2002 U. S. NATIONAL CHEMISTRY OLYMPIAD

NATIONAL EXAM—PART I

Prepared by the American Chemical Society 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 21, 2002, after which tests can be returned to students and their teachers for further study.

Allow time for the student 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 **1 hour, 30 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 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–PART I

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 both 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 1 hour, 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.

Not valid for use as an USNCO National Exam after April 21, 2002.

ABBREVIATIONS AND SYMBOLS					
amount of substance	n	equilibrium constant	K	measure of pressure	mmHg
ampere	A	Faraday constant	F	milli- prefix	m
atmosphere	atm	formula molar mass	M	molal	m
atomic mass unit	u	free energy	G	molar	M
atomic molar mass	A	frequency	ν	mole	mol
atomic number	Z	gas constant	R	Planck's constant	h
Avogadro constant	N_A	gram	g	pressure	P
Celsius temperature	°C	heat capacity	C_p	rate constant	k
centi- prefix	c	hour	h	retention factor	R_f
coulomb	C	joule	J	second	s
electromotive force	E	kelvin	K	speed of light	c
energy of activation	E_a	kilo- prefix	k	temperature, K	T
enthalpy	H	liter	L	time	t
entropy	S			volt	V

CONSTANTS
$R = 8.314\ \text{J·mol}^{-1}\text{·K}^{-1}$
$R = 0.0821\ \text{L·atm·mol}^{-1}\text{·K}^{-1}$
$1\ F = 96{,}500\ \text{C·mol}^{-1}$
$1\ F = 96{,}500\ \text{J·V}^{-1}\text{·mol}^{-1}$
$N_A = 6.022 \times 10^{23}\ \text{mol}^{-1}$
$h = 6.626 \times 10^{-34}\ \text{J·s}$
$c = 2.998 \times 10^{8}\ \text{m·s}^{-1}$
1 atm = 760 mmHg

USEFUL EQUATIONS

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

PERIODIC TABLE OF THE ELEMENTS

1 **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** 181.0	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** 226.0	89 **Ac** 227.0	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (263)	107 **Bh** (262)	108 **Hs** (265)	109 **Mt** (266)	110 (269)	111 (272)	112 (277)		114 (289)				

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** 237.0	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** (260)

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.
- You may write on the test booklet, but it will not be used for grading.
- 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. Which element commonly exhibits both +1 and +3 oxidation states?

(A) Al (Z = 13) **(B)** Sc (Z = 21)

(C) Sn (Z = 50) **(D)** Tl (Z = 81)

2. Which procedure is best to extinguish burning magnesium?

(A) Add water to it.

(B) Blow nitrogen gas over it.

(C) Cover it with sand.

(D) Throw ice on it.

3. Which two sets of reactants best represent the amphoterism of $Zn(OH)_2$?

Set **1.** $Zn(OH)_{2(s)}$ and $OH^{-}_{(aq)}$

Set **2.** $Zn(OH)_{2(s)}$ and $H_2O_{(l)}$

Set **3.** $Zn(OH)_{2(s)}$ and $H^{+}_{(aq)}$

Set **4.** $Zn(OH)_{2(s)}$ and $NH_{3(aq)}$

(A) Sets **1** and **2** **(B)** Sets **1** and **3**

(C) Sets **2** and **4** **(D)** Sets **3** and **4**

4. Which of these statements about sulfur is ***not*** correct?

(A) It exists in different allotropic forms.

(B) It can behave as either an oxidizing agent or a reducing agent.

(C) It can form up to six covalent bonds in compounds.

(D) It is a liquid at 25 °C and 1 atm pressure.

5. A solution of sulfuric acid in water that is 25% H_2SO_4 by mass has a density of 1.178 $g \cdot mL^{-1}$. Which expression gives the molarity of this solution?

(A) $0.25 \times 98 \times 1178$ **(B)** $\dfrac{0.25 \times 1178}{98}$

(C) $\dfrac{0.25}{98 \times 1178}$ **(D)** $\dfrac{1178}{0.25 \times 98}$

6. A weighed quantity of a gas is collected over water at 25 °C and 742 mmHg. The molar mass of the gas is to be determined at standard temperature and pressure. If the vapor pressure of water is ignored during the calculation, what is the effect on the calculated pressure and calculated molar mass of the gas?

	pressure	molar mass
(A)	low	low
(B)	low	high
(C)	high	low
(D)	high	high

7. A 0.1 M solution of which substance is most acidic?

(A) $NaHSO_4$ **(B)** Na_2SO_4

(C) NaHS **(D)** $NaHCO_3$

8. The mineral *trona* has the formula $Na_2CO_3 \cdot NaHCO_3 \cdot 2H_2O$ and a formula mass of 226 $g \cdot mol^{-1}$. How many mL of 0.125 M HCl are needed to convert all the carbonate and bicarbonate in a 0.407 g sample of *trona* into carbon dioxide and water?

(A) 43.2 mL **(B)** 28.8 mL

(C) 21.6 mL **(D)** 14.4 mL

9. The percentages by mass of C, H, and Cl in a compound are C 52.2%, H 3.7%, and Cl 44.1%. How many carbon atoms are in the simplest formula of the compound?

(A) 3 **(B)** 4 **(C)** 6 **(D)** 7

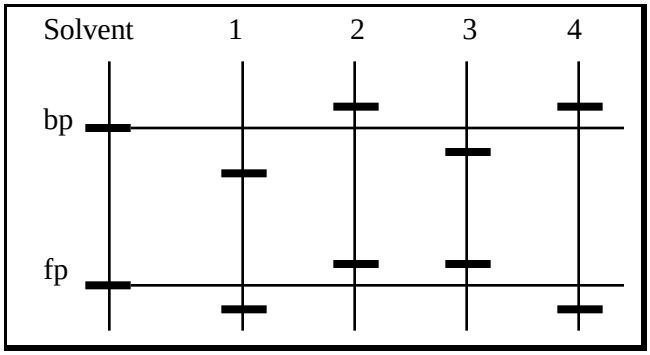
10. $4KO_{2(s)} + 2CO_{2(g)} \rightarrow 2K_2CO_{3(s)} + 3O_{2(g)}$

What is the maximum volume of oxygen that can be produced when 150. mL of CO_2 is passed over 0.500 g of KO_2? Assume all gases are measured at 0 °C and 1 atm.

(A) 118 mL **(B)** 157 mL

(C) 225 mL **(D)** 475 mL

11. The first vertical line in the diagram represents a thermometer with the boiling and freezing points for a pure solvent. The numbered lines represent possible boiling and freezing points for a solution of a nonvolatile solute in the same solvent. Which line best represents the boiling point and freezing point of a solution relative to values for the pure solvent?
Note: The differences in temperatures are not to scale.



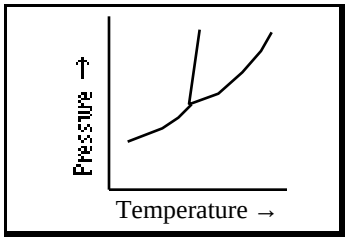
(A) 1 **(B)** 2 **(C)** 3 **(D)** 4

12. Equal masses of gaseous N_2, NH_3, and N_2O are injected into an evacuated container to produce a total pressure of 3 atm. How do the partial pressures of N_2, NH_3, and N_2O compare?

(A) $P_{N_2} = P_{NH_3} = P_{N_2O}$ **(B)** $P_{N_2} < P_{NH_3} < P_{N_2O}$

(C) $P_{NH_3} < P_{N_2} < P_{N_2O}$ **(D)** $P_{N_2O} < P_{N_2} < P_{NH_3}$

13. According to this phase diagram, which phases can exist at pressures lower than the triple point pressure?



(A) gas only **(B)** solid and gas only

(C) liquid only **(D)** solid and liquid only

14. 1.00 g of water is introduced into a 5.00 L evacuated flask at 50 °C.

Vapor Pressure, 50 °C	
H_2O	92.5 mmHg

What mass of water is present as liquid when equilibrium is established?

(A) 0.083 g **(B)** 0.41 g

(C) 0.59 g **(D)** 0.91 g

15. Which substance has the greatest lattice energy?

(A) NaF **(B)** KCl **(C)** MgO **(D)** CaS

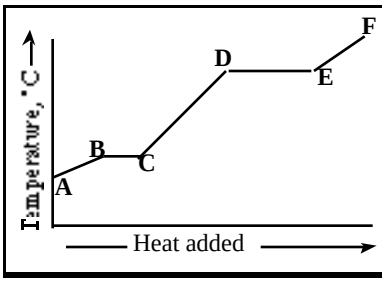
16. When the temperature of a sample of H_2S gas is lowered, the pressure decreases more than predicted by the ideal gas equation. To what is this deviation from expected behavior due?

1. attractive forces between molecules
2. mass of the molecules
3. volume of the molecules

(A) **1** only **(B)** **2** only

(C) **1** and **3** only **(D)** **2** and **3** only

17. This curve is produced when a pure substance is heated. Which characteristic of this curve is related to the value for the enthalpy of fusion of the substance?



(A) length of **AB** **(B)** length of **BC**

(C) slope of **AB** **(D)** slope of **CD**

18. Which statement is correct?

(A) In a coffee-cup calorimeter, $q = \Delta H$.

(B) In a coffee-cup calorimeter, $w = 0$.

(C) In a bomb calorimeter, $q = \Delta S$.

(D) In a bomb calorimeter, $w > 0$.

19. Consider this reaction.
$4PH_{3(g)} + 8O_{2(g)} \rightarrow P_4O_{10(s)} + 6H_2O_{(g)} \quad \Delta H^o = -4500$ kJ
Calculate ΔH_f^o of $P_4O_{10(s)}$ in kJ·mol^{-1}.

Substance	ΔH_f^o, kJ·mol^{-1}
$PH_{3(g)}$	+9.2
$H_2O_{(g)}$	–241.8

(A) –5914 kJ **(B)** –4751 kJ

(C) –4249 kJ **(D)** –3012 kJ

20. For which substances and conditions can $S^o = 0$?

I. elements at 0 K
II. compounds at 0 K
III. gases at 298 K

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

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

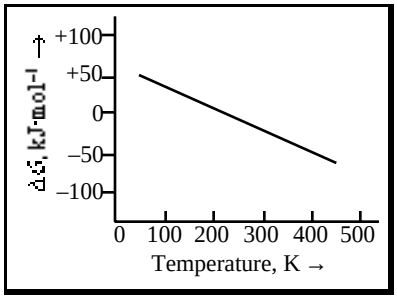
21. 50.0 mL of 0.10 M HCl is mixed with 50.0 mL of 0.10 M NaOH. The solution temperature rises by 3.0 °C. Calculate the enthalpy of neutralization per mole of HCl.

Solution Values	
C_p	4.18 J·g^{-1}·°C^{-1}
density	1.0 g·mL^{-1}

(A) -2.5×10^2 kJ **(B)** -1.3×10^2 kJ

(C) -8.4×10^1 kJ **(D)** -6.3×10^1 kJ

22. What can be concluded about the values of ΔH and ΔS from this graph?



(A) $\Delta H > 0,\ \Delta S > 0$ **(B)** $\Delta H > 0,\ \Delta S < 0$

(C) $\Delta H < 0,\ \Delta S > 0$ **(D)** $\Delta H < 0,\ \Delta S < 0$

23. The boiling point of chloroform, $CHCl_3$, is 61.7 °C and its enthalpy of vaporization is 31.4 kJ·mol^{-1}. Calculate the molar entropy of vaporization for chloroform.

(A) 10.7 J·mol^{-1}·K^{-1} **(B)** 93.8 J·mol^{-1}·K^{-1}

(C) 301 J·mol^{-1}·K^{-1} **(D)** 509 J·mol^{-1}·K^{-1}

24. ΔG^o for a reaction at 25 °C is 30.5 kJ·mol^{-1}. What is the value of K?

(A) 2.2×10^5 **(B)** 1.1

(C) 0.86 **(D)** 4.5×10^{-6}

25. This is the rate law for a reaction that consumes **X**.

$$\text{rate} = k\,[\mathbf{X}]^2$$

Which plot gives a straight line?

(A) [**X**] *vs.* time **(B)** ln [**X**] *vs.* time

(C) 1 / [**X**] *vs.* time **(D)** 1 / ln [**X**]^2 *vs.* time

26. For a first order reaction, the concentration decreases to 30% of its initial value in 5.0 min. What is the rate constant?

(A) 0.46 min^{-1} **(B)** 0.24 min^{-1}

(C) 0.14 min^{-1} **(D)** 0.060 min^{-1}

27. The rate of a reaction at 75 °C is 30.0 times that at 25 °C. What is its activation energy?

(A) 58.6 kJ·mol^{-1} **(B)** 25.5 kJ·mol^{-1}

(C) 7.05 kJ·mol^{-1} **(D)** 1.51 kJ·mol^{-1}

28. $6I^-(aq) + BrO_3^-(aq) + 6H^+(aq) \rightarrow 3I_2(aq) + Br^-(aq) + 3H_2O(l)$

These data were obtained when this reaction was studied.

$[I^-]$, M	$[BrO_3^-]$, M	$[H^+]$, M	Reaction rate, mol·L^{-1}·s^{-1}
0.0010	0.0020	0.010	8.0×10^{-5}
0.0020	0.0020	0.010	1.6×10^{-4}
0.0020	0.0040	0.010	1.6×10^{-4}
0.0010	0.0040	0.020	1.6×10^{-4}

What are the units of the rate constant for this reaction?

(A) s^{-1} **(B)** mol·L^{-1}·s^{-1}

(C) L·mol^{-1}·s^{-1} **(D)** L^2·mol^{-1}·s^{-1}

29. Consider this gas phase reaction.

$$Cl_2(g) + CHCl_3(g) \rightarrow HCl(g) + CCl_4(g)$$

The reaction is found experimentally to follow this rate law.

$$\text{rate} = k\,[CHCl_3]\,[Cl_2]^{1/2}$$

Based on this information, what conclusions can be drawn about this proposed mechanism?

Step **1**. $Cl_2(g) \rightleftharpoons 2Cl(g)$

Step **2**. $Cl(g) + CHCl_3(g) \rightarrow HCl(g) + CCl_3(g)$

Step **3**. $Cl(g) + CCl_3(g) \rightarrow CCl_4(g)$

(A) Step **1** is the rate-determining step.

(B) Step **2** is the rate-determining step.

(C) Step **3** is the rate-determining step.

(D) The rate-determining step cannot be identified.

30. Determine the value of the equilibrium constant for this reaction

$$2NOCl(g) + O_2(g) \rightleftharpoons 2NO_2(g) + Cl_2(g)$$

from the K values for these reactions.

$2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$ $\quad K_p = 1.7 \times 10^{-2}$

$2NO_2(g) \rightleftharpoons 2NO(g) + O_2(g)$ $\quad K_p = 5.9 \times 10^{-5}$

(A) 1.0×10^{-6} **(B)** 1.0×10^{-3}

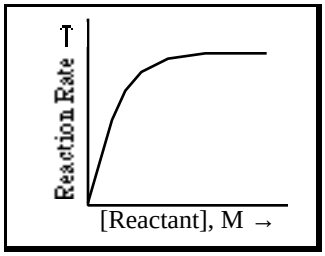
(C) 3.5×10^{-3} **(D)** 2.9×10^2

31. What is the pH of a 0.15 M solution of hydrazine, N_2H_4?

Hydrazine	K_b
N_2H_4	1.0×10^{-6}

(A) 3.41 **(B)** 6.82 **(C)** 10.59 **(D)** 11.00

32. The rates of many catalyzed reactions follow the profile shown in the graph. Why does the reaction rate level off?



(A) The reactant is used up.

(B) The reverse reaction becomes dominant.

(C) The catalyst decomposes as the reaction proceeds.

(D) The active sites on the catalyst are occupied.

Questions **33** and **34** refer to aqueous solutions of formic acid, HCOOH, which has a K_a value of 1.9×10^{-4} at 25 °C.

33. What is the percent ionization of a 0.10 M solution of formic acid at 25 °C?

(A) 0.19% **(B)** 1.4% **(C)** 4.4% **(D)** 14%

34. How many moles of sodium formate must be added to 1.0 L of a 0.20 M formic acid solution to produce a pH of 4.00?

(A) 0.38 **(B)** 0.80 **(C)** 1.9 **(D)** 3.8

35. During the titration of a weak base with a strong acid, one should use an acid-base indicator that changes color in the

(A) acidic range. **(B)** basic range.

(C) buffer range. **(D)** neutral range.

36. What is the solubility of calcium hydroxide in $mol \cdot L^{-1}$?

Substance	K_{sp}
calcium hydroxide	4.0×10^{-6}

(A) 1.6×10^{-2} **(B)** 1.0×10^{-2}

(C) 2.0×10^{-3} **(D)** 1.0×10^{-3}

37. What is the average oxidation number of tungsten in the ion, $W_6O_6Cl_{12}^{2-}$?

(A) 2.7 **(B)** 3.3 **(C)** 3.7 **(D)** 4.3

38. How many moles of electrons must be removed from each mole of toluene, $C_6H_5CH_3$, when it is oxidized to benzoic acid, C_6H_5COOH?

(A) 1 **(B)** 2 **(C)** 4 **(D)** 6

Questions **39** and **40** refer to the reaction represented by this equation.

$$2Al(s) + 3Cu^{2+}(aq) \rightarrow 2Al^{3+}(aq) + 3Cu(s)$$

39. What is the value of E^o for a voltaic cell based on this reaction?

Reaction	E^o
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	+0.34 V
$Al^{3+}(aq) + 3e^- \rightarrow Al(s)$	–1.66 V

(A) 1.32 V **(B)** 2.00 V

(C) 2.30 V **(D)** 4.34 V

40. What value should be used for n in the Nernst equation to determine the effect of changes in $Al^{3+}(aq)$ and $Cu^{2+}(aq)$ concentrations in this reaction?

(A) 6 **(B)** 5 **(C)** 3 **(D)** 2

41. Use the given standard reduction potentials to determine the reduction potential for this half-reaction.

$$MnO_4^-(aq) + 3e^- + 4H^+ \rightarrow MnO_2(s) + 2H_2O(l)$$

Reaction	E^o
$MnO_4^-(aq) + e^- \rightarrow MnO_4^{2-}(aq)$	+0.564 V
$MnO_4^{2-}(aq) + 2e^- + 4H^+ \rightarrow MnO_2(s) + 2H_2O(l)$	+2.261 V

(A) 1.695 V **(B)** 2.825 V

(C) 3.389 V **(D)** 5.086 V

42. How many Faradays are required to reduce all the chromium in 0.150 L of 0.115 M of $Cr_2O_7^{2-}$ to Cr^{2+}?

(A) 0.920 *F* **(B)** 0.690 *F*

(C) 0.138 *F* **(D)** 0.069 *F*

43. In which list are the elements arranged in order of increasing first ionization energy?

(A) Li, Na, K **(B)** S, O, F

(C) Na, Mg, Al **(D)** F, Ne, Na

44. Which quantum number is associated with the shape of an atomic orbital?

(A) n **(B)** l **(C)** m_l **(D)** m_s

45. Consider the ions Li^+, Na^+, Be^{2+}, and Mg^{2+}. Which two are closest to one another in size?

(A) Li^+ and Na^+ **(B)** Be^{2+} and Mg^{2+}

(C) Be^{2+} and Li^+ **(D)** Li^+ and Mg^{2+}

46. What is the electron configuration for a gas phase +3 ion of iron (Z = 26)?

(A) [Ar] $3d^5$ **(B)** [Ar] $4s^2\,3d^3$

(C) [Ar] $4s^1\,3d^4$ **(D)** [Ar] $4s^2\,3d^6$

47. Magnesium (Z = 12) has isotopes that range from Mg–20 to Mg–31. Only Mg–24, Mg–25, and Mg–26 are not radioactive. What mode of radioactive decay would convert Mg–20, Mg–21, Mg–22, and Mg–23 into stable isotopes most quickly?

(A) electron emission **(B)** alpha particle emission

(C) gamma emission **(D)** positron emission

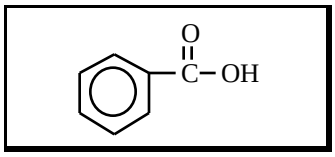
48. Which oxides exist as individual molecules?

1. Al_2O_3 **2**. SiO_2 **3**. P_4O_{10}

(A) **2** only **(B)** **3** only

(C) **1** and **3** only **(D)** **2** and **3** only

49. How many sigma and pi bonds are in this compound?



(A) 9 sigma, 6 pi **(B)** 10 sigma, 6 pi

(C) 10 sigma, 3 pi **(D)** 15 sigma, 4 pi

50. Which pair of ions has the same shape?

(A) CO_3^{2-} and NO_3^- **(B)** CO_3^{2-} and SO_3^{2-}

(C) NO_3^- and ClO_3^- **(D)** CO_3^{2-} and ClO_3^-

51. Which resonance form makes the greatest contribution to the structure of N_2O?

(A)  **(B)** 

(C)  **(D)** 

52. Which species has the strongest oxygen-oxygen bond according to molecular orbital theory?

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

53. How many atoms are covalently bonded to the chromium atom in $Cr(NH_3)_4Cl_3$?

(A) 3 **(B)** 4 **(C)** 6 **(D)** 7

54. When the carbon-oxygen bonds in H_3COH, H_2CO, and HCO_2^- are arranged in order of increasing length, what is the correct order?

(A) H_3COH, H_2CO, HCO_2^-

(B) HCO_2^-, H_3COH, H_2CO

(C) H_2CO, HCO_2^-, H_3COH

(D) H_3COH, HCO_2^-, H_2CO

55. Which reaction is an oxidation? (Only the carbon-containing molecules are shown.)

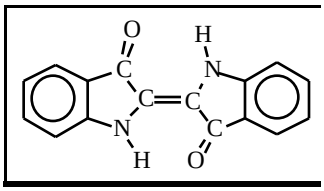
(A) $CH_2CH_2 \rightarrow CH_3CH_2OH$

(B) $CH_3CH_2OH \rightarrow CH_2CHO$

(C) $CH_3CH_2OH + HCOOH \rightarrow CH_3CH_2OOCH$

(D) $2\,CH_3CH_2OH \rightarrow CH_3CH_2OCH_2CH_3$

Use this structure for the indigo molecule to answer questions **56** and **57**.



56. What is the molecular formula of indigo?

(A) C_8HNO **(B)** $C_{16}H_2N_2O_2$

(C) $C_{16}H_{10}N_2O_2$ **(D)** $C_{16}H_{22}N_2O_2$

57. What is the hybridization of the carbon atoms bonded to oxygen?

(A) *sp* **(B)** sp^2 **(C)** sp^3 **(D)** sp^3d

58. Aniline, $C_6H_5NH_2$, does not dissolve well in water. Which reagent could be used to increase its aqueous solubility?

(A) 1 M HCl **(B)** 1 M NaOH

(C) diethyl ether **(D)** toluene

59. Which molecule reacts most rapidly with water?

(A) $CH_3CH_2CH_2Cl$ **(B)** $CH_3CHClCH_3$

(C) $(CH_3)_2CHCH_2Cl$ **(D)** $(CH_3)_3CCl$

60. Which of these elements is found in hemoglobin?

(A) Cr **(B)** Fe **(C)** Mg **(D)** Ni

END OF TEST

U. S. National Chemistry Olympiad – 2002
National Examination—Part I
SCORING KEY

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