2013 U.S. NATIONAL CHEMISTRY OLYMPIAD

NATIONAL EXAM PART I

Prepared by the American Chemical Society Chemistry Olympiad Examinations Task Force

OLYMPIAD EXAMINATIONS TASK FORCE

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DIRECTIONS TO THE EXAMINER – PART I

The USNCO Subcommittee is conducting a survey in an effort to determine the impact of the Olympiad program on students. The first phase of this effort is represented by several questions added to the end of this year's exam, which should be answered on the same Scantron sheet students use for the exam. These questions may be administered before or after the 90 minutes allotted for the exam, at your discretion, but 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 15, 2013, 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** have 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 questions**	**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.

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		

CONS
R = 8.314 J•mol
R = 0.0821 L•atm•mol
1 F = 96,500 C•mol^{-1}
1 F = 96,500 J•V^{-1}•mol^{-1}
N_A = 6.022 × 10^{23} mol^{-1}
h = 6.626 × 10^{-34} J•s
c = 2.998 × 10^{8} m•s^{-1}
0 °C = 273.15 K
1 atm = 760 mm Hg

EQUATIONS

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

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** 78.96	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** 95.94	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 (Uut) (284)	114 (Uuq) (289)	115 (Uup) (288)	116 (Uuh) (293)	117 (Uus) (294)	118 (Uuo) (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 pencil. Make a heavy, full mark, but no stray marks. If you decide to change an answer, erase the unwanted mark very
- There is only one correct answer to each question. Any questions for which more than one response has been blackened **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 reaction mixture is prepared containing 0.60 mol of aluminum and 1.20 mol of manganese dioxide. The mixture is heated until one of the reactants has been completely consumed according to the equation:

$$2\ Al + 3\ MnO_2 \rightarrow 3\ Mn + Al_2O_3$$

What quantity of which reactant remains uncombined?

(A) 0.20 mol Al **(B)** 0.40 mol Al

(C) 0.30 mol MnO_2 **(D)** 0.60 mol MnO_2

2. A solution with a mass of 1.263 g containing an unknown amount of potassium ions was treated with excess sodium tetraphenylborate to precipitate 1.003 g of $KB(C_6H_5)_4$ (M = 358.33). What is the mass percentage of potassium in the original solution?

(A) 8.67% **(B)** 9.16% **(C)** 10.9% **(D)** 13.8%

3. A typical polyethylene grocery bag weighs 12.4 g. How many metric tons of CO_2 would be released into the atmosphere if the 102 billion bags used in one year in the United States were burned? [1 metric ton = 1000 kg]

(A) 4.52×10^4 **(B)** 1.99×10^6

(C) 3.98×10^6 **(D)** 3.98×10^9

4. Which mixture of water and H_2SO_4 represents a solution with a concentration that is closest to 30% by mass H_2SO_4?

(A) 30 g H_2SO_4 + 100 g H_2O

(B) 1 mol H_2SO_4 + 200 g H_2O

(C) 30 mol H_2SO_4 + 0.70 kg H_2O

(D) 0.30 mol H_2SO_4 + 0.70 mol H_2O

5. How would the freezing point depression of a 0.05 m $CaCl_2$ solution compare with that of a NaCl solution? It would be

(A) less than that for a 0.10 m NaCl solution.

(B) between that for a 0.10 m NaCl solution and a 0.20 m NaCl solution.

(C) between that for a 0.20 m NaCl solution and a 0.30 m NaCl solution.

(D) greater than that for a 0.30 m NaCl solution.

6. What is the mole fraction of CH_3OH in an aqueous solution that is 12.0 m in CH_3OH?

(A) 0.178 **(B)** 0.216 **(C)** 0.400 **(D)** 0.667

7. Three different oxides of nitrogen each contain 7.00 g of nitrogen and weigh 15.0 g, 23.0 g and 19.0 g, respectively. What are their empirical formulas?

(A) NO, NO_2, N_2O_3 **(B)** NO, N_2O_3, N_2O_5

(C) N_2O, NO_2, N_2O_5 **(D)** NO_2, N_2O_3, N_2O_5

8. Which substance is used in self-contained breathing equipment because it absorbs exhaled CO_2 and H_2O and releases O_2 gas?

(A) KO_2 **(B)** Na_2O_2 **(C)** NaOH **(D)** Li_2O

9. A sample of a white solid is known to be $NaHCO_3$, $AgNO_3$, Na_2S, or $CaBr_2$. Which 0.1 M aqueous solution can be used to confirm the identity of the solid?

(A) NH_3(aq) **(B)** HCl(aq)

(C) NaOH(aq) **(D)** KCl(aq)

10. The infrared frequency of the CX vibration for CH_3X depends on which of the following?

I. mass of X
II. strength of the CX bond
III. type of CX vibration (stretch or bend)

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

(C) II. and III. only **(D)** I., II. and III.

11. When the permanganate ion, MnO_4^-, acts as an oxidizing agent it forms different products depending on the pH of the solution. Which species correspond to the conditions listed?

	acidic	basic	neutral
A	Mn^{2+}	$Mn(OH)_2$	MnO_2
B	Mn^{2+}	MnO_4^{2-}	MnO_2
C	MnO_2	MnO_4^{2-}	$Mn(OH)_2$
D	Mn^{2+}	$Mn(OH)_2$	MnO_4^{2-}

(A) A **(B)** B **(C)** C **(D)** D

12. In an experiment to verify the value of absolute zero, a student is instructed to measure the volume of He in a 10-mL syringe at 10 °C intervals between 0 ° and 100 °C. She is told to plot the volume versus temperature and to extrapolate this graph to zero volume and read the resulting temperature. Which modification of the experimental procedure will give the best value for absolute zero?

(A) Correcting each measured volume to one atmosphere pressure before plotting.

(B) Doubling the number of temperature-volume values between 0 ° and 100 °C.

(C) Using a thermometer that can measure temperature to $\pm$ 0.10 °C between 0° and 100 °C.

(D) Measuring the volume of He in the syringe at – 40 °C and – 80 °C.

13. The Henry's law constant for oxygen gas in water at 25 °C k_{O_2} is 1.3×10^{-3} M •atm^{-1}. What is the partial pressure of O_2 above a solution at 25 °C with an O_2 concentration of 2.3×10^{-4} M at equilibrium?

(A) 5.7 atm **(B)** 0.18 atm

(C) 1.3×10^{-3} atm **(D)** 3.0×10^{-7} atm

14. A sample of gas measured at 20 °C and 4.0 atm is heated to 40 °C at constant volume. Which statement(s) is (are) true of the gas after heating relative to its initial state?

I. The average molecular kinetic energy is increased.
II. The average molecular speed is unchanged.
III. The pressure of the gas is increased to 8.0 atm.
IV. The number of molecular collisions per second is unchanged.

(A) I. only **(B)** I. and IV. only

(C) II. and III. only **(D)** II. and IV. only

15. Under what conditions does the behavior of real gases deviate most from that predicted by the ideal gas law?

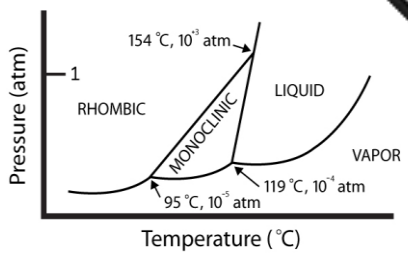
(A) low P, low T **(B)** high P, low T

(C) low P, high T **(D)** high P, high T

16. When 0.25 L of liquid nitrogen (d = 0.807 g/mL) is vaporized, what volume does the resulting gas occupy at 25 °C and 5.00 atm?

(A) 71 L **(B)** 54 L **(C)** 35 L **(D)** 32 L

17.



The phase diagram for sulfur is shown above. Which statement about this diagram is correct?

(A) The critical point is above 154 °C and 10^3 atm.

(B) There are only two triple points in this diagram.

(C) Monoclinic sulfur is more dense than rhombic sulfur at any temperature.

(D) Monoclinic sulfur forms rhombic sulfur at higher pressure or lower temperature.

18. What is the principal difference between crystalline and amorphous solids?

	crystalline solids	amorphous solids
(A)	ionic bonding	covalent bonding
(B)	higher molar masses	lower molar masses
(C)	stoichiometric solids	non-stoichiometric solids
(D)	long-range order	lack of long-range order

19. Which is (are) state properties?

I. enthalpy II. heat III. volume

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

(C) I. and III. only **(D)** II. and III. only

20. $HNO_2(l) + NaCl(s) \rightarrow HCl(g) + NaNO_2(s)$

Calculate the ΔH° value for the reaction above from the information below.

Reaction	ΔH° kJ•mol^{-1}
$NO(g) + NO_2(g) + Na_2O(s) \rightarrow 2NaNO_2(s)$	– 427.0
$NO(g) + NO_2(g) \rightarrow N_2O(g) + O_2(g)$	– 43.0
$2NaCl(s) + H_2O(l) \rightarrow 2HCl(g) + Na_2O(s)$	507.0
$2HNO_2(l) \rightarrow N_2O(g) + O_2(g) + H_2O(l)$	34.0

(A) 157 kJ **(B)** 78.5 kJ

(C) –78.5 kJ **(D)** –157 kJ

21. For which reaction(s) is the ΔH value close to the ΔE value?

I. $CH_4(g) + 2\ O_2(g) \rightarrow CO(g) + 2\ H_2O(l)$
II. $C_2H_4(g) + 3\ O_2(g) \rightarrow 2\ CO_2(g) + 2\ H_2O(g)$

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

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

22. What is the value of ΔS° for the reaction below?

$$Fe_2O_3(s) + 3\ CO(g) \rightarrow 2\ Fe(s) + 3\ CO_2(g)$$

Substance	Fe(s)	$Fe_2O_3(s)$	CO(g)	$CO_2(g)$
S° ($J \cdot mol^{-1} \cdot K^{-1}$)	27.3	87.4	197.7	213.8

(A) $-44.0\ J \cdot K^{-1}$ **(B)** $-11.8\ J \cdot K^{-1}$

(C) $15.5\ J \cdot K^{-1}$ **(D)** $42.8\ J \cdot K^{-1}$

23. What is the temperature at which the reaction below is at equilibrium?

$$2\ NO(g) + O_2(g) \rightarrow 2\ NO_2(g)$$

$\Delta H^\circ_{rxn} = -113\ kJ \cdot mol^{-1}$ $\Delta S^\circ_{rxn} = -145\ J \cdot mol^{-1} \cdot K^{-1}$

(A) –195 °C **(B)** 77.9 °C

(C) 506 °C **(D)** 779 °C

24. The K_{sp} for $Al(OH)_3$ is 2.0×10^{-31}. What is the value of ΔG° for the precipitation of $Al(OH)_3$ at 25 °C?

$$Al^{3+}(aq) + 3\ OH^-(aq) \rightarrow Al(OH)_3(s)$$

(A) $-175\ kJ \cdot mol^{-1}$ **(B)** $-14.7\ kJ \cdot mol^{-1}$

(C) $14.7\ kJ \cdot mol^{-1}$ **(D)** $175\ kJ \cdot mol^{-1}$

25. Ammonia reacts with oxygen according to the equation:

$$4\ NH_3(g) + 5\ O_2(g) \rightarrow 4\ NO(g) + 6\ H_2O(l)$$

In an experiment in which the rate of change of nitric oxide is found to be $1.10\ M \cdot min^{-1}$, what is the rate of change of oxygen gas?

(A) $-1.38\ M \cdot min^{-1}$ **(B)** $-0.880\ M \cdot min^{-1}$

(C) $-0.275\ M \cdot min^{-1}$ **(D)** $-0.220\ M \cdot min^{-1}$

26. A first-order reaction has a rate constant of $k = 0.320\ min^{-1}$. For an initial reactant concentration of 1.22 M, how long does it take for its concentration to fall to 0.150 M?

(A) 0.671 min **(B)** 2.60 min

(C) 6.55 min **(D)** 25.4 min

27. Iodine monochloride reacts with hydrogen according to the equation:

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

The rate data below have been obtained.

$[ICl]$, M	$[H_2]$, M	Initial Rate, $M \cdot s^{-1}$
0.10	0.10	0.030
0.20	0.10	0.060
0.10	0.050	0.015

What is the rate law for the reaction?

(A) Rate = $k[ICl][H_2]$ **(B)** Rate = $k[ICl]^2[H_2]$

(C) Rate = $k[ICl][H_2]^{1/2}$ **(D)** Rate = $k[ICl]^2[H_2]^{1/2}$

28. Which graph is linear for a reaction th… order in [A]?

(A) [A] vs time **(B)** ln[A] vs t…

(C) $[A]^2$ vs time **(D)** 1/[A] vs time

29. The reaction of nitrogen dioxide with carbon monoxide

$$NO_2(g) + CO(g) \rightarrow CO_2(g) + NO(g)$$

has been studied and the following mechanism has been proposed:

$NO_2(g) + NO_2(g) \rightarrow NO_3(g) + NO(g)$ slow

$NO_3(g) + CO(g) \rightarrow NO_2(g) + CO_2(g)$ fast

What rate law corresponds to this mechanism?

(A) Rate = $k[NO_2]$ **(B)** Rate = $k[NO_2][CO]$

(C) Rate = $k[NO_2]^2$ **(D)** Rate = $k[NO_2]^2[CO]$

30. A reaction has a rate constant $k = 8.54 \times 10^{-4}\ M^{-1} \cdot s^{-1}$ at 45 °C and an activation energy, $E_a = 90.8$ kJ. What is the value of k at 25 °C?

(A) $4.46 \times 10^{-5}\ M^{-1} \cdot s^{-1}$ **(B)** $8.54 \times 10^{-5}\ M^{-1} \cdot s^{-1}$

(C) $8.52 \times 10^{-4}\ M^{-1} \cdot s^{-1}$ **(D)** $8.54 \times 10^{-3}\ M^{-1} \cdot s^{-1}$

31. For which reaction will K_p be larger than K_c at 25 °C?

(A) $CO_2(g) + C(s) \rightleftharpoons 2\ CO(g)$

(B) $2\ NO_2(g) \rightleftharpoons N_2O_4(g)$

(C) $H_2(g) + F_2(g) \rightleftharpoons 2\ HF(g)$

(D) $O_3(g) + NO(g) \rightleftharpoons NO_2(g) + O_2(g)$

32. $2\ SO_3(g) \rightleftharpoons 2\ SO_2(g) + O_2(g)$

When $SO_3(g)$ is added to a sealed bulb at a pressure of 2.0 atm, it undergoes the reaction above. At equilibrium, 76% of the $SO_3(g)$ has reacted. What is the value of K_p at this temperature?

(A) 15 **(B)** 7.6 **(C)** 3.8 **(D)** 2.4

33. The pH of pure water at 50 °C is 6.63. What is the value of K_w at 50 °C?

(A) 1.8×10^{-15} **(B)** 1.0×10^{-14}

(C) 5.5×10^{-14} **(D)** 2.2×10^{-13}

34. Alanine, $H_2NCH(CH_3)CO_2H$, has $K_a = 4.5 \times 10^{-3}$ and $K_b = 7.4 \times 10^{-5}$. Which species has the highest concentration at a pH of 7.00 in H_2O?

(A) $H_2NCH(CH_3)CO_2H$ **(B)** $^+H_3NCH(CH_3)CO_2H$

(C) $H_2NCH(CH_3)CO_2^-$ **(D)** $^+H_3NCH(CH_3)CO_2^-$

35. What is the pH of the solution formed by mixing 25.0 mL of a 0.15 M solution of NH_3 with 25.0 mL of 0.12 M HCl? (K_b for $NH_3 = 1.8 \times 10^{-5}$)

(A) 4.14 **(B)** 5.34 **(C)** 8.65 **(D)** 9.86

36. What is the $[OH^-]$ in a suspension of the antacid $Mg(OH)_2$? ($K_{sp} = 2.06 \times 10^{-13}$)

(A) 7.4×10^{-5} M **(B)** 5.9×10^{-5} M

(C) 4.7×10^{-5} M **(D)** 3.7×10^{-5} M

37. When the equation below is balanced correctly using the simplest whole number coefficients, what is the coefficient for $CO_2(g)$?

$\_\_ Cr_2O_7^{2-}(aq) + \_\_ H_2C_2O_4(aq) + \_\_ H^+(aq) \rightarrow$
$\_\_ Cr^{3+}(aq) + \_\_ CO_2(g) + \_\_ H_2O(l)$

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

38.

$Au^{3+} + 3e^- \rightarrow Au(s)$	E° = 1.50 V
$Ag^+ + e^- \rightarrow Ag(s)$	E° = 0.80 V
$Cu^{2+} + 2e^- \rightarrow Cu(s)$	E° = 0.34 V

According to the standard reduction potentials above, a substance that can oxidize only one of these metals must have an E° value

(A) less than 0.34 V.

(B) between 0.34 and 0.80 V.

(C) between 0.80 and 1.50 V.

(D) greater than 1.50 V.

39. What is the ΔG° value for the electrochemical cell below?
$Cu(s) \mid Cu^{2+}(aq) \parallel NO_3^-(aq) \mid NO(s) \mid Pt(s)$

Half-Reaction	E°, V
$NO_3^-(aq) + 4H^+(aq) + 3e^- \rightarrow NO(g) + 2H_2O(l)$	0.960
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	0.340

(A) –753 kJ **(B)** –359 kJ

(C) –179 kJ **(D)** –59.8 kJ

40. An aqueous solution of $CuSO_4$ is electrolyzed for 1.50 hours with a current of 2.50 amps. What mass of copper metal is formed?

(A) 8.88 g **(B)** 4.44 g **(C)** 0.296 g **(D)** 0.0741 g

41. Under what conditions is the Nernst equation used to calculate cell potential voltages in a voltaic cell?

(A) non-standard concentrations only

(B) non-spontaneous reactions only

(C) reactions at equilibrium only

(D) reactions of ions with the same charge only

42.

Half-Reaction	V
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	
$Sn^{2+}(aq) + 2e^- \rightarrow Sn(s)$	
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	
$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$	–0.
$Mg^{2+}(aq) + 2e^- \rightarrow Mg(s)$	–2.37

According to the standard reduction potentials above, cathodic protection of iron can be achieved by

(A) Cu(s) only. **(B)** Cu(s) and Sn(s) only.

(C) Mg(s) only. **(D)** Mg(s) and Zn(s) only.

43. Which is an acceptable set of quantum numbers for an electron?

(A) 1, 1, 0, 1/2 **(B)** 2, 1, 0, 0

(C) 2, 1, –1, –1/2 **(D)** 3, 2, –3, 1/2

44. Which orbital has the most radial nodes?

(A) 4*s* **(B)** 4*p* **(C)** 4*d* **(D)** 4*f*

45. Ionization energies vary from left to right across the periodic table. Factors that contribute to this variation include which of the following?

I. changes in the nuclear charge
II. differences in shielding by valence electrons
III. differences in shielding by core electrons

(A) I. only **(B)** III. only

(C) I. and II. only **(D)** I., II. and III.

46. Which gaseous ion has exactly three unpaired electrons?

(A) Fe^{3+} **(B)** Ni^{2+} **(C)** Ti^{4+} **(D)** V^{2+}

47. Which element has the highest second ionization energy?

(A) Na **(B)** Mg **(C)** S **(D)** F

48. The ions below are listed in order of increasing radii except

(A) $Al^{3+} < Mg^{2+} < Na^+$ **(B)** $K^+ < Cl^- < Se^{2-}$

(C) $Cl^- < Br^- < I^-$ **(D)** $O^{2-} < F^- < Na^+$

49. How many sigma bonds are present in P_4?

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

50. Using VSEPR theory, the molecular structure of IF_5 is best described as

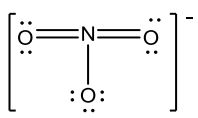
(A) octahedral **(B)** square pyramidal

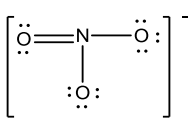
(C) trigonal bipyramidal **(D)** trigonal pyramidal

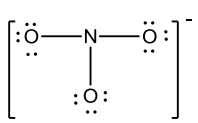
51. What is the formal charge on the oxygen atom in :C:::O:?

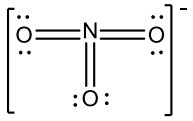
(A) +1 **(B)** 0 **(C)** –1 **(D)** –2

52. Which is a valid Lewis structure for the nitrate ion, NO_3^-?

(A) 

(B) 

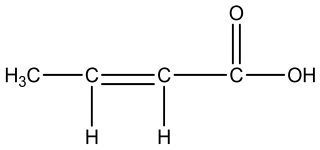
(C) 

(D) 

53. Based on molecular orbital theory, which species has the highest bond order?

(A) O_2^+ **(B)** O_2 **(C)** O_2^- **(D)** O_2^{2-}

54. How many carbon atoms can be described as sp^2 hybridized in this molecule?



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

55. Which compound contains four co-linear carbon atoms?

(A) butane **(B)** *cis*-2-butene

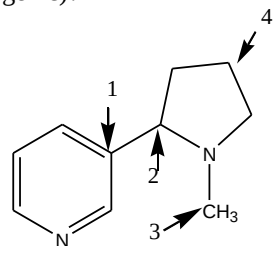
(C) *trans*-2 butene **(D)** 2-butyne

56. Which substance can exist in boat and chair configurations?

(A) benzene **(B)** cyclohexane

(C) cyclopentadiene **(D)** naphthalene

57. Which of the numbered carbons in nicotine is chiral (stereogenic)?



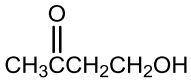
(A) 1 **(B)** 2 **(C)** 3 **(D)** 4

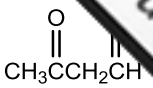
58. All of the following are monosaccharides except

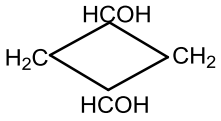
(A) fructose **(B)** glucose

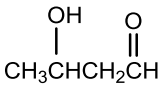
(C) ribose **(D)** sucrose

59. What is the product when two molecu… CH_3CHO, undergo an aldol condensatio…

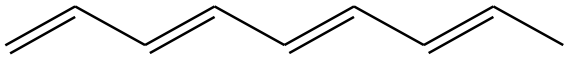
(A) 

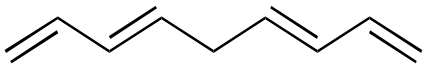
(B) 

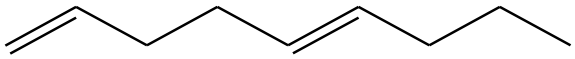
(C) 

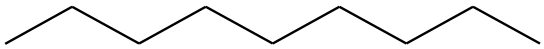
(D) 

60. Which molecule will have the longest wavelength absorbance maximum?

(A) 

(B) 

(C) 

(D) 

END OF TEST

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 2013
USNCO National Exam Part I
KEY

Number	Answer
1.	C
2.	A
3.	C
4.	B
5.	A
6.	A
7.	A
8.	A
9.	B
10.	D
11.	B
12.	D
13.	B
14.	A
15.	B
16.	C
17.	D
18.	D
19.	C
20.	B
21.	B
22.	C
23.	C
24.	A
25.	A
26.	C
27.	A
28.	D
29.	C
30.	B

Number	Answer
31.	A
32.	B
33.	C
34.	D
35.	C
36.	A
37.	B
38.	B
39.	B
40.	B
41.	A
42.	D
43.	C
44.	A
45.	C
46.	D
47.	A
48.	D
49.	D
50.	B
51.	A
52.	B
53.	A
54.	D
55.	D
56.	B
57.	B
58.	D
59.	D
60.	A