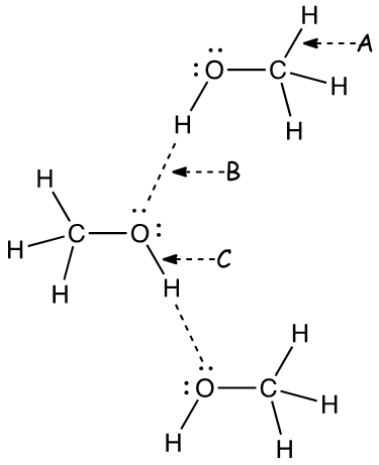
(A) Hydrogen bonding

(B) Dipole-dipole interactions

(C) London dispersion forces

(D) Covalent bonding

15. The diagram represents a molecular view of a sample of liquid methanol, CH_3OH. Which letters in the diagram show hydrogen bonds?



(A) *A* only **(B)** *B* only

(C) *C* only **(D)** *A* and *C*

16. The triple point of ammonia is 195.40 K at 0.006 bar, while its melting point is 195.42 K at 1 bar pressure. Which statement about ammonia is correct?

(A) Solid ammonia is denser than liquid ammonia at 195.4 K.

(B) Ammonia vapor cannot coexist with liquid ammonia at equilibrium at 195.5 K.

(C) Ammonia vapor cannot coexist with solid ammonia at equilibrium at 195.3 K.

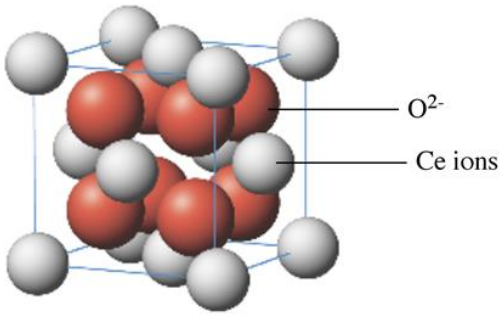
(D) Solid ammonia and liquid ammonia cannot coexist at equilibrium at 195.5 K.

17. Acetone, C_3H_6O, has a vapor pressure of 0.307 bar at 25 ºC. A sample of 0.100 mol acetone is added to a container that contains 1.00 L of argon gas at 1.00 bar pressure and 25 ºC. The volume of the container is then increased to 4.00 L while maintaining the same temperature. What is the pressure in the container after the expansion?

(A) 0.250 bar **(B)** 0.307 bar

(C) 0.557 bar **(D)** 0.870 bar

18. What is the formula of the oxide whose unit cell is shown?



(A) Ce_7O_4 **(B)** CeO **(C)** Ce_2O_3 **(D)** CeO_2

19. A spontaneous endothermic chemical reaction takes place at constant pressure and volume in a well-insulated container. As the reaction proceeds, what happens to the temperature of the system and to the internal energy of the reactants as they are transformed into products?

(A) Both the temperature and the reactants' internal energy increase.

(B) The temperature increases while the reactants' internal energy decreases.

(C) The temperature decreases while the reactants' internal energy increases.

(D) Both the temperature and the reactants' internal energy decrease.

20. What is the standard heat of formation (ΔH^o_f) of gaseous ethylene, $C_2H_4(g)$?

$H_2(g) + \frac{1}{2} O_2(g) \rightarrow H_2O(g)$ $\Delta H^o = -242$ kJ mol^{-1}

$2\ C(s, \text{graphite}) + 3\ H_2(g) + \frac{1}{2} O_2(g) \rightarrow C_2H_5OH(l)$ $\Delta H^o = -278$ kJ mol^{-1}

$C_2H_4(g) + H_2O(g) \rightarrow C_2H_5OH(l)$ $\Delta H^o = -88$ kJ mol^{-1}

(A) 16 kJ mol^{-1} **(B)** 52 kJ mol^{-1}

(C) 83 kJ mol^{-1} **(D)** 285 kJ mol^{-1}

21. The K_{sp} of AgBr is 5.0×10^{-13} at 25.0 ºC and 6.5×10^{-12} at 50.0 ºC. What is ΔH^o_{rxn} for the precipitation of AgBr shown?

$Ag^+(aq) + Br^-(aq) \rightarrow AgBr(s)$ $\Delta H^o_{rxn} = ???$

(A) –82 kJ mol^{-1} **(B)** –1.1 kJ mol^{-1}

(C) 1.1 kJ mol^{-1} **(D)** 82 kJ mol^{-1}

22. For benzene, C_6H_6, the heat of fusion is 9.9 kJ mol^{-1} at its melting point of 5 ºC, its heat of vaporization is 30.8 kJ mol^{-1} at its normal boiling point of 80 ºC, and the molar heat capacity of the liquid is 135 J mol^{-1} K^{-1}. To a system consisting of 1.00 mol pure solid C_6H_6 at 5 ºC is added 20.0 kJ of heat while maintaining the pressure at 1 atm. In what phases is the benzene found?

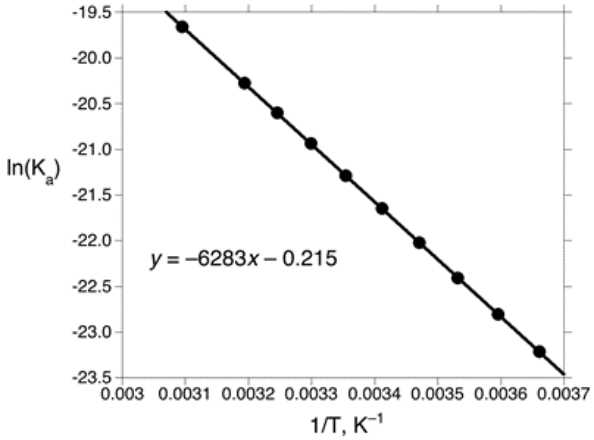
(A) Mixture of solid and liquid

(B) Liquid only

(C) Mixture of liquid and gas

(D) Gas only

23. The natural logarithm of the K_a of NH_4^+ is plotted below as a function of the reciprocal of the absolute temperature.



Which statements are correct?

I. The pH of a 0.100 M solution of NH_4NO_3 increases as the temperature is raised.

II. ΔS^o for the acid dissociation of ammonium ion is positive.

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

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

24. The molar heat capacity of ice is 37 J mol^{-1} K^{-1} and the molar heat capacity of liquid water is 76 J mol^{-1} K^{-1}. What can be concluded about the relative magnitudes of the heat of fusion of ice at 263 K (ΔH_{263}) compared to the heat of fusion of ice at 273 K (ΔH_{273})?

(A) $\Delta H_{263} < \Delta H_{273}$

(B) $\Delta H_{263} = \Delta H_{273}$

(C) $\Delta H_{263} > \Delta H_{273}$

(D) No conclusion about the relative magnitudes of the heats of fusion can be drawn based on the information given.

25. The rate constant k for the reaction shown is 1.63×10^{-6} M^{-1} s^{-1}. What is the overall order of the reaction?

$$2\ ICl(g) + H_2(g) \rightarrow 2\ HCl(g) + I_2(g)$$

(A) 0 **(B)** 1 **(C)** 2 **(D)** 3

26. The initial rate of the reaction A + B → products varies with the initial concentrations of A and B as follows:

[A], M	[B], M	Initial rate, M s^{-1}
0.20	0.30	2.1×10^{-4}
0.40	0.30	4.2×10^{-4}
0.20	0.90	1.9×10^{-3}

What is the rate law for this reaction?

(A) Rate = k[A] **(B)** Rate = k[A][B]

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

27. Polonium-210 undergoes alpha decay with a half-life of 138 d, forming the stable isotope lead-206. How much time would it take for the activity of a ^{210}Po sample to decrease to 15.0% of its initial value?

(A) 138 d **(B)** 182 d **(C)** 276 d **(D)** 377 d

28. An irreversible reaction A + B → products is studied under conditions where the initial concentrations of A and B are equal. Under these circumstances, a graph of ln([A]) as a function of time is linear. What is the order in A?

(A) Zeroth order

(B) First order

(C) Second order

(D) The order in A cannot be determined based on the information given.

29. Nitric oxide reacts with hydrogen according to the following equation:

$$2\ NO(g) + 2\ H_2(g) \rightarrow N_2(g) + 2\ H_2O(g)$$

A possible mechanism for this reaction is

$2\ NO(g) \leftrightarrows N_2O_2(g)$ fast, unfavorable

$N_2O_2(g) + H_2(g) \rightarrow N_2O(g) + H_2O(g)$ slow

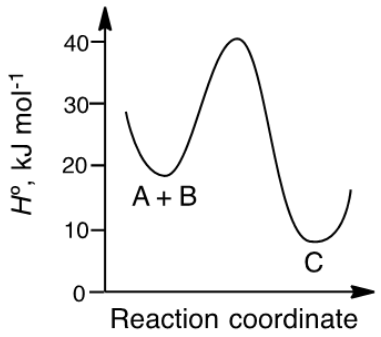
$N_2O(g) + H_2(g) \rightarrow N_2(g) + H_2O(g)$ fast

What rate law is implied by this mechanism?

(A) Rate = k[NO][H_2] **(B)** Rate = k[NO]^2[H_2]

(C) Rate = k[NO][H_2]^2 **(D)** Rate = k[NO]^2[H_2]^2

30. The reaction A + B → C is represented by the energy diagram shown.



Which statements about this reaction are correct?

I. The overall reaction is endothermic.

II. The activation enthalpy of the reaction is 40 kJ mol^{-1}.

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

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

31. What is the pH of a saturated solution of $Co(OH)_2$? The K_{sp} of $Co(OH)_2$ is 5.9×10^{-15}.

(A) 7.19 **(B)** 9.06 **(C)** 9.36 **(D)** 9.56

32. Which of the following solutions is capable of dissolving the most $CaC_2O_4(s)$?

(A) Pure H_2O **(B)** 0.10 M $CaCl_2$

(C) 0.10 M $H_2C_2O_4$ **(D)** 0.10 M HCl

33. Silver ion forms a complex ion with thiosulfate ion, $Ag(S_2O_3)_2^{3-}$, with $K_f = 2.8 \times 10^{13}$. How much AgBr ($K_{sp} = 5.4 \times 10^{-13}$) will dissolve in 1.00 L of 0.200 M $Na_2S_2O_3$ solution?

(A) 0.089 mol **(B)** 0.10 mol

(C) 0.16 mol **(D)** 0.78 mol

34. 100.0 mL 0.15 M aqueous HF ($K_a = 6.8 \times 10^{-4}$) is mixed with 125.0 mL 0.23 M NaF. What is the pH of the resulting solution?

(A) 2.17 **(B)** 3.17 **(C)** 3.35 **(D)** 3.45

35. For a given reaction, a graph of $\ln(K_{eq})$ vs. 1/T is linear and has a positive slope. Which statements about this reaction must be correct?

I. $\Delta H^o_{rxn} < 0$ II. $\Delta S^o_{rxn} > 0$

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

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

36. The following reaction has $K_p = 50.4$ at 448 ºC.

$$H_2(g) + I_2(g) \rightleftharpoons 2\ HI(g)$$

If a 3.00 L flask initially contains 0.0500 moles each of H_2 and I_2, how many moles of HI are present when the contents have reached equilibrium at 448 °C?

(A) 0.0130 mol **(B)** 0.0146 mol

(C) 0.0260 mol **(D)** 0.0780 mol

37. Iodide ion is oxidized to hypoiodite ion by permanganate ion in basic solution according to the following *unbalanced* equation:

$$I^-(aq) + MnO_4^-(aq) \rightarrow IO^-(aq) + MnO_2(s)$$

What is the ratio of hydroxide ions to iodide ions in the balanced equation?

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

38. In the carbon monoxide complex $Na[V(CO)_6]$, what is the oxidation number of vanadium?

(A) –1 **(B)** +3 **(C)** +5 **(D)** +6

39. What is the K_{sp} of $Fe(OH)_2$ at 298 K?

Half-Reaction	E^o, V (at 298 K)
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	–0.44
$Fe(OH)_2(s) + 2e^- \rightarrow Fe(s) + 2\ OH^-(aq)$	–0.89

(A) 2.4×10^{-8} **(B)** 6.0×10^{-16}

(C) 1.0×10^{-45} **(D)** 8.3×10^{-46}

40. A 0.100-g sample of an alloy of copper and silver is dissolved in nitric acid to give a solution containing Cu^{2+} and Ag^+ ions. This mixture is electrolyzed exhaustively to redeposit all the metal ions as the elemental metals, requiring a current of 0.150 A for 1429 s. What is the mass percent of copper in the alloy?

(A) 20.0% **(B)** 58.3% **(C)** 70.6% **(D)** 77.2%

41. Which electrochemical cell has the greatest (most positive) standard cell potential?

Half-Reaction	E^o, V
$Cd^{2+}(aq) + 2e^- \rightarrow Cd(s)$	–0.40
$Tl^+(aq) + e^- \rightarrow Tl(s)$	–0.34
$AgCl(s) + e^- \rightarrow Ag(s) + Cl^-(aq)$	+0.22
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	+0.34

(A) $Cu(s) \mid Cu^{2+}(aq) \parallel Cd^{2+}(aq) \mid Cd(s)$

(B) $Tl(s) \mid Tl^+(aq) \parallel AgCl(s) \mid Ag(s), Cl^-(aq)$

(C) $Cd(s) \mid Cd^{2+}(aq) \parallel AgCl(s) \mid Ag(s), Cl^-(aq)$

(D) $Tl(s) \mid Tl^+(aq) \parallel Cu^{2+}(aq) \mid Cu(s)$

42. The galvanic cell below has equal volumes in the two half-cells. As it is discharged at 25 ºC, the cell potential gradually decreases to zero, whereupon the discharge stops. What is the concentration of $Cu^{2+}(aq)$ when the discharge stops?

$Cu(s) \mid Cu^{2+}(aq)$, 1.00 M $\parallel Fe(CN)_6^{3-}(aq)$, 0.200 M | $Fe(CN)_6^{4-}(aq)$, 0.200 M | Pt

Half-Reaction	E^o, V
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	+0.337
$Fe(CN)_6^{3-}(aq) + e^- \rightarrow Fe(CN)_6^{4-}(aq)$	+0.360

(A) 0.80 M **(B)** 0.96 M **(C)** 1.04 M **(D)** 1.20 M

43. In which gas-phase atom are the 2*s* electrons closest on average to the nucleus?

(A) N **(B)** O **(C)** Al **(D)** Si

44. Which electron configuration corresponds to a gas-phase oxygen atom in an excited state?

(A) $1s^2 1p^2 2s^2 2p^2$ **(B)** $1s^2 2p^6$

(C) $1s^2 2s^2 2p^3$ **(D)** $1s^2 2s^2 2p^4$

45. Alkali metals (Group 1) differ from alkaline earth metals (Group 2) of the same period in which way?

(A) Alkali metals have larger ionic radii.

(B) Alkali metals have higher melting points.

(C) Alkali metals have greater first ionization energies.

(D) Alkali metals have greater densities.

46. Atoms of which element release the most energy when an electron is added to them in the gas phase?

(A) C **(B)** O **(C)** Si **(D)** S

47. How many unpaired electrons does a ground-state gas-phase Cr^{2+} ion have?

(A) 0 **(B)** 2 **(C)** 4 **(D)** 6

48. Which nuclide undergoes beta decay?

(A) ^{11}C **(B)** ^{13}N **(C)** ^{19}O **(D)** ^{22}Na

49. Which molecule has a nonzero dipole moment?

(A) BF_3 **(B)** CF_4 **(C)** NF_3 **(D)** SF_6

50. What is the geometry of XeF_4?

(A) Square planar **(B)** Tetrahedral

(C) See-saw **(D)** Square pyramidal

51. Which statements are correct about the cyanate ion, NCO^-?

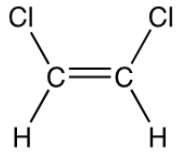
I. Cyanate is more thermodynamically stable than its isomer fulminate (CNO^-).

II. The carbon-nitrogen bond is shorter than the carbon-oxygen bond in gas-phase cyanate ion.

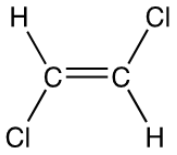
(A) I only **(B)** II only

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

52. Which statement best describes the results of attempted separation by fractional distillation of the two isomers of 1,2-dichloroethene?



Isomer **1**



Isomer **2**

(A) The two isomers can be separated by fractional distillation, with isomer **1** boiling at the lower temperature.

(B) The two isomers can be separated by fractional distillation, with isomer **2** boiling at the lower temperature.

(C) The two isomers cannot be separated by fractional distillation because both isomers have the same boiling point.

(D) The two isomers cannot be separated by fractional distillation because they interconvert rapidly at the temperatures at which they distill.

53. What is the coordination geometry of cobalt in the complex ion $[Co(H_2NCH_2CH_2NH_2)_2Br_2]^+$?

(A) Tetrahedral **(B)** Square planar

(C) Octahedral **(D)** Trigonal prismatic

54. Sulfur tetrafluoride adopts a see-saw geometry with two axial F atoms with a F–S–F angle of about 180º and two equatorial F atoms at about 90º from the axial fluorines. Which statement most accurately describes the axial and equatorial S–F bonds?

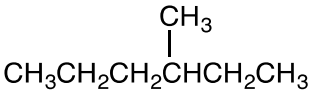
(A) The axial S–F bonds are longer because the two fluorines must share bonding to the same orbital on sulfur.

(B) The axial S–F bonds are longer because they experience greater repulsion from the other fluorine atoms in the molecule.

(C) The equatorial S–F bonds are longer because the equatorial F–S–F bond angle is the smallest in the molecule.

(D) The equatorial S–F bonds are longer because they experience greater repulsion from the lone pair on sulfur.

55. Which statement about the branched hydrocarbon shown is correct?



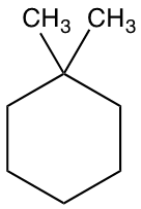
(A) Its IUPAC name is 4-methylhexane.

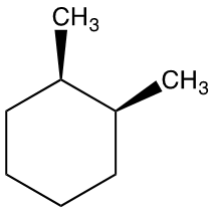
(B) It is chiral.

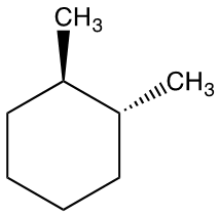
(C) It has six primary hydrogens.

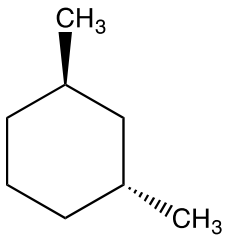
(D) Radical chlorination gives 1-chloro-4-methylhexane as the major product.

56. In which dimethylcyclohexane are both methyl groups equatorial in its most stable chair conformation?

(A)


(B)


(C)


(D)


57. How many distinct acyclic compounds have the formula C_5H_{10}?

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

58. When acetaldehyde (CH_3CHO) reacts in methanol (CH_3OH) solution under basic conditions, which compound is NOT formed?

(A) $CH_3CH(OH)(OCH_3)$ **(B)** $CH_3CH(OCH_3)_2$

(C) $CH_3CH(OH)CH_2CHO$ **(D)** $CH_3CH{=}CHCHO$

59. In what way does the reactivity of $CH_3C{\equiv}CH$ differ from $CH_3CH{=}CH_2$?

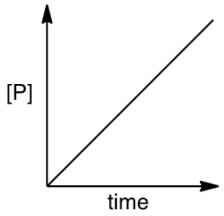
(A) Propyne is deprotonated by $NaNH_2$, while propene is not.

(B) Propyne does not react with bromine, while propene reacts readily with bromine.

(C) Propyne undergoes catalytic hydrogenation over platinum, while propene does not.

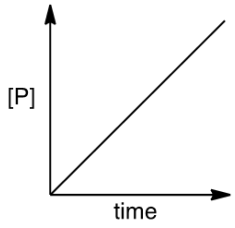
(D) Propyne is readily hydrated at pH = 0, while propene is not.

60. An enzyme catalyzes the transformation of a substrate into a product P, with the appearance of product over time as shown below:

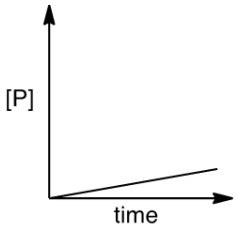


Under the same conditions, except in the presence of a competitive inhibitor of the enzyme, which graph best represents the appearance of product over time?

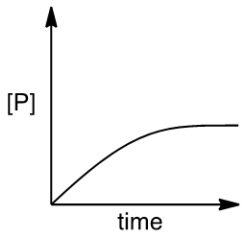
(A)



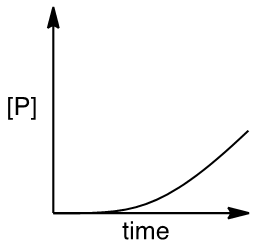
(B)



(C)



(D)



END OF TEST

PLEASE ANSWER THE FOLLOWING FOUR QUESTIONS

THANK YOU!

When you have finished answering this examination or time has been called by the Examiner, please provide responses to the following 4 items. Your answers will not affect your score on the exam but will help with a study being conducted by the U.S. National Chemistry Olympiad (USNCO) Subcommittee.

61. The amount of time I spend doing experiments in the laboratory per week on average during my chemistry course was/is?

(A) less than ½ hour
(B) between ½ and 1 hour
(C) between 1 and 2 hours
(D) more than 2 hours

The following questions should be answered using the scale

(A) Strongly agree
(B) Agree
(C) Disagree
(D) Strongly disagree

62. **As a result of my participation in the USNCO program**, I plan to study more chemistry.

63. **As a result of my participation in the USNCO program**, I plan to major in chemistry in college.

64. **As a result of my participation in the USNCO program**, I have a more positive view of chemistry than I did before participating.

Olympiad 2018
USNCO National Exam Part I
KEY

Question	Correct Answer	% Correct Answer
1.	B	69%
2.	B	86%
3.	C	86%
4.	D	78%
5.	A	25%
6.	D	34%
7.	B	31%
8.	A	50%
9.	C	53%
10.	C	40%
11.	D	53%
12.	C	45%
13.	D	64%
14.	C	67%
15.	B	87%
16.	A	46%
17.	C	49%
18.	D	45%
19.	C	66%
20.	B	90%
21.	A	31%
22.	B	62%
23.	D	15%
24.	A	34%
25.	C	73%
26.	D	90%
27.	D	88%
28.	D	7%
29.	B	78%
30.	D	54%

Question	Correct Answer	% Correct Answer
31.	C	60%
32.	D	70%
33.	A	24%
34.	D	53%
35.	A	47%
36.	D	42%
37.	D	47%
38.	A	35%
39.	B	59%
40.	B	37%
41.	D	54%
42.	C	44%
43.	D	50%
44.	B	69%
45.	A	75%
46.	D	12%
47.	C	51%
48.	C	60%
49.	C	80%
50.	A	68%
51.	C	42%
52.	B	48%
53.	C	27%
54.	A	11%
55.	B	45%
56.	C	34%
57.	D	18%
58.	B	26%
59.	A	31%
60.	B	47%