2015 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. Students should be encouraged to answer these questions and asked to complete the survey on the same Scantron sheet used for the exam. These questions should be completed before the 90 minutes allotted for the exam.

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 20, 2015, 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, 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.

Before you start this exam, you are encouraged to respond 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

Questions **62–64** 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.

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

$R = 8.314\ \text{J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$

$R = 0.0821\ \text{L}\cdot\text{atm}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$

$1\ F = 96{,}500\ \text{C}\cdot\text{mol}^{-1}$

$1\ F = 96{,}500\ \text{J}\cdot\text{V}^{-1}\cdot\text{mol}^{-1}$

$N_A = 6.022 \times 10^{23}\ \text{mol}^{-1}$

$h = 6.626 \times 10^{-34}\ \text{J}\cdot\text{s}$

$c = 2.998 \times 10^{8}\ \text{m}\cdot\text{s}^{-1}$

0 °C = 273.15 K

1 atm = 760 mm Hg

Specific heat capacity of H_2O = $4.184\ \text{J}\cdot\text{g}^{-1}\cdot\text{K}^{-1}$

EQUATIONS

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

PERIODIC TABLE OF THE ELEMENTS

1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1 **H** 1.008																	2 **He** 4.003
3 **Li** 6.941	4 **Be** 9.012											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.88	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.39	31 **Ga** 69.72	32 **Ge** 72.61	33 **As** 74.92	34 **Se** 78.96	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 **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 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. Calcium carbonate, $CaCO_3$, decomposes upon heating to calcium oxide and carbon dioxide. What mass of solid calcium carbonate is required to produce 2.40 liters of carbon dioxide measured at STP?

(A) 10.7 g **(B)** 21.4 g **(C)** 50.0 g **(D)** 100. g

2. Aspirin, $C_9H_8O_4$, is prepared by the acetylation of salicylic acid, $C_7H_6O_3$, according to the following equation:

$$C_7H_6O_3 + (CH_3CO)_2O \rightarrow C_9H_8O_4 + CH_3COOH$$

If the yield of this reaction is 83%, what mass of salicylic acid would be required to prepare 1.0 kg of aspirin?

(A) 0.77 kg **(B)** 0.92 kg

(C) 1.2 kg **(D)** 1.3 kg

3. A solution is prepared by mixing 25.0 mL of 6.0 M HCl with 45.0 mL of 3.0 M HNO_3. What is $[H^+]$ in the resulting solution?

(A) 1.9 M **(B)** 2.1 M **(C)** 4.1 M **(D)** 4.5 M

4. A 5.73 g sample of a liquid hydrocarbon burned in excess oxygen produces 17.48 g CO_2. What is the formula of the hydrocarbon?

(A) C_5H_{12} **(B)** C_6H_6

(C) C_6H_{10} **(D)** C_6H_{12}

5. A solution of 3.00 g of which substance, dissolved in 100 g H_2O, has the highest boiling point?

(A) $HOCH_2CH(OH)CH_2OH$ (M = 92.1)

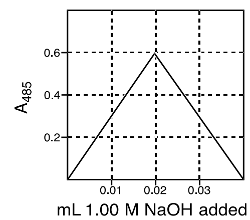
(B) RbF (M = 104.5)

(C) $AlCl_3$ (M = 133.3)

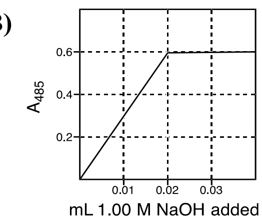
(D) $TlNO_3$ (M = 390.4)

6. Nitrophenol is a colorless weak monoprotic acid (pK_a = 7.2) whose conjugate base is bright yellow. To 2.00 mL of a solution of 0.0100 M nitrophenol is added 1.00 M NaOH in 0.001 mL portions, and the absorbance of the solution at 485 nm is monitored. What does the graph of A_{485} as a function of added volume of NaOH look like?

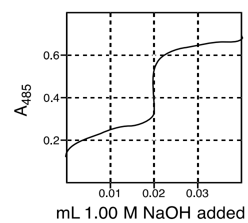
(A)



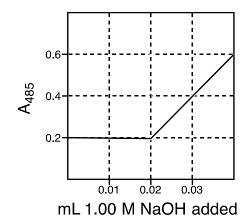
(B)



(C)



(D)



7. Each of the following substances dissolves exothermically in water EXCEPT

(A) $NaOH(s)$. **(B)** $NH_4NO_3(s)$.

(C) $CuSO_4(s)$. **(D)** $H_2SO_4(l)$.

8. Which solid is most soluble in water at 25 ºC?

(A) $AgNO_3$ **(B)** $CaCO_3$ **(C)** PbO **(D)** ZnS

9. A student standardizes a solution of $Na_2S_2O_3$ by titrating it against a solution containing a known mass of $NaIO_3$ that has been dissolved in an excess of a freshly prepared solution of KI in dilute HCl. Which of the following errors will lead to a value of the molarity of the thiosulfate solution that is higher than the true value?

(A) The student overshoots the endpoint of the titration.

(B) The $NaIO_3$ is contaminated with NaCl.

(C) The KI/HCl solution is allowed to stand overnight before it is used in the titration.

(D) The sample of sodium thiosulfate pentahydrate used to make the $Na_2S_2O_3$ solution had partially dehydrated on standing.

10. Mixing equal volumes of 0.1 M $Ca(NO_3)_2$ and AgF solutions results in

(A) no precipitate and a colorless solution.

(B) no precipitate and a colored solution.

(C) a white precipitate and a colorless solution.

(D) a colored precipitate and a colorless solution.

11. Elemental silicon is oxidized by O_2 to give a compound which dissolves in molten Na_2CO_3. When this solution is treated with aqueous hydrochloric acid, a precipitate forms. What is the precipitate?

(A) SiH_4 **(B)** $SiCO_3$ **(C)** SiO_2 **(D)** $SiCl_4$

12. A metal dissolves in 3.0 M NaOH solution with evolution of gas to form a clear, colorless solution. Upon neutralization, the solution forms a gelatinous precipitate. What is the metal?

(A) Al **(B)** Ag **(C)** Cu **(D)** Mg

13. Which of the following substances experience London dispersion forces?

I. CH_3CH_3 II. CH_3OH

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

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

14. Which of these pure substances has the highest normal boiling point?

(A) CH_4 **(B)** NH_3 **(C)** SiH_4 **(D)** PH_3

15. A mixture of 0.50 mol of H_2 gas and 1.3 mol of Ar gas is in a sealed container with a volume of 4.82 L. If the temperature of the mixture is 50.0 °C, what is the partial pressure of H_2 in the sample?

(A) 1.5 atm **(B)** 2.8 atm

(C) 7.2 atm **(D)** 9.9 atm

16. For which pair of allotropes is one a molecular solid and the other a network covalent solid?

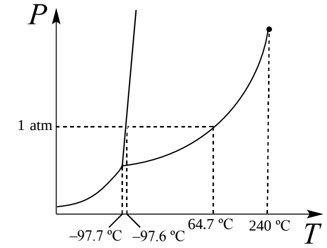
(A) Dioxygen and ozone

(B) White phosphorus and red phosphorus

(C) Rhombic sulfur and monoclinic sulfur

(D) Gray tin and white tin

17. According to the phase diagram of methanol shown below, which statement is correct?



(A) Solid methanol has a greater density than liquid methanol.

(B) Solid methanol sublimes at atmospheric pressure.

(C) Solid, liquid, and gaseous methanol can only coexist at pressures above 1 atm.

(D) At 200 ºC and 1 atm pressure, methanol is a supercritical fluid.

18. Which statement about atoms arranged in a body-centered cubic (bcc) crystal structure is correct?

(A) It is not observed as the structure of any metallic elements.

(B) It is also called the cubic closest-packed (ccp) structure.

(C) The unit cell contains two atoms.

(D) Each atom has 6 nearest neighbors.

19. A system consists of a gas contained in a thin balloon. If the balloon deflates as the temperature of the gas changes from 90 ºC to 25 ºC, then

(A) Heat is transferred out of the system and work is done on the system.

(B) Heat is transferred out of the system and work is done by the system.

(C) Heat is transferred into the system and work is done on the system.

(D) Heat is transferred into the system and work is done by the system.

20. The ΔH_f^o of MgO is –602 kJ•mol^{-1}. When 20.15 g MgO is decomposed at constant pressure according to the equation below, how much heat will be transferred?

$$2\ MgO(s) \rightarrow 2\ Mg(s) + O_2(g)$$

(A) 1.20×10^3 kJ of heat is released

(B) 6.02×10^2 kJ of heat is absorbed

(C) 6.02×10^2 kJ of heat is released

(D) 3.01×10^2 kJ of heat is absorbed

21. What mass of ice at 0.0 ºC must be added to 100. g H_2O at 25.0 ºC to cool it to 0.0 ºC? The heat of fusion of ice is 334 J•g^{-1}.

(A) 1.25 g **(B)** 7.49 g **(C)** 31.3 g **(D)** 100. g

22. Using the bond dissociation enthalpies (BDE) in the table, estimate ΔH° for the disproportionation of hydrazine described in the equation below.

$$3\ N_2H_4(g) \rightarrow 4\ NH_3(g) + N_2(g)$$

Bond	BDE, kJ•mol^{-1}	Bond	BDE, kJ•mol^{-1}
N–N	163	N≡N	944
N=N	409	N–H	388

(A) +283 kJ•mol^{-1} **(B)** –283 kJ•mol^{-1}

(C) –393 kJ•mol^{-1} **(D)** –455 kJ•mol^{-1}

23. Which halogen has the highest standard entropy, S°?

(A) $F_2(g)$ **(B)** $Cl_2(g)$ **(C)** $Br_2(l)$ **(D)** $I_2(s)$

24. A chemical reaction has $K_{eq} = 1 \times 10^{-5}$ at 25 ºC, and the value of K_{eq} increases with increasing temperature. From these statements, what may one conclude?

(A) $\Delta H^\circ > 0$ and $\Delta S^\circ > 0$

(B) $\Delta H^\circ < 0$ and $\Delta S^\circ < 0$

(C) $\Delta H^\circ < 0$ and $\Delta S^\circ > 0$

(D) $\Delta H^\circ > 0$ and no conclusion may be drawn about the sign of ΔS°

25. For the reaction

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

the rate law is rate = $k[H_2][NO]^2$. At a given temperature, what is the effect on the reaction rate if the concentration of H_2 is doubled and the concentration of NO is halved?

(A) The reaction rate is halved.

(B) The reaction rate is unchanged.

(C) The reaction rate is doubled.

(D) The reaction rate increases eightfold.

26. A substance X decomposes in a second-order reaction. A solution that is initially 1.00 M in X requires 0.50 h for its concentration to decrease to 0.50 M. How much time will it take for a solution of X to decrease in concentration from 1.00 M to 0.25 M?

(A) 0.50 h **(B)** 1.0 h **(C)** 1.5 h **(D)** 2.0 h

27. The reaction

$$H_2O_2(aq) + 3\ I^-(aq) + 2\ H^+(aq) \rightarrow I_3^-(aq) + 2\ H_2O(l)$$

has a rate law of rate = $k[H_2O_2][I^-]$. What is the order of the reaction with respect to H^+, and what is the overall order of the reaction?

(A) 0th order in H^+, 2nd order overall

(B) 1st order in H^+, 2nd order overall

(C) 1st order in H^+, 3rd order overall

(D) 2nd order in H^+, 6th order overall

28. Which of the following are reasons why reaction rates increase as temperature increases?

I. Collisions are more frequent between molecules at higher temperatures.

II. A greater fraction of collisions have sufficient energy to exceed E_a at higher temperatures.

III. Reactant concentrations are higher at higher temperatures.

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

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

29. What is the effect of adding a catalyst on the rate of a reversible reaction in the forward and the reverse direction?

(A) It has no effect on the rate in either direction.

(B) Both rates increase by the same factor.

(C) The rate in the forward direction increases by a greater factor than the rate in the reverse direction.

(D) The rate in the reverse direction increases by a greater factor than the rate in the forward direction.

30. Consider the proposed mechanism for the destruction of ozone in the stratosphere:

$$O_3 + Cl\bullet \rightarrow ClO\bullet + O_2$$

$$ClO\bullet + O_3 \rightarrow Cl\bullet + 2\ O_2$$

Which of the statements about this mechanism is correct?

(A) Cl• is a catalyst.

(B) O_2 is an intermediate.

(C) Equal amounts of Cl• and ClO• are present.

(D) The number of moles of O_2 produced equals the number of moles of O_3 consumed.

31. For the reaction

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

which statements are correct?

I. $K_c = [SO_2][O_2]/[SO_3]$

II. Addition of $O_2(g)$ to the system at constant temperature and volume would decrease the value of K_c.

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

32. What is the value of K_p for the following reaction?

$$N_2(g) + 2\ O_2(g) \rightleftharpoons N_2O_4(g)$$

Reaction	K_p
$\frac{1}{2}\ N_2O_4(g) \rightleftharpoons NO_2(g)$	x
$\frac{1}{2}\ N_2(g) + O_2(g) \rightleftharpoons NO_2(g)$	y

(A) y/x **(B)** y^2/x^2 **(C)** x^2/y^2 **(D)** xy^2

33. Which solution has the greatest percent ionization?

(A) 0.10 M NH_3 ($K_b = 1.8 \times 10^{-5}$)

(B) 0.25 M HNO_2 ($K_a = 4.5 \times 10^{-4}$)

(C) 1.00 M HCOOH ($K_a = 1.7 \times 10^{-4}$)

(D) 2.00 M CH_3NH_2 ($K_b = 4.4 \times 10^{-4}$)

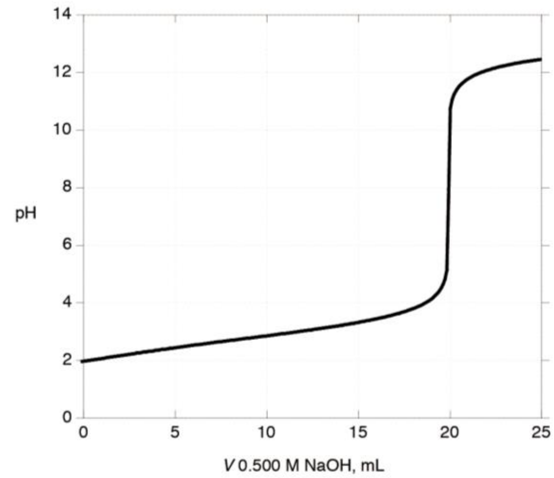
34. What is the pH of a 0.200 M solution of C_6H_5COONa? (The K_a of C_6H_5COOH is 6.4×10^{-5}.)

(A) 5.25 **(B)** 5.40 **(C)** 8.60 **(D)** 8.75

35. Silver chloride, AgCl ($K_{sp} = 1.8 \times 10^{-10}$), can be dissolved in solutions containing ammonia due to the formation of the soluble complex ion $Ag(NH_3)_2^+$ ($K_f = 1.0 \times 10^8$). What is the minimum amount of NH_3 that would need to be added to dissolve 0.010 mol AgCl in 1.00 L of solution?

(A) 0.010 mol **(B)** 0.020 mol
(C) 0.095 mol **(D)** 0.13 mol

36. A sample of 100 mL of a solution of a weak monoprotic acid of unknown concentration is titrated with 0.500 M NaOH to give the titration curve shown.



All of the statements are correct EXCEPT:

(A) Phenolphthalein would be a suitable indicator for this titration.

(B) A buffer solution is formed when 15 mL of NaOH is added.

(C) The pKa of the acid is 4.0.

(D) The initial concentration of the acid is 0.10 M.

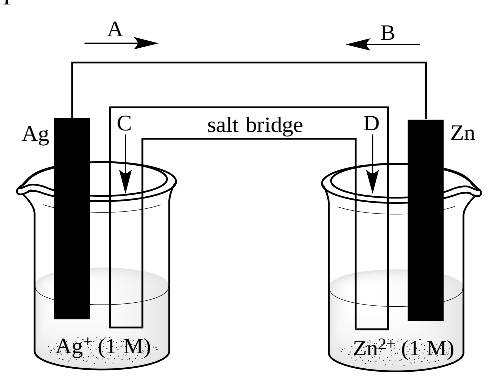
37. What is the oxidation number of Re in $Mg(ReO_4)_2$?

(A) +4 **(B)** +5 **(C)** +6 **(D)** +7

38. It takes 126.5 minutes using a current of 5.15 A to deposit all of the nickel from 225 mL of a solution containing Ni^{2+}. What was the original concentration of Ni^{2+} in the solution?

(A) 3.60 M **(B)** 1.80 M
(C) 0.900 M **(D)** 1.50×10^{-2} M

39. In the galvanic cell shown below, which arrow indicates the spontaneous electron flow?



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

40. What is the coefficient of I_2 (s) when the reaction below is balanced with smallest whole number coefficients?

$$\_\_\ Cr_2O_7^{2-}(aq) + \_\_\ I^-(aq) + \_\_\ H^+(aq) \rightarrow$$
$$\_\_\ I_2(s) + \_\_\ Cr^{3+}(aq) + \_\_\ H_2O(l)$$

(A) 2 **(B)** 3 **(C)** 4 **(D)** 6

41. Lithium ion batteries are now commonly used in rechargeable consumer electronic devices. The main reason lithium is used in these devices is because

(A) lithium has a lower electronegativity than nickel in common nickel-cadmium batteries.
(B) lithium batteries are not as toxic as common alkaline batteries.
(C) lithium batteries have a reduced risk of leakage of chemicals.
(D) lithium batteries achieve a greater amount of energy stored per unit mass than other common batteries.

42. The standard reduction potential of $Cd^{2+}(aq)$ is –0.402 V. A voltaic cell described by

$$Cd(s) + 2\ H^+(aq) \rightarrow Cd^{2+}(aq) + H_2(aq)$$

has $[Cd^{2+}]$ = 0.900 M and a hydrogen pressure of 0.975 atm. Its cell potential at 25 ºC is measured as E = +0.192 V. What is the pH in the $H^+ \mid H_2$ half-cell?

(A) 3.28 **(B)** 3.58 **(C)** 6.54 **(D)** 7.15

43. Which of the following sets of quantum numbers n, l, m_l, m_s correspond to a valence electron in a neutral atom of arsenic (As)?

(A) 3, 0, 0, +1/2 **(B)** 3, 2, 1, –1/2
(C) 4, 0, 0, +1/2 **(D)** 4, 2, 1, –1/2

44. Which gas-phase atom has the largest radius?

(A) Na **(B)** K **(C)** Mg **(D)** Ca

45. Which of the following does NOT represent the arrangement of electrons in the *p* subshell in the ground state of any gas-phase atom?

(A) ↑↓ ↑ __ **(B)** ↑ ↑ ↑
(C) ↑↓ ↓ ↓ **(D)** __ __ __

46. Which element's electronegativity is closest to that of S?

(A) O **(B)** P **(C)** Cl **(D)** Se

47. Atomic nitrogen has a higher ionization energy than atomic oxygen. This is best explained by

(A) the lower electron-electron repulsion in nitrogen.
(B) the greater effective nuclear charge of nitrogen.
(C) the fact that the electron ionized in N is from the 2*s* subshell, while that ionized from O is from the 2*p* subshell.
(D) the fact that N has an odd number of electrons while O has an even number.

48. The energy required to break one mole of hydrogen-hydrogen bonds in H_2 is 436 kJ. What is the longest wavelength of light with sufficient energy to break a single hydrogen-hydrogen bond?

(A) 122 nm **(B)** 132 nm
(C) 274 nm **(D)** 656 nm

49. In the Lewis structure for the selenite ion, SeO_3^{2-}, how many lone pairs are around the central atom?

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

50. Removing an electron from molecular oxygen, O_2, to form the dioxygenyl cation, O_2^+, causes what changes in the bond length and in the number of unpaired electrons?

	Bond length	Number of unpaired electrons
(A)	Increase	Increase
(B)	Increase	Decrease
(C)	Decrease	Increase
(D)	Decrease	Decrease

51. Which of the following molecules has a dipole moment of zero?

(A) HCN **(B)** CH_2Cl_2
(C) SO_2 **(D)** CO_2

52. Formamide has the structure $HC(O)NH_2$. Which atoms in formamide have a trigonal planar geometry?

(A) C only **(B)** N only
(C) Both C and N **(D)** None of them

53. What is the coordination geometry of nickel in $Ni(CO)_4$?

(A) Tetrahedral **(B)** Square planar
(C) See-saw **(D)** T-shaped

54. Which of the following are ionic compounds?

I. NH_2NO_2 II. NH_4NO_3

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

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

55. What is the formula for ethyl propanoate?

(A) $CH_3CH_2CO_2CH_2CH_3$

(B) $CH_3CH_2CH_2CO_2CH_2CH_3$

(C) $CH_3CH_2CO_2CH_2CH_2CH_3$

(D) $CH_3CH_2COCH_2CH_2OCH_3$

56. Which substance can exist in enantiomeric forms?

(A) 3-methylpentane **(B)** 2-methylpentane

(C) 3-methyl-1-butanol **(D)** 2-methyl-1-butanol

57. Which of the following is a difference between benzene and cyclooctatetraene?

(A) Benzene reacts rapidly with bromine and cyclooctatetraene does not.

(B) Benzene contains sp^2-hybridized carbon atoms and cyclooctatetraene does not.

(C) Benzene has the formula C_nH_n and cyclooctatetraene does not.

(D) Benzene is planar and cyclooctatetraene is not.

58. Which base is found in RNA, but not DNA?

(A) Adenine **(B)** Guanine

(C) Thymine **(D)** Uracil

59. A triglyceride is formed from

(A) one molecule of glycerin and two molecules of fatty acid.

(B) one molecule of glycerin and three molecules of fatty acid.

(C) three molecules of glycerin and one molecule of fatty acid.

(D) two molecules of glycerin and one molecule of fatty acid.

60. Which of these amino acids has the most hydrophobic side chain at neutral pH?

(A) Cysteine, $HSCH_2CH(NH_2)COOH$

(B) Glutamine, $H_2NC(O)CH_2CH_2CH(NH_2)COOH$

(C) Leucine, $(CH_3)_2CHCH_2CH(NH_2)COOH$

(D) Lysine, $H_2NCH_2CH_2CH_2CH_2CH(NH_2)COOH$

END OF TEST

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KEY

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