2014 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 after the 90 minutes allotted for the exam, and 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 28, 2014, 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.

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•m
R = 0.0821 L•atm•mo
1 F = 96,500 C•mol^{-1}
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 = 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** (271)	107 **Bh** (270)	108 **Hs** (277)	109 **Mt** (276)	110 **Ds** (281)	111 **Rg** (280)	112 **Cn** (285)	113 (Uut) (284)	114 **Fl** (289)	115 (Uup) (288)	116 **Lv** (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 w **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. Boron carbide, B_4C, is made by the high temperature reaction of boron oxide with graphite, yielding carbon monoxide as a by-product.

$$\_\_\ B_2O_3 + \_\_\ C \rightarrow \_\_\ B_4C + \_\_\ CO$$

What is the total of the smallest coefficients for the reactants and products in the balanced equation?

(A) 9 **(B)** 10 **(C)** 15 **(D)** 16

2. A compound with 69.41% C, 4.16% H and 26.42% O has a molar mass of 230 – 250 g•mol^{-1}. What is its molecular formula?

(A) $C_{13}H_9O_4$ **(B)** $C_{14}H_{10}O_4$

(C) $C_{13}H_6O_4$ **(D)** $C_{15}H_{14}O_3$

3. Aluminum reacts with sulfur to form aluminum sulfide. If 31.9 g of Al are reacted with 72.2 g of S, what is the theoretical yield of aluminum sulfide in grams?

(A) 88.8 g **(B)** 69.7 g **(C)** 57.2 g **(D)** 113 g

4. According to EPA guidelines the permissible level for lead in drinking water is 15 parts per billion (ppb). What is the maximum allowable mass of lead that could be present in 1.00 L of H_2O?

(A) 0.015 ng **(B)** 0.015 µg

(C) 0.015 mg **(D)** 0.015 g

5. Aqueous solutions of electrolytes that produce two ions upon ionization typically exhibit freezing point depressions that are twice as large as solutions of non-electrolytes with the same concentration. Which 0.10 M electrolyte solution will show the smallest depression?

(A) HCl **(B)** NaBr **(C)** KNO_3 **(D)** $MgSO_4$

6. Interferon is a water-soluble protein. A solution prepared by dissolving 15.0 mg of interferon in 2.50 mL of H_2O exhibits an osmotic pressure of 5.80 mm Hg at 25 °C. What is the molar mass of interferon?

(A) 1.92×10^4 g•mol^{-1} **(B)** 1.92×10^7 g•mol^{-1}

(C) 1.95×10^6 g•mol^{-1} **(D)** 1.61×10^3 g•mol^{-1}

7. Which noble gas is most abundant in the earth's atmosphere?

(A) He **(B)** Ne **(C)** Ar **(D)** Rn

8. Which of the acids below has the most ionizable hydrogen atoms per molecule?

I. H_3PO_4 II. H_3PO_3 III. H_3PO_2

(A) I only

(B) II only

(C) III only

(D) Each one contains the same number of ionizable H atoms.

9. Aluminum is most often found in nature as the

(A) carbonate. **(B)** chloride.

(C) oxide. **(D)** sulfide.

10. According to the Tyndall effect, a beam of light becomes visible when passed through all of the following except a(n)

(A) aerosol. **(B)** colloid.

(C) emulsion. **(D)** solution.

11. All of the following can be used as primary standards in acid-base titrations EXCEPT

(A) oxalic acid.

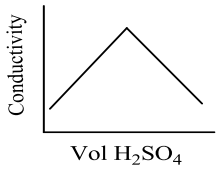
(B) potassium hydrogen phthalate.

(C) sodium carbonate.

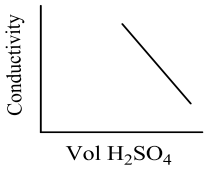
(D) sodium hydroxide.

12. Which of the graphs shown below would best represent the changes when 0.10 M barium hydroxide was titrated with 0.10 M sulfuric acid?

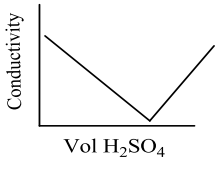
(A)



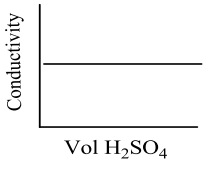
(B)



(C)



(D)



13. Which physical property decreases with an increase in intermolecular molecular forces?

(A) boiling point

(B) enthalpy of vaporization

(C) vapor pressure

(D) viscosity

14. A 0.180 g sample of liquid H_2O is injected into a 5.00 L flask at 25 °C. What will be present in the flask when equilibrium is established?
(Vapor pressure H_2O at 25 °C = 23.8 mm Hg)

(A) H_2O vapor at a pressure of 186 mm Hg

(B) H_2O vapor at a pressure of 37.2 mm Hg

(C) liquid H_2O and H_2O vapor at a pressure of 37.2 mm Hg

(D) liquid H_2O and H_2O vapor at a pressure of 23.8 mm Hg

15. The atmospheric pressure on the summit of Mt. Everest is 0.333 atmospheres. At what temperature (in °C) does H_2O boil there? (ΔH_{vap} H_2O = 40.7 kJ•mol^{-1})

(A) 71 °C **(B)** 87 °C **(C)** 96 °C **(D)** 98 °C

16. The arrangement of ions in a solid is best investigated by means of

(A) infrared spectroscopy.

(B) mass spectroscopy.

(C) UV-visible spectroscopy.

(D) x-ray crystallography.

17. Benzene and toluene form an ideal solution. The vapor pressure of benzene at 55 °C is 400 mm Hg while the vapor pressure of toluene at 55 °C is 130 mm Hg. What is the vapor pressure of a solution consisting of 0.5 mole fraction of benzene and 0.5 mole fraction of toluene at 55 °C?

(A) lower than 130 mm Hg

(B) between 130 and 400 mm Hg

(C) exactly 400 mm Hg

(D) greater than 400 mm Hg

18. An oxide of rhenium crystallizes with eight rhenium atoms at the corners of the unit cell and 12 oxygen atoms on the edges between them. What is the formula of this oxide?

(A) ReO **(B)** Re_2O_3 **(C)** ReO_2 **(D)** ReO_3

19. The combustion of 2-propanol (M = [illegible]) occurs according to the equation,
$2\ CH_3CHOHCH_3(l) + 9\ O_2(g) \rightarrow 6\ CO_2(g)$ [illegible]
What is q for the combustion of 15.0 g of 2-pr[illegible]

	$CH_3CHOHCH_3(l)$	$CO_2(g)$	[illegible]
ΔH_f, kJ•mol^{-1}	–318.2	–393.5	–285

(A) -5.01×10^2 kJ **(B)** -1.00×10^3 kJ

(C) -2.01×10^3 kJ **(D)** -4.01×10^3 kJ

20. At what temperature does the reaction below change from favoring products to favoring reactants?
$SO_2(g) + ½\ O_2(g) \rightleftharpoons SO_3(g)$

	$SO_2(g)$	$O_2(g)$	$SO_3(g)$
$\Delta H_f°$, kJ•mol^{-1}	–296.8		–395.7
$S°$, kJ•mol^{-1}•K^{-1}	0.248	0.205	0.257

(A) 162 K **(B)** 509 K **(C)** 1060 K **(D)** 1540 K

21. Which isomer of C_4H_8 has the lowest absolute entropy at 25 °C?

(A) 1-butene **(B)** *cis*-2-butene

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

22. A 10.0 g piece of gallium (M = 69.7) at 25.0 °C is placed in 10.0 g of H_2O at 55.0 °C. What is the final temperature when this system comes to equilibrium? (Assume the specific heat capacity of liquid Ga is the same as that of solid Ga.)

	C_p, J•g^{-1}•K^{-1}	melting point °C	ΔH_{fus}, kJ•mol^{-1}
Ga	0.371	30.0	5.576
H_2O	4.184		

(A) 35.0 °C **(B)** 38.1 °C

(C) 41.8 °C **(D)** 52.6 °C

23. In the Born-Haber calculation of the lattice enthalpy of LiF from its elements, which process is exothermic?

(A) dissociation energy of $F_2(g)$

(B) electron affinity of F(g)

(C) ionization energy of Li(g)

(D) sublimation energy of Li(s)

24. How much work is done by the gas when 1.00 g of sodium azide, NaN_3 (M = 65.01 g•mol^{-1}), decomposes in a container of changeable volume (e.g. an airbag in a car) against a constant pressure of 1.00 atm at 298 K?
$2\ NaN_3(s) \rightarrow 2\ Na(s) + 3\ N_2(g)$

(A) +114 J **(B)** +57.2 J **(C)** –114 J **(D)** –57.2 J

25. When the kinetics of the reaction, 2 A + 2 B → C, were studied using the method of initial rates, the data in the table below were obtained.

Trial	$[A]_0$ in mol•L^{-1}	$[B]_0$ in mol•L^{-1}	Initial Rate of Formation of C in mol•L^{-1}•s^{-1}
1	0.060	0.040	3.6×10^{-4}
2	0.060	0.080	7.2×10^{-4}
3	0.030	0.12	5.4×10^{-4}

What is the rate law for the reaction?

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

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

26. $2\ NO_2(g) \rightarrow 2\ NO(g) + O_2(g)$

For the reaction above, a straight line for which plot indicates a second order reaction?

(A) $[NO_2]$ vs. time **(B)** $[NO_2]^2$ vs. time

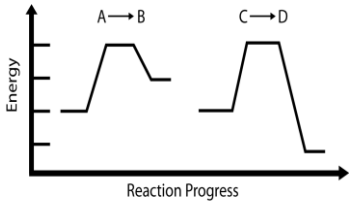
(C) $1/[NO_2]$ vs. time **(D)** $1/[NO_2]^2$ vs. time

27. What are the units for the rate constant of a zero-order reaction?

(A) time **(B)** time^{-1}

(C) M•time **(D)** M•time^{-1}

28. From the energy profiles for the two unimolecular reactions below, how will the rates of the two reactions compare if the temperature of each reaction is increased from 25 °C to 75 °C?



(A) The rate of reaction A → B will increase more than the rate of reaction C → D.

(B) The rate of reaction C → D will increase more than the rate of reaction A → B.

(C) The rates of the two reactions will increase by the same amount.

(D) The rate of reaction A → B will increase but the rate of reaction C → D will decrease.

29. The half-life of a first-order reaction is 1.5 hours. How much time is needed for 94% of the reactant to change to product?

(A) 0.13 hours **(B)** 6.1 hours

(C) 2.3 hours **(D)** 36 hours

30. For the reaction, 2 A + B → C + D, the rate = k[B]. Which of the following mechanisms would be consistent with this information?

(A) A + B → M (slow)
A + M → C + D (fast)

(B) A + A → M (slow)
B + M → C + D (fast)

(C) B → M (slow)
M + A → N (fast)
N + A → C + D (fast)

(D) B → M (fast)
M + A → N (slow)
N + A → C + D (fast)

31. A 50.0 mL sample of a 1.00 M solution of a diprotic acid H_2A ($Ka_1 = 1.0 \times 10^{-6}$ and $Ka_2 = 1.0 \times 10^{-10}$) is titrated with 2.00 M NaOH. What is the minimum volume of 2.00 M NaOH needed to reach a pH of 10.00?

(A) 12.5 mL **(B)** 37.5 mL

(C) 25.0 mL **(D)** 50.0 mL

32. For the reaction, $O_2(g) + 2\ F_2(g) \rightleftharpoons 2\ OF_2(g)$, $K_p = 41.0$. If $P_{O_2}(g) = 0.116$ atm and $P_{F_2}(g) = 0.0461$ atm at equilibrium, what is the pressure of $OF_2(g)$?

(A) 0.101 atm **(B)** 0.132 atm

(C) 0.760 atm **(D)** 166 atm

33. For the reaction $2\ HI(g) \rightleftharpoons H_2(g) + I_2(g)$, what is the relationship between K_c and K_p at 25 °C?

(A) $K_c = K_p$

(B) $K_c > K_p$

(C) $K_c < K_p$

(D) The relationship varies depending on the pressure.

34. Calcium hydroxide is slightly soluble in water with a K_{sp} of 1.3×10^{-6}. What is the pH of a saturated solution of calcium hydroxide at 25 °C?

(A) 12.34 **(B)** 12.14 **(C)** 12.04 **(D)** 11.84

35. For the reaction, ADP + phosphate → ATP, $\Delta G° = 30.50$ kJ•mol^{-1}. What is the value of the equilibrium constant, K, for this process under physiological conditions of 37.5 °C?

(A) 4.5×10^{-6} **(B)** 7.4×10^{-6}

(C) 1.3×10^{5} **(D)** 2.2×10^{5}

36. When 0.0030 mol of HCl is added to 100. mL of a 0.10 M solution of a weak base, R_2NH, the solution has a pH of 11.10. What is K_b for the weak base?

(A) 2.9×10^{-3} **(B)** 5.4×10^{-4}

(C) 4.1×10^{-5} **(D)** 1.6×10^{-5}

37. Based on the reactions and data below, which reaction is least spontaneous?

Reduction	$E°$ (V)
$2\ Hg^{2+} + 2\ e^- \rightarrow Hg_2^{2+}$	1.82
$I_2 + 2\ e^- \rightarrow 2\ I^-$	0.53
$2\ H_2O + 2\ e^- \rightarrow H_2 + 2\ OH^-$	–0.83

(A) $2\ Hg^{2+} + 2\ I^- \rightarrow Hg_2^{2+} + I_2$

(B) $H_2 + 2\ OH^- + I_2 \rightarrow 2\ H_2O + 2\ I^-$

(C) $2\ H_2O + Hg_2^{2+} \rightarrow H_2 + 2\ OH^- + 2\ Hg^{2+}$

(D) $H_2 + 2\ OH^- + 2\ Hg^{2+} \rightarrow 2\ H_2O + Hg_2^{2+}$

38. An increase in pH will promote which of the reactions below?

I. $2\ MnO_4^- + MnO_2 + 4\ OH^- \rightarrow 3\ MnO_4^{2-} + 2\ H_2O$

II. $6\ Cl_2 + 2\ I^- + 6\ H_2O \rightarrow 12\ Cl^- + 2\ IO_3^- + 12\ H^+$

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

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

39. Given the reactions and data below, what is the K value for this electrochemical cell?

$Cu|CuNO_3(1.0\ M)||\ I^-(1.0\ M), I_2(1.0\ M)|Pt$ at 25 °C

Reaction	$E°$ (V)
$Cu^+ + e^- \rightarrow Cu$	0.518
$I_2 + 2\ e^- \rightarrow 2\ I^-$	0.534

(A) 0.288 **(B)** 1.86 **(C)** 2.23 **(D)** 3.48

40. The advantages of methane fuel cells over internal combustion engines (ICEs) that burn methane include which of the following?

I. Methane fuel cells are less polluting.

II. Methane fuel cells are more efficient.

III. Methane fuel cells are less expensive.

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

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

41. A steady current of 1.20 Ampere is passed through a solution of MCl_x for 2 hours and 33 minutes. If 2.98 g of metal M are plated out, what is the identity of the metal?

(A) Al **(B)** Cr **(C)** Ni **(D)** Zn

42. $MnO_4^- + 5\ Fe^{2+} + 8\ H^+ \rightarrow Mn^{2+} + 5\ Fe^{3+} + 4\ H_2O$

$E° = 0.743$ V

What is the value of E for the cell based on the reaction above at 25 °C for the following conditions?

$[MnO_4^-]$	$[Fe^{2+}]$	$[Mn^{2+}]$	$[Fe^{3+}]$	pH
2.3×10^{-2} M	1×10^{-4} M	1.0 M	1.0 M	3.00

(A) 0.20 V **(B)** 0.45 V **(C)** 0.64 V **(D)** 1.28 V

43. How many angular nodes does a d orbital possess?

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

44. For the transition metal with the electron configuration $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$, how many unpaired electrons are present in its +2 ion in the ground state?

(A) 0 **(B)** 2 **(C)** 4 **(D)** [illegible]

45. What is the velocity of an electron ($m = 9.11 \times 10^{-28}$ g) that exhibits a de Broglie wavelength of 10.0 nm? [1 J = 1 kg•m^2•s^{-2}]

(A) 72.7 m•s^{-1} **(B)** 270 m•s^{-1}

(C) 7.27×10^4 m•s^{-1} **(D)** 7.27×10^6 m•s^{-1}

46. Which atom has the highest first ionization energy?

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

47. What are the two most common oxidation states for antimony?

(A) –1 and –3 **(B)** –1 and +2

(C) +3 and –3 **(D)** +3 and +5

48. For which pair of species are the radii most similar?

(A) Li and Na **(B)** Na and Mg

(C) Mn and Fe **(D)** Fe^{2+} and Fe^{3+}

49. When arranged in order of increasing bond strength, which order is correct?

(A) O–O < S–S < O=O < S=S

(B) O–O < S–S < S=S < O=O

(C) S–S < O–O < O=O < S=S

(D) S–S < O–O < S=S < O=O

50. Molecules with a permanent dipole moment include which of the following?

I. HCN II. O_3 III. XeF_2

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

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

51. How many stable resonance forms can be written for the oxalate ion, $C_2O_4^{2-}$?

(A) two **(B)** three **(C)** four **(D)** five

52. What is the geometry of ICl_4^- according to VSEPR theory?

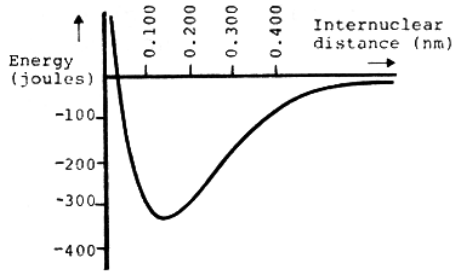
(A) see-saw **(B)** square planar

(C) tetrahedral **(D)** T-shaped

53. According to the molecular orbital theory, what is the bond order of the He–H bond?

(A) ½ **(B)** ¾ **(C)** 1 **(D)** 1 ½

54. As two atoms approach one another in space, the potential energy decreases then increases as shown in the diagram below.



To what are these two changes attributed?
[NOTE: p^+ = proton, e^- = electron]

	decrease (from 0.40 to 0.15 nm)	increase (from 0.15 to 0 nm)
(A)	increased p^+ e^- attraction	increased p^+ p^+ repulsion
(B)	increased p^+ e^- attraction	increased e^- e^- repulsion
(C)	decreased p^+ p^+ repulsion	increased e^- e^- repulsion
(D)	decreased p^+ e^- repulsion	increased p^+ p^+ repulsion

55. Mild oxidation of 1-propanol, $CH_3CH_2CH_2OH$, leads to the formation of

(A) propanal, CH_3CH_2CHO.

(B) propanoic acid, CH_3CH_2COOH.

(C) 2-propanone, CH_3COCH_3.

(D) dipropyl ether, $CH_3CH_2CH_2OCH_2CH_2CH_3$.

56. Which is the principal cation within cellular fluid?

(A) Na^+ **(B)** K^+ **(C)** Mg^{2+} **(D)** Ca^{2+}

57. The shape of a chain segment of polypeptide chains in a protein is known as its

(A) primary structure. **(B)** secondary structure.

(C) tertiary structure. **(D)** quaternary structure.

58. Which property that polyacetylene exhibits is unusual for an organic polymer?

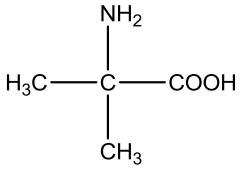
(A) electrical conductivity

(B) flexibility

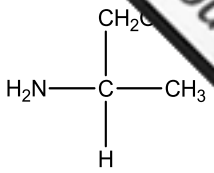
(C) high boiling point

(D) strength

59. Which of the compounds below can exhibit optical isomerism (i.e., exist as enantiomers)?



I.



II.

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

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

60. Which type of dietary fat is the least healthy for humans?

(A) *cis*-monounsaturated fat

(B) polyunsaturated fat

(C) saturated fat

(D) *trans*-monounsaturated fat

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.

AMERICAN CHEMICAL SOCIETY

U.S. National Chemistry Olympiad

Olympiad 2014
USNCO National Exam Part I
KEY

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

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