2011 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

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 18, 2011, 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 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•mo
R = 0.0821 L•atm•mo
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

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** (266)	107 **Bh** (264)	108 **Hs** (277)	109 **Mt** (268)	110 **Ds** (281)	111 **Rg** (272)	112 **Cn** (277)	113 (Uut)	114 (Uuq)	115 (Uup)	116 (Uuh)	117 (Uus)	118 (Uuo)

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 ve
- 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. Which solid does not react with a small amount of 3 M HNO_3?

(A) calcium carbonate **(B)** manganese(II) sulfide

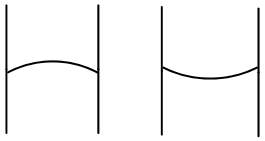
(C) potassium sulfite **(D)** silver chloride

2. A metal dissolves in dilute HCl in the absence of air to form a pale green solution that turns yellow upon exposure to air. The metal could be

(A) iron. **(B)** manganese.

(C) nickel. **(D)** vanadium.

3. In a glass tube columns of water and mercury appear as shown.



This is best attributed to the differences in their

(A) densities. **(B)** molar masses.

(C) surface tensions. **(D)** viscosities.

4. Compounds of uranium-235 and uranium-238 can be separated from one another by

(A) distillation.

(B) effusion.

(C) fractional crystallization.

(D) paper chromatography.

5. A Material Safety Data Sheet (MSDS) provides what type(s) of information about a chemical?

I First aid measures II Handling and storage tips

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

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

6. When a 25.00 mL volumetric flask weighing 20.340 g is filled partially with metal shot the mass is 119.691 g. The flask is then filled to the 25.00 mL mark with methanol ($d = 0.791$ g•cm^{-3}) and has a total mass of 130.410 g. What is the density of the metal?

(A) 6.96 g•cm^{-3} **(B)** 8.68 g•cm^{-3}

(C) 9.27 g•cm^{-3} **(D)** 11.7 g•cm^{-3}

7. An aqueous solution contains the ions Ag^+, Ba^{2+}, and Ni^{2+}. Dilute aqueous solutions of NaCl, Na_2S, and Na_2SO_4 are available. In what order should these solutions be added if the goal is to precipitate each of the three cations separately?

(A) Na_2S, Na_2SO_4, NaCl **(B)** Na_2S, NaCl, Na_2SO_4

(C) Na_2SO_4, Na_2S, NaCl **(D)** NaCl, Na_2SO_4, Na_2S

8. A 10.00 g sample of a compound containing C, H, and O is burned completely to produce 14.67 g of CO_2 and 6.000 g of H_2O. What is the empirical formula of this compound?

(A) CHO **(B)** CH_2O **(C)** CH_2O_2 **(D)** C_2H_4O

9. What is the molality of a solution made by dissolving 36.0 g of glucose ($C_6H_{12}O_6$, $M = 180.2$) in 64.0 g of H_2O?

(A) 0.0533 **(B)** 0.200 **(C)** 0.360 **(D)** 3.12

10. Which aqueous solution freezes at the lowest temperature?

(A) 0.30 *m* C_2H_5OH **(B)** 0.25 *m* KNO_3

(C) 0.20 *m* $CaBr_2$ **(D)** 0.10 *m* $FeCl_3$

11. Element E reacts with oxygen to produce EO_2. Identify element E if 16.5 g of it react with excess oxygen to form 26.1 g of EO_2.

(A) manganese **(B)** nickel

(C) sulfur **(D)** titanium

12. Ethanol (C_2H_5OH, $M = 46$) and methanol (CH_3OH, $M = 32$) form an ideal solution when mixed. What is the vapor pressure of a solution prepared by mixing equal masses of ethanol and methanol? (The vapor pressures of ethanol and methanol are 44.5 mm Hg and 88.7 mm Hg, respectively.)

(A) 133 mm Hg **(B)** 70.6 mm Hg

(C) 66.6 mm Hg **(D)** 44.5 mm Hg

13. A 5.00 L evacuated cylinder is charged with 25.5 g of NH_3 and 36.5 g of HCl. Calculate the final pressure at 85.0 °C after the two compounds have reacted completely. $NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$

(A) 2.94 atm **(B)** 5.88 atm

(C) 8.82 atm **(D)** 14.7 atm

14. Pure samples of which of the following exhibit hydrogen bonding?

I CH_3OH II CH_3NO_2 III CH_3CN

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

15. The average molecular velocity in a gas sample at 300 K is 500 m/s. The temperature of this gas is increased until the average velocity of its molecules is 1000 m/s. What is the new temperature?

(A) 420 K **(B)** 573 K **(C)** 600 K **(D)** 1200K

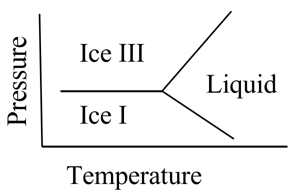
16. Which of the following compounds has the lowest boiling point?

(A) HF **(B)** HCl **(C)** HBr **(D)** HI

17. What is the coordination number of each atom in a hexagonal close-packed solid?

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

18. Water ice exists in several different forms depending on the pressure and temperature. A portion of the phase diagram for ice I, ice III, and liquid water is shown below.



Which statement about the densities of these three phases is correct?

(A) The density of liquid water is greater than the densities of either ice I or ice III.
(B) The density of ice I is greater than the densities of either ice III or liquid water.
(C) The density of ice III is greater than the densities of either ice I or liquid water.
(D) The densities of ice I and ice III are equal and greater than the density of liquid water.

19. Spontaneous reactions always

(A) go to completion.
(B) are fast.
(C) involve phase changes.
(D) release energy and/or show an increase in the system's entropy.

20. The standard enthalpies of combustio[illegible]yde, $H_2C{=}O(g)$, and formic acid, $HCOOH(l)$, [illegible] $-270\ kJ{\bullet}mol^{-1}$ respectively. What is ΔH° fo[illegible] following reaction?

$H_2C{=}O(g) + 1/2\ O_2(g) \rightarrow HCOOH(l)$

(A) $-833\ kJ{\bullet}mol^{-1}$ **(B)** $-293\ kJ{\bullet}mol^{-1}$
(C) $293\ kJ{\bullet}mol^{-1}$ **(D)** $833\ kJ{\bullet}mol^{-1}$

21. What is ΔH° for the reaction below?

$TiCl_4(g) + 2\ H_2O(l) \rightarrow TiO_2(s) + 4\ HCl(g)$

Species	$TiCl_4(g)$	$H_2O(l)$	$TiO_2(s)$	$HCl(g)$
$\Delta H^\circ_f\ kJ{\bullet}mol^{-1}$	–763	–286	–945	–92

(A) $298\ kJ{\bullet}mol^{-1}$ **(B)** $22\ kJ{\bullet}mol^{-1}$
(C) $12\ kJ{\bullet}mol^{-1}$ **(D)** $-264\ kJ{\bullet}mol^{-1}$

22. For Br_2, $\Delta H^\circ_{vap} = 31\ kJ{\bullet}mol^{-1}$. If S° values for $Br_2(g)$ and $Br_2(l)$ are $245\ J{\bullet}mol^{-1}{\bullet}K^{-1}$ and $153\ J{\bullet}mol^{-1}{\bullet}K^{-1}$ respectively, what is the normal boiling point for $Br_2(l)$?

(A) 340 K **(B)** 200 K **(C)** 130 K **(D)** 70 K

23. When MgO reacts with H_2O at 25 ˚C and 1 atm, the volume change is $-4.6\ mL{\bullet}mol^{-1}$.

$MgO(s) + H_2O(l) \rightarrow Mg(OH)_2(s)$

What is the value of $\Delta H - \Delta E$ for this reaction?

(A) $-4.7 \times 10^{-1}\ J{\bullet}mol^{-1}$ **(B)** $-4.7 \times 10^{2}\ J{\bullet}mol^{-1}$
(C) $4.7 \times 10^{2}\ J{\bullet}mol^{-1}$ **(D)** $4.7 \times 10^{-1}\ J{\bullet}mol^{-1}$

24. For the dissolution of Ag_2SO_4, $\Delta H^\circ = 17.8\ kJ{\bullet}mol^{-1}$ and $\Delta S^\circ = -34.9\ J{\bullet}mol^{-1}{\bullet}K^{-1}$ at 25 ˚C. What is the value of the K_{sp} for Ag_2SO_4 at this temperature?

(A) 5.0×10^{-2} **(B)** 7.6×10^{-4}
(C) 5.3×10^{-4} **(D)** 1.1×10^{-5}

25. A rigid container holds an equal number of moles of N_2 and H_2 gas at a total pressure of 10.0 atm. The gases react according to the equation, $N_2(g) + 3\ H_2(g) \rightleftharpoons 2\ NH_3(g)$. If the total pressure of the gas decreases at a rate of $0.20\ atm{\bullet}s^{-1}$, what is the rate of change of the partial pressure of N_2 in the container?

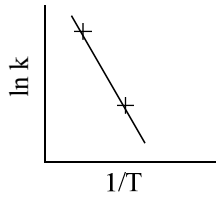
(A) decreases at $0.40\ atm{\bullet}s^{-1}$
(B) decreases at $0.30\ atm{\bullet}s^{-1}$
(C) decreases at $0.20\ atm{\bullet}s^{-1}$
(D) decreases at $0.10\ atm{\bullet}s^{-1}$

26. A reaction is found to have the rate law: Rate = $k[A]^2[B]$. Which set of data is consistent with this finding?

	[A], mol•L^{-1}	[B], mol•L^{-1}	Rate, mol•L^{-1}•s^{-1}
Given	0.010	0.010	1.2×10^{-4}
A	0.010	0.020	2.4×10^{-4}
B	0.020	0.010	6.0×10^{-4}
C	0.020	0.020	4.8×10^{-4}
D	0.010	0.020	4.8×10^{-4}

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

27. The value of the specific rate constant, k, for a reaction is determined at two different temperatures and plotted in the accompanying graph.



What is the relationship between the slope of the graph and the activation energy, E_a?

(A) slope = E_a **(B)** slope = $-E_a$

(C) slope = $-E_a/R$ **(D)** slope = $E_a \times R$

28. Consider the reaction, $2\ NO(g) + Cl_2(g) \rightarrow 2\ NOCl$. Which of the following is/are required for a successful reaction between NO and Cl_2 molecules?

I Proper orientation
II NO/Cl_2 Ratio of 2 to 1
III Sufficient collision energy

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

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

29. When sucrose, $C_{12}H_{22}O_{11}$, is dissolved in H_2O in the presence of an acid catalyst it reacts according to the equation $C_{12}H_{22}O_{11} + H_2O \rightarrow 2\ C_6H_{12}O_6$ with a rate law of Rate = $k[C_{12}H_{22}O_{11}]$. If 3.00 g of sucrose decreases to 2.70 g in 2.50 hours in the presence of a certain concentration of an acid catalyst, what is the half-life for this reaction under these same conditions?

(A) 12.5 hours **(B)** 16.4 hours

(C) 23.7 hours **(D)** 37.9 hours

30. For the reaction $H_2(g) + 2\ ICl(g) \rightarrow 2$ [illegible] one proposed mechanism is

$H_2(g) + ICl(g) \rightarrow HICl(g) + H(g)$ slow
$H(g) + ICl(g) \rightarrow HCl(g) + I(g)$ fast
$HICl(g) \rightarrow HCl(g) + I(g)$ fast
$I(g) + I(g) \rightarrow I_2(g)$ fast

Intermediates in this reaction include which of the following?

(A) HICl only **(B)** I only

(C) HICl and H only **(D)** HICl, H, and I

31. For the hypothetical reaction: A + B → C + D, the equilibrium constant, K, is less than 1.0 at 25 ˚C and decreases by 35% on changing the temperature to 45 ˚C. What must be true according to this information?

(A) The ΔH° for the reaction is negative.

(B) The ΔS° for the reaction is positive.

(C) The ΔG° for the reaction at 25˚ is negative.

(D) The ΔG° for the reaction at 45˚ is zero.

32. Consider the reaction carried out at constant volume:
$2\ SO_2(g) + O_2(g) \rightleftharpoons 2\ SO_3(g)$.
For initial concentrations of SO_2 and O_2 of 2.0 M and 1.5 M, respectively, the equilibrium O_2 concentration is 0.80 M. What is the value of K_c for this reaction?

(A) 6.8 **(B)** 2.9 **(C)** 0.34 **(D)** 0.15

33. Correct statements about the percentage ionization of weak acids in water include which of the following?

I The percentage ionization increases as the ionization constant of the acid becomes larger.
II The percentage ionization increases as the concentration of the acid becomes smaller.

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

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

34. What is the pH of the solution made by mixing 25.0 mL of 1.00×10^{-3} M HNO_3 and 25.0 mL of 1.00×10^{-3} M NH_3? [K_b for $NH_3 = 1.8 \times 10^{-5}$]

(A) 4.02 **(B)** 6.28 **(C)** 7.72 **(D)** 9.98

35. For the synthesis of ammonia, K_c is 1.2 at 375 ˚C
$N_2(g) + 3\ H_2(g) \rightleftharpoons 2\ NH_3(g)$,
What is K_p at this temperature?

(A) 4.1×10^{-8} **(B)** 4.2×10^{-4}

(C) 1.3×10^{-3} **(D)** 3.4×10^{3}

36. Calculate the aqueous solubility of $Ca(OH)_2$ in grams per liter. [$K_{sp} = 8.0 \times 10^{-6}$]

(A) 5.9×10^{-4} **(B)** 2.0×10^{-2}

(C) 0.93 **(D)** 1.5

37. What is the coefficient for Zn when the equation below is balanced with the smallest whole number coefficients?
$Zn + H^+(aq) + NO_3^-(aq) \rightarrow Zn^{2+}(aq) + N_2O(g) + H_2O(l)$

(A) 2 **(B)** 4 **(C)** 6 **(D)** 8

38. Which change occurs as the chemical reaction takes place in the standard electrochemical cell represented below?

$Zn(s)|Zn^{2+}(aq)||Sn^{2+}(aq)|Sn(s)$

Reduction Half-reaction	E° (Volts at 298 K)
$Sn^{2+}(aq) + 2e^- \rightarrow Sn(s)$	–0.136
$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$	–0.763

I Electrons move through the external circuit from Zn to Sn.
II The concentration of $Zn^{2+}(aq)$ increases.
III The voltage increases from a negative value to zero.

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

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

39. For the reaction:
$C_3H_8(g) + 5\ O_2(g) \rightarrow 3\ CO_2(g) + 4\ H_2O(l)$,
$\Delta G^\circ = -2.108 \times 10^3$ kJ•mol^{-1}. What is the value of the standard electrode potential, E° for a fuel cell based on this reaction?

(A) 1.09 V **(B)** 2.18 V **(C)** 4.37 V **(D)** 21.8 V

40. What occurs when an aqueous solution of Na_2SO_4 containing several drops of phenolphthalein is electrolyzed between Pt electrodes?

(A) The colorless solution turns pink at the anode but remains colorless at the cathode.

(B) The colorless solution turns pink at the cathode but remains colorless at the anode.

(C) The pink solution becomes colorless at the anode but remains pink at the cathode.

(D) The pink solution becomes colorless at the cathode but remains pink at the anode.

41. A current of 12 A is used to plate nickel from a $Ni(NO_3)_2$ solution. Both Ni(s) and H_2(g) are produced at the cathode. If the current efficiency with respect to the formation of Ni(s) is 62%, how many grams of nickel are plated on the cathode in 45 minutes?

(A) 0.10 **(B)** 6.1 **(C)** 9.9 **(D)** 12

42. Calculate the cell potential, E, for a si[illegible]oride electrode immersed in 0.800 M KCl at 2[illegible]
[$Ag^+ + e^- \rightarrow Ag$, $E^\circ = 0.799$ V; $K_{sp} = 1.8 \times$[illegible]

(A) 1.37 V **(B)** 0.80 V **(C)** 0.57 V **(D)**

43. Which gas-phase atom in its ground state has exactly three unpaired electrons?

(A) Sc **(B)** Fe **(C)** Co **(D)** Se

44. The first ionization energy of Na is 495.9 kJ•mol^{-1}. What is the longest wavelength of light that could remove an electron from a Na atom?

(A) 2.41×10^{-7} m **(B)** 2.41×10^{-4} m

(C) 4.14 m **(D)** 4.14×10^3 m

45. Which set of quantum numbers could represent an electron in a 5f orbital?

(A) $l = 4, m_l = 2$ **(B)** $l = 2, m_l = -3$

(C) $l = 3, m_l = 4$ **(D)** $l = 3, m_l = 0$

46. Which orbital possesses one angular node and one radial node?

(A) 2s **(B)** 2p **(C)** 3p **(D)** 3d

47. The radius of which ion is closest to that of the Li^+ ion?

(A) Na^+ **(B)** Be^{2+} **(C)** Mg^{2+} **(D)** Al^{3+}

48. Of the atoms listed, which has the largest third ionization energy?

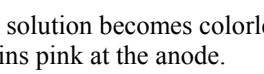
(A) Ca **(B)** Mg **(C)** Al **(D)** Si

49. When the molecules N_2, N_2O, and N_2O_4 are arranged in order of decreasing N – N bond length, which order is correct?

(A) N_2O_4, N_2O, N_2 **(B)** N_2, N_2O, N_2O_4

(C) N_2O, N_2, N_2O_4 **(D)** N_2, N_2O_4, N_2O

50. From a consideration of the Lewis structure,



what are the formal charges?

(A) N = –1, C = 0, O = 0 **(B)** N = 0, C = 0, O = –1

(C) N = –1, C = +1, O = –1 **(D)** N = –1, C = –1, O = +1

51. For the reaction:
$3\ H_2 + N_2 \rightarrow 2\ NH_3$ $\Delta H^\circ = -97$ kJ•mol^{-1}.
The H_2 and N_2 bond energies are 436 and 941 kJ•mol^{-1}, respectively. What is the bond energy of a single N–H bond in kJ•mol^{-1}?

(A) 246 **(B)** 359 **(C)** 391 **(D)** 782

52. What is the geometry of the IBr_2^- ion?

(A) linear

(B) bent with a bond angle of about 90˚

(C) bent with a bond angle of about 109˚

(D) bent with a bond angle of about 120˚

53. How many isomers exist for the $[Co(NH_3)_4Cl_2]^+$ and $[Co(en)_2Cl_2]^+$ ions, respectively? [en = $H_2NC_2H_4NH_2$]

(A) 2 and 2 **(B)** 2 and 3

(C) 3 and 2 **(D)** 3 and 3

54. Which statement best describes the structure of the allene molecule, $H_2C=C=CH_2$?

(A) The C atoms form an angle of 120˚ and the H atoms lie in the same plane as the C atoms.

(B) The C atoms form an angle of 120˚ and the H atoms lie in a plane perpendicular to that of the C atoms.

(C) The C atoms form an angle of 180˚ and the four H atoms lie in the same plane.

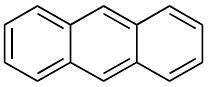
(D) The C atoms form an angle of 180˚ and the two CH_2 groups are perpendicular to one another.

55. Oxidation of a secondary alcohol with $K_2Cr_2O_7$ in sulfuric acid gives a product with which functional group?

(A) aldehyde **(B)** carboxylic acid

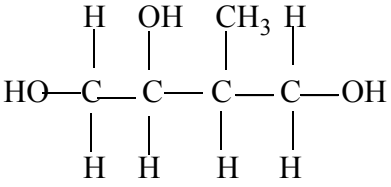
(C) ester **(D)** ketone

56. What is the formula for anthracene, which has the structure shown?



(A) $C_{10}H_{10}$ **(B)** $C_{10}H_{20}$ **(C)** $C_{14}H_{10}$ **(D)** $C_{14}H_{14}$

57. How many chiral centers are present in the molecule shown?



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

58. What is the major product when nitrobenzene is treated with a mixture of HNO_3 and H_2SO_4?

(A) 1,1-dinitrobenzene **(B)** 1,2-dinitrobenzene

(C) 1,3-dinitrobenzene **(D)** 1,4-dinitrobenzene

59. Polysaccharides are biochemical mole[illegible]sist of polymers of monosaccharide molecul[illegible] sugars). All of the following are classified a[illegible] polysaccharides EXCEPT

(A) cellulose. **(B)** fructose.

(C) glycogen. **(D)** starch.

60. Which metal is found in vitamin B_{12}?

(A) Co **(B)** Cu **(C)** Fe **(D)** Mn

END OF TEST

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Part I
KEY

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

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