



# 2000 U. S. NATIONAL CHEMISTRY OLYMPIAD

## NATIONAL EXAM—PART I

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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 16, 2000, 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 **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 Olympiad Examination. You have the option of administering the three parts in any order, and you are free to schedule rest-breaks between parts.

<b>Part I</b>	<b>60 questions</b>	<b>single-answer multiple-choice</b>	<b>1 hour, 30 minutes</b>
<b>Part II</b>	<b>8 questions</b>	<b>problem-solving, explanations</b>	<b>1 hour, 45 minutes</b>
<b>Part III</b>	<b>2 lab problems</b>	<b>laboratory practical</b>	<b>1 hour, 30 minutes</b>

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 as 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 which 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 having 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.

**Not valid for use as an USNCO National Exam after April 16, 2000.**

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ABBREVIATIONS AND SYMBOLS			
amount of substance	<i>n</i>	equilibrium constant	<i>K</i>
ampere	<i>A</i>	Faraday constant	<i>F</i>
atmosphere	atm	formula molar mass	<i>M</i>
atomic mass unit	<i>u</i>	free energy	<i>G</i>
atomic molar mass	<i>A</i>	frequency	$\nu$
Avogadro constant	$N_A$	gas constant	<i>R</i>
Celsius temperature	$^{\circ}\text{C}$	gram	<i>g</i>
centi- prefix	<i>c</i>	hour	<i>h</i>
coulomb	<i>C</i>	joule	<i>J</i>
electromotive force	<i>E</i>	kelvin	<i>K</i>
energy of activation	$E_a$	kilo- prefix	<i>k</i>
enthalpy	<i>H</i>	liter	<i>L</i>
entropy	<i>S</i>	measure of pressure	mmHg
		milli- prefix	<i>m</i>
		molal	<i>m</i>
		molar	<i>M</i>
		mole	mol
		Planck's constant	<i>h</i>
		pressure	<i>P</i>
		rate constant	<i>k</i>
		retardation factor	$R_f$
		second	<i>s</i>
		speed of light	<i>c</i>
		temperature, K	<i>T</i>
		time	<i>t</i>
		volt	<i>V</i>

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

## PERIODIC TABLE OF THE ELEMENTS

1 <b>H</b> 1.008																	2 <b>He</b> 4.003
3 <b>Li</b> 6.941	4 <b>Be</b> 9.012											5 <b>B</b> 10.81	6 <b>C</b> 12.01	7 <b>N</b> 14.01	8 <b>O</b> 16.00	9 <b>F</b> 19.00	10 <b>Ne</b> 20.18
11 <b>Na</b> 22.99	12 <b>Mg</b> 24.31											13 <b>Al</b> 26.98	14 <b>Si</b> 28.09	15 <b>P</b> 30.97	16 <b>S</b> 32.07	17 <b>Cl</b> 35.45	18 <b>Ar</b> 39.95
19 <b>K</b> 39.10	20 <b>Ca</b> 40.08	21 <b>Sc</b> 44.96	22 <b>Ti</b> 47.88	23 <b>V</b> 50.94	24 <b>Cr</b> 52.00	25 <b>Mn</b> 54.94	26 <b>Fe</b> 55.85	27 <b>Co</b> 58.93	28 <b>Ni</b> 58.69	29 <b>Cu</b> 63.55	30 <b>Zn</b> 65.39	31 <b>Ga</b> 69.72	32 <b>Ge</b> 72.61	33 <b>As</b> 74.92	34 <b>Se</b> 78.96	35 <b>Br</b> 79.90	36 <b>Kr</b> 83.80
37 <b>Rb</b> 85.47	38 <b>Sr</b> 87.62	39 <b>Y</b> 88.91	40 <b>Zr</b> 91.22	41 <b>Nb</b> 92.91	42 <b>Mo</b> 95.94	43 <b>Tc</b> (98)	44 <b>Ru</b> 101.1	45 <b>Rh</b> 102.9	46 <b>Pd</b> 106.4	47 <b>Ag</b> 107.9	48 <b>Cd</b> 112.4	49 <b>In</b> 114.8	50 <b>Sn</b> 118.7	51 <b>Sb</b> 121.8	52 <b>Te</b> 127.6	53 <b>I</b> 126.9	54 <b>Xe</b> 131.3
55 <b>Cs</b> 132.9	56 <b>Ba</b> 137.3	57 <b>La</b> 138.9	72 <b>Hf</b> 178.5	73 <b>Ta</b> 181.0	74 <b>W</b> 183.8	75 <b>Re</b> 186.2	76 <b>Os</b> 190.2	77 <b>Ir</b> 192.2	78 <b>Pt</b> 195.1	79 <b>Au</b> 197.0	80 <b>Hg</b> 200.6	81 <b>Tl</b> 204.4	82 <b>Pb</b> 207.2	83 <b>Bi</b> 209.0	84 <b>Po</b> (209)	85 <b>At</b> (210)	86 <b>Rn</b> (222)
87 <b>Fr</b> (223)	88 <b>Ra</b> 226.0	89 <b>Ac</b> 227.0	104 <b>Rf</b> (261)	105 <b>Db</b> (262)	106 <b>Sg</b> (263)	107 <b>Bh</b> (262)	108 <b>Hs</b> (265)	109 <b>Mt</b> (266)	110 (269)	111 (272)	112 (277)						

58 <b>Ce</b> 140.1	59 <b>Pr</b> 140.9	60 <b>Nd</b> 144.2	61 <b>Pm</b> (145)	62 <b>Sm</b> 150.4	63 <b>Eu</b> 152.0	64 <b>Gd</b> 157.3	65 <b>Tb</b> 158.9	66 <b>Dy</b> 162.5	67 <b>Ho</b> 164.9	68 <b>Er</b> 167.3	69 <b>Tm</b> 168.9	70 <b>Yb</b> 173.0	71 <b>Lu</b> 175.0
90 <b>Th</b> 232.0	91 <b>Pa</b> 231.0	92 <b>U</b> 238.0	93 <b>Np</b> 237.0	94 <b>Pu</b> (244)	95 <b>Am</b> (243)	96 <b>Cm</b> (247)	97 <b>Bk</b> (247)	98 <b>Cf</b> (251)	99 <b>Es</b> (252)	100 <b>Fm</b> (257)	101 <b>Md</b> (258)	102 <b>No</b> (259)	103 <b>Lr</b> (260)

**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 carefully.
- Make no marks on the test booklet. Do all calculations on scratch paper provided by your instructor.
- 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 of these ions is expected to be colored in aqueous solution?

I Fe<sup>3+</sup>      II Ni<sup>2+</sup>      III Al<sup>3+</sup>

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

2. Which substance is stored in contact with water to prevent it from reacting with air?

- (A) bromine                      (B) lithium  
(C) mercury                      (D) phosphorus

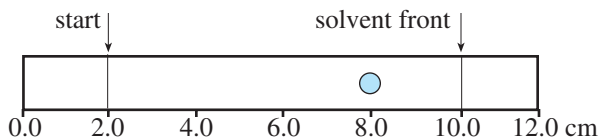
3. A solution of concentrated aqueous ammonia is added dropwise to 1 mL of a dilute aqueous solution of copper(II) nitrate until a total of 1 mL of the ammonia solution has been added. What observations can be made during this process?

- (A) The colorless copper(II) nitrate solution turns blue and yields a dark blue precipitate.  
(B) The colorless copper(II) nitrate solution yields a white precipitate which turns dark blue upon standing.  
(C) The light blue copper(II) nitrate solution yields a precipitate which redissolves to form a dark blue solution.  
(D) The light blue copper(II) nitrate solution turns dark blue and yields a dark blue precipitate.

4. What gas is produced when dilute HNO<sub>3</sub> is added to silver metal?

- (A) NO      (B) H<sub>2</sub>      (C) NH<sub>3</sub>      (D) N<sub>2</sub>

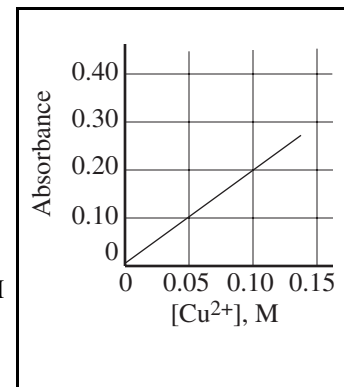
5. A substance is analyzed by paper chromatography, giving the chromatogram shown.



What is the  $R_f$  value of the substance represented by the spot at 8.0 cm?

- (A) 0.80      (B) 0.75      (C) 0.67      (D) 0.60

6. The molarity of a Cu<sup>2+</sup> solution is to be determined from its absorbance, measured under the same conditions as those used to prepare this calibration curve. What will be the percent uncertainty in the concentration of a 0.050 M solution if the uncertainty in the absorbance reading is  $\pm 0.01$  absorbance units?



- (A) 5%      (B) 10%      (C) 15%      (D) 20%

7. A 1.50 g sample of an ore containing silver was dissolved, and all of the Ag<sup>+</sup> was converted to 0.124 g of Ag<sub>2</sub>S. What was the percentage of silver in the ore?

- (A) 6.41%                      (B) 7.20%  
(C) 8.27%                      (D) 10.8%

8. Methyl-*t*-butyl ether, C<sub>5</sub>H<sub>12</sub>O, is added to gasoline to promote cleaner burning. How many moles of oxygen gas, O<sub>2</sub>, are required to burn 1.0 mol of this compound completely to form carbon dioxide and water?

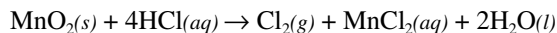
- (A) 4.5 mol                      (B) 6.0 mol  
(C) 7.5 mol                      (D) 8.0 mol

9. A 0.200 g sample of benzoic acid, C<sub>6</sub>H<sub>5</sub>COOH, is titrated with a 0.120 M Ba(OH)<sub>2</sub> solution. What volume of the Ba(OH)<sub>2</sub> solution is required to reach the equivalence point?

Substance	Molar Mass
C <sub>6</sub> H <sub>5</sub> COOH	122.1 g·mol <sup>-1</sup>

- (A) 6.82 mL                      (B) 13.6 mL  
(C) 17.6 mL                      (D) 35.2 mL

10. Chlorine can be prepared by reacting HCl with MnO<sub>2</sub>. The reaction is represented by this equation.



Assuming the reaction goes to completion what mass of concentrated HCl solution (36.0% HCl by mass) is needed to produce 2.50 g of Cl<sub>2</sub>?

- (A) 5.15 g                      (B) 14.3 g  
(C) 19.4 g                      (D) 26.4 g
11. What is the Na<sup>+</sup> ion concentration in the solution formed by mixing 20. mL of 0.10 M Na<sub>2</sub>SO<sub>4</sub> solution with 50. mL of 0.30 M Na<sub>3</sub>PO<sub>4</sub> solution?

- (A) 0.15 M                      (B) 0.24 M  
(C) 0.48 M                      (D) 0.70 M

12. A solution prepared by dissolving a 2.50 g sample of an unknown compound dissolved in 34.0 g of benzene, C<sub>6</sub>H<sub>6</sub>, boils 1.38 °C higher than pure benzene. Which expression gives the molar mass of the unknown compound?

Compound	K <sub>b</sub>
C <sub>6</sub> H <sub>6</sub>	2.53 °C·m <sup>-1</sup>

- (A)  $2.53 \times \frac{2.50}{1.38}$   
(B)  $1.38 \times \frac{34.0}{2.53} \times 2.50$   
(C)  $2.50 \times 10^3 \times \frac{2.53}{34.0} \times \frac{1}{1.38}$   
(D)  $2.50 \times 10^3 \times \frac{1.38}{34.0} \times 2.53$

13. What is the total pressure in a 2.00 L container that holds 1.00 g He, 14.0 g CO, and 10.0 g of NO at 27.0 °C?

- (A) 21.6 atm                      (B) 13.2 atm  
(C) 1.24 atm                      (D) 0.310 atm

14. What type of solid is generally characterized by having low melting point and low electrical conductivity?

- (A) ionic                      (B) metallic  
(C) molecular                      (D) network covalent

15. How many nearest neighbors surround each particle in a face-centered cubic lattice?

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

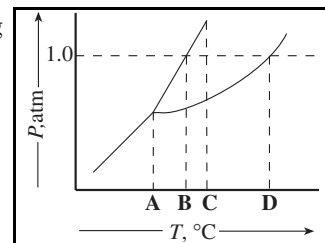
16. Hydrogen is collected over water at 22 °C and a barometer reading

Compound	Vapor Pressure
H <sub>2</sub> O	20 mmHg

of 740 mmHg. If 300. mL of hydrogen is collected which expression will give the volume of dry hydrogen at the same temperature and pressure?

- (A)  $300 \text{ mL} \times \frac{740 \text{ mmHg} - 20 \text{ mmHg}}{740 \text{ mmHg}}$   
(B)  $300 \text{ mL} \times \frac{740 \text{ mmHg} + 20 \text{ mmHg}}{740 \text{ mmHg}}$   
(C)  $300 \text{ mL} \times \frac{740 \text{ mmHg}}{740 \text{ mmHg} - 20 \text{ mmHg}}$   
(D)  $300 \text{ mL} \times \frac{740 \text{ mmHg}}{740 \text{ mmHg} + 20 \text{ mmHg}}$

17. What is the normal melting point of the substance represented by the phase diagram?



- (A) A                      (B) B                      (C) C                      (D) D

18. A bomb calorimeter has a heat capacity of 783 J·°C<sup>-1</sup> and contains 254 g of water, which has a specific heat of 4.184 J·g<sup>-1</sup>·°C<sup>-1</sup>. How much heat is evolved or absorbed by a reaction when the temperature goes from 23.73 °C to 26.01 °C?

- (A) 1.78 kJ absorbed                      (B) 2.42 kJ absorbed  
(C) 1.78 kJ evolved                      (D) 4.21 kJ evolved

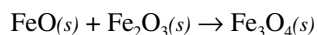
19. Consider this equation and the associated value for ΔH°.



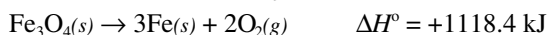
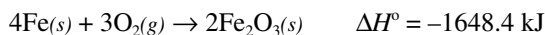
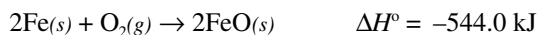
Which statement about this information is *incorrect*?

- (A) If the equation is reversed, the ΔH° value equals +92.3 kJ.  
(B) The four HCl bonds are stronger than the four bonds in H<sub>2</sub> and Cl<sub>2</sub>.  
(C) The ΔH° value will be -92.3 kJ if the HCl is produced as a liquid.  
(D) 23.1 kJ of heat will be evolved when 1 mol of HCl(g) is produced.

20. Determine the heat of reaction for this process.



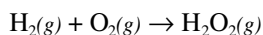
Given information:



- (A)  $-1074.0 \text{ kJ}$  (B)  $-22.2 \text{ kJ}$   
 (C)  $+249.8 \text{ kJ}$  (D)  $+2214.6 \text{ kJ}$
21. For which process will  $\Delta H^\circ$  and  $\Delta G^\circ$  be expected to be most similar?

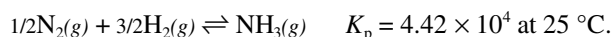
- (A)  $2\text{Al}(s) + \text{Fe}_2\text{O}_3(s) \rightarrow 2\text{Fe}(s) + \text{Al}_2\text{O}_3(s)$   
 (B)  $2\text{Na}(s) + 2\text{H}_2\text{O}(l) \rightarrow 2\text{NaOH}(aq) + \text{H}_2(g)$   
 (C)  $2\text{NO}_2(g) \rightarrow \text{N}_2\text{O}_4(g)$   
 (D)  $2\text{H}_2(g) + \text{O}_2(g) \rightarrow 2\text{H}_2\text{O}(g)$

22. Use bond energies to estimate  $\Delta H$  for this reaction.



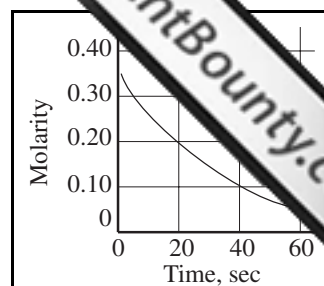
Bond	Bond Energy
H-H	436 kJ·mol <sup>-1</sup>
O-O	142 kJ·mol <sup>-1</sup>
O=O	499 kJ·mol <sup>-1</sup>
H-O	460 kJ·mol <sup>-1</sup>

- (A)  $-127 \text{ kJ}$  (B)  $-209 \text{ kJ}$   
 (C)  $-484 \text{ kJ}$  (D)  $-841 \text{ kJ}$
23. For a particular reaction,  $\Delta H^\circ = -38.3 \text{ kJ}$  and  $\Delta S^\circ = -113 \text{ J}\cdot\text{K}^{-1}$ . This reaction is
- (A) spontaneous at all temperatures.  
 (B) nonspontaneous at all temperatures.  
 (C) spontaneous at temperatures below  $66^\circ\text{C}$ .  
 (D) spontaneous at temperatures above  $66^\circ\text{C}$ .
24. What is  $\Delta G^\circ$  for this reaction?



- (A)  $-26.5 \text{ kJ}\cdot\text{mol}^{-1}$  (B)  $-11.5 \text{ kJ}\cdot\text{mol}^{-1}$   
 (C)  $-2.2 \text{ kJ}\cdot\text{mol}^{-1}$  (D)  $-0.97 \text{ kJ}\cdot\text{mol}^{-1}$

25. A reaction follows this concentration-time diagram. The instantaneous rate for this reaction at 20 seconds will be closest to which value?

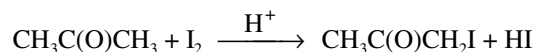


- (A)  $4 \times 10^{-3} \text{ M}\cdot\text{sec}^{-1}$  (B)  $8 \times 10^{-3} \text{ M}\cdot\text{sec}^{-1}$   
 (C)  $2 \times 10^{-2} \text{ M}\cdot\text{sec}^{-1}$  (D)  $1 \times 10^{-1} \text{ M}\cdot\text{sec}^{-1}$
26. If the half-life of a reaction increases as the initial concentration of substance increases, the order of the reaction is
- (A) zero. (B) first.  
 (C) second. (D) third.

27. The radioisotope N-13, which has a half-life of 10 minutes, is used to image organs in the body. If an injected sample has an activity of 40 microcuries ( $40 \mu\text{Ci}$ ), what is its activity after 25 minutes in the body?

- (A)  $0.75 \mu\text{Ci}$  (B)  $3.5 \mu\text{Ci}$   
 (C)  $7.1 \mu\text{Ci}$  (D)  $12 \mu\text{Ci}$

28. Propanone reacts with iodine in acid solution as shown in this equation.



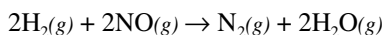
These data were obtained when the reaction was studied.

$[\text{CH}_3\text{C}(\text{O})\text{CH}_3], \text{M}$	$[\text{I}_2], \text{M}$	$[\text{H}^+], \text{M}$	Relative Rate
0.010	0.010	0.010	1
0.020	0.010	0.010	2
0.020	0.020	0.010	2
0.020	0.010	0.020	4

What is the rate equation for the reaction?

- (A)  $\text{rate} = k[\text{CH}_3\text{C}(\text{O})\text{CH}_3][\text{I}_2]$   
 (B)  $\text{rate} = k[\text{CH}_3\text{C}(\text{O})\text{CH}_3]^2$   
 (C)  $\text{rate} = k[\text{CH}_3\text{C}(\text{O})\text{CH}_3][\text{I}_2][\text{H}^+]$   
 (D)  $\text{rate} = k[\text{CH}_3\text{C}(\text{O})\text{CH}_3][\text{H}^+]$
29. A particular reaction rate increases by a factor of five when the temperature is increased from  $5^\circ\text{C}$  to  $27^\circ\text{C}$ . What is the activation energy of the reaction?
- (A)  $6.10 \text{ kJ}\cdot\text{mol}^{-1}$  (B)  $18.9 \text{ kJ}\cdot\text{mol}^{-1}$   
 (C)  $50.7 \text{ kJ}\cdot\text{mol}^{-1}$  (D)  $157 \text{ kJ}\cdot\text{mol}^{-1}$

30. Consider this reaction.



The rate law for this reaction is  $\text{rate} = k [\text{H}_2] [\text{NO}]^2$ . Under what conditions could these steps represent the mechanism?

- Step 1.  $2\text{NO} \rightleftharpoons \text{N}_2\text{O}_2$   
 Step 2.  $\text{N}_2\text{O}_2 + \text{H}_2 \rightarrow \text{N}_2\text{O} + \text{H}_2\text{O}$   
 Step 3.  $\text{N}_2\text{O} + \text{H}_2 \rightarrow \text{N}_2 + \text{H}_2\text{O}$

- (A) These steps cannot be the mechanism under any circumstances.  
 (B) These steps could be the mechanism if step 1 is the slow step.  
 (C) These steps could be the mechanism if step 2 is the slow step.  
 (D) These steps could be the mechanism if step 3 is the slow step.

31. A reaction has a forward rate constant of  $2.3 \times 10^6 \text{ s}^{-1}$  and an equilibrium constant of  $4.0 \times 10^8$ . What is the rate constant for the reverse reaction?

- (A)  $1.1 \times 10^{-15} \text{ s}^{-1}$                       (B)  $5.8 \times 10^{-3} \text{ s}^{-1}$   
 (C)  $1.7 \times 10^2 \text{ s}^{-1}$                       (D)  $9.2 \times 10^{14} \text{ s}^{-1}$

32. For the reaction  $2\text{A}(\text{g}) + 2\text{B}(\text{g}) \rightleftharpoons 3\text{C}(\text{g})$  at a certain temperature,  $K$  is  $2.5 \times 10^{-2}$ . For which conditions will the reaction proceed to the right at the same temperature?

	[A], M	[B], M	[C], M
(A)	0.10	0.10	0.10
(B)	1.0	1.0	1.0
(C)	1.0	0.10	0.10
(D)	1.0	1.0	0.10

33. What is the  $K_b$  of a weak base that produces one  $\text{OH}^-$  per molecule if a 0.050 M solution is 2.5% ionized?

- (A)  $7.8 \times 10^{-8}$                       (B)  $1.6 \times 10^{-6}$   
 (C)  $3.2 \times 10^{-5}$                       (D)  $1.2 \times 10^{-3}$

34. What is the  $[\text{OH}^-]$  of a 0.65 M solution of NaOCl?

Acid	$K_a$
HOCl	$2.8 \times 10^{-8}$

- (A)  $4.8 \times 10^{-4} \text{ M}$                       (B)  $1.3 \times 10^{-4} \text{ M}$   
 (C)  $3.5 \times 10^{-7} \text{ M}$                       (D)  $2.1 \times 10^{-11} \text{ M}$

35. Which acid is the strongest?

- (A)  $\text{H}_3\text{BO}_3$                       (B)  $\text{H}_3\text{PO}_4$   
 (C)  $\text{H}_2\text{SO}_3$                       (D)  $\text{HClO}_3$

36. What is the conjugate acid of  $\text{HPO}_4^{2-}$ ?

- (A)  $\text{H}_3\text{PO}_4(\text{aq})$                       (B)  $\text{H}_2\text{PO}_4^-(\text{aq})$   
 (C)  $\text{H}_3\text{O}^+(\text{aq})$                       (D)  $\text{PO}_4^{3-}(\text{aq})$

37. The amount of sodium hydrogen carbonate,  $\text{NaHCO}_3$ , in an antacid tablet is to be determined

Acid	$K_a$
$\text{H}_2\text{CO}_3$	$2.5 \times 10^{-4}$
$\text{HCO}_3^-$	$2.4 \times 10^{-8}$

by dissolving the tablet in water and titrating the resulting solution with hydrochloric acid. Which indicator is the most appropriate for this titration?

- (A) methyl orange,  $\text{p}K_{\text{in}} = 3.7$   
 (B) bromothymol blue,  $\text{p}K_{\text{in}} = 7.0$   
 (C) phenolphthalein,  $\text{p}K_{\text{in}} = 9.3$   
 (D) alizarin yellow,  $\text{p}K_{\text{in}} = 12.5$

38. How many moles of NaOCl must be added to 150 mL of 0.025 M HOCl to obtain a buffer solution with a pH = 7.50?

Acid	$K_a$
HOCl	$2.8 \times 10^{-8}$

- (A)  $2.6 \times 10^{-5}$                       (B)  $1.1 \times 10^{-3}$   
 (C)  $3.3 \times 10^{-3}$                       (D)  $2.2 \times 10^{-2}$

39. If equal volumes of  $\text{BaCl}_2$  and NaF solutions are mixed, which of these combinations will *not* give a precipitate?

Substance	$K_{\text{sp}}$
$\text{BaF}_2$	$1.7 \times 10^{-7}$

- (A) 0.0040 M  $\text{BaCl}_2$  and 0.020 M NaF  
 (B) 0.010 M  $\text{BaCl}_2$  and 0.015 M NaF  
 (C) 0.015 M  $\text{BaCl}_2$  and 0.010 M NaF  
 (D) 0.020 M  $\text{BaCl}_2$  and 0.0020 M NaF

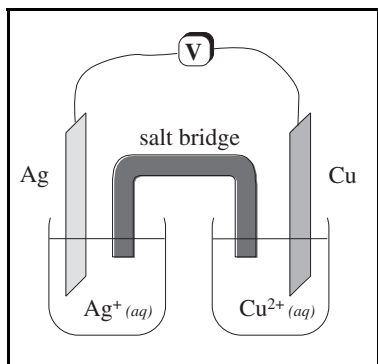
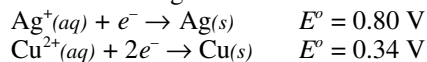
40. What takes place when zinc metal is added to a aqueous solution containing magnesium nitrate and silver nitrate?

- Zn is oxidized.
- $\text{Mg}^{2+}$  is reduced.
- $\text{Ag}^+$  is reduced.
- No reaction takes place.

- (A) 1 and 2 only                      (B) 1 and 3 only  
 (C) 1, 2, and 3 only                      (D) 4 only



Questions 41, 42, and 43 should be answered with reference to this information and diagram.



41. What is the value for  $\Delta G^\circ$  when  $[\text{Ag}^+] = [\text{Cu}^{2+}] = 1.0 \text{ M}$ ?

- (A)  $-44.4 \text{ kJ}$                       (B)  $-88.8 \text{ kJ}$   
 (C)  $-243 \text{ kJ}$                       (D)  $-374 \text{ kJ}$

42. Which expression gives the voltage for this cell if  $[\text{Cu}^{2+}] = 1.00 \text{ M}$  and  $[\text{Ag}^+] = 0.010 \text{ M}$ ?

- (A)  $0.46 \text{ V} + 0.0591 \text{ V}$   
 (B)  $0.46 \text{ V} + 2 \times 0.0591 \text{ V}$   
 (C)  $0.46 \text{ V} - 0.0591 \text{ V}$   
 (D)  $0.46 \text{ V} - 2 \times 0.0591 \text{ V}$

43. Which increases immediately if the surface area of the silver electrode is increased?

- (A) overall cell voltage  
 (B) rate of change of  $[\text{Ag}^+]$   
 (C) mass of Cu electrode  
 (D) change in ratio of electrode masses;  $\Delta \left( \frac{\text{mass of Cu}}{\text{mass of Ag}} \right)$

44. In the galvanizing process, iron is coated with zinc. The resulting chemical protection is most similar to that provided when

- (A) a magnesium bar is connected to an iron pipe.  
 (B) an iron can is plated with tin.  
 (C) copper pipes are connected using lead solder.  
 (D) a copper pipe is covered with epoxy paint.

45. How many unpaired electrons are in a  $\text{d}^9$  ion in the ground state?

- (A) 0                      (B) 2                      (C) 4

46. Which element has the smallest first-ionization energy?

- (A) Mg                      (B) Al                      (C) Si                      (D) P

47. Which set of orbitals is listed in the sequential order of filling in a many-electron atom?

- (A)  $3s, 3p, 3d$                       (B)  $3d, 4s, 4p$   
 (C)  $3d, 4p, 5s$                       (D)  $4p, 4d, 5s$

48. Which set is expected to show the smallest difference in first-ionization energy?

- (A) He, Ne, Ar                      (B) B, N, O  
 (C) Mg,  $\text{Mg}^+$ ,  $\text{Mg}^{2+}$                       (D) Fe, Co, Ni

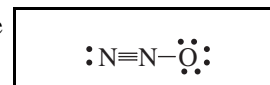
49. When the atoms Li, Be, B, and Na are arranged in order of increasing atomic radius, what is the correct order?

- (A) B, Be, Li, Na                      (B) Li, Be, B, Na  
 (C) Be, Li, B, Na                      (D) Be, B, Li, Na

50. Which species has the same shape as the  $\text{NO}_3^-$  ion?

- (A)  $\text{SO}_3$                       (B)  $\text{SO}_3^{2-}$   
 (C)  $\text{ClF}_3$                       (D)  $\text{ClO}_3^-$

51. What is the formal charge on the central atom in  $\text{N}_2\text{O}$ ?



- (A) +1                      (B) 0                      (C) -1                      (D) -2

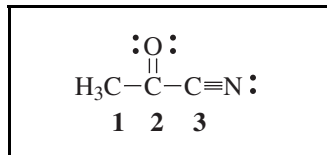
52. How many bonding pairs and lone pairs surround the central atom in the  $\text{I}_3^-$  ion?

	Bonding Pairs	Lone Pairs
(A)	2	2
(B)	2	3
(C)	3	2
(D)	4	3

53. The nitrogen atoms in  $\text{NH}_3$ ,  $\text{NH}_2^-$ , and  $\text{NH}_4^+$  are all surrounded by eight electrons. When these three species are arranged in order of increasing H–N–H bond angle, what is the correct order?

- (A)  $\text{NH}_3$ ,  $\text{NH}_2^-$ ,  $\text{NH}_4^+$       (B)  $\text{NH}_4^+$ ,  $\text{NH}_2^-$ ,  $\text{NH}_3$   
 (C)  $\text{NH}_3$ ,  $\text{NH}_4^+$ ,  $\text{NH}_2^-$       (D)  $\text{NH}_2^-$ ,  $\text{NH}_3$ ,  $\text{NH}_4^+$

54. What hybrid orbitals are employed by carbon atoms 1, 2, and 3, respectively, as labeled in the compound shown?



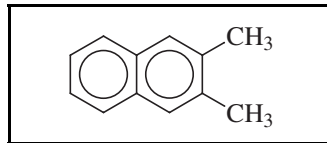
- (A)  $sp^3$ ,  $sp$ ,  $sp$       (B)  $sp^2$ ,  $sp^2$ ,  $sp$   
 (C)  $sp^3$ ,  $sp^2$ ,  $sp$       (D)  $sp^3$ ,  $sp^2$ ,  $sp^2$

55. In which pair, or pairs, is the stronger bond found in the first species?

1.  $\text{O}_2^-$ ,  $\text{O}_2$       2.  $\text{N}_2$ ,  $\text{N}_2^+$       3.  $\text{NO}^+$ ,  $\text{NO}^-$

- (A) 1 only      (B) 2 only  
 (C) 1 and 3 only      (D) 2 and 3 only

56. What is the molecular formula of this chemical structure?



- (A)  $\text{C}_{10}\text{H}_{12}$       (B)  $\text{C}_{10}\text{H}_{14}$   
 (C)  $\text{C}_{12}\text{H}_{12}$       (D)  $\text{C}_{12}\text{H}_{14}$

57. Which is the formula for an alkyne?

- (A)  $\text{C}_2\text{H}_4$       (B)  $\text{C}_3\text{H}_6$   
 (C)  $\text{C}_3\text{H}_8$       (D)  $\text{C}_4\text{H}_6$

58. How many isomers have the formula  $\text{C}_3\text{H}_8\text{O}$ ?

- (A) 2      (B) 3      (C) 4      (D) 5

59. Which type of organic compound is most resistant to oxidation by acidified potassium dichromate?

- (A) acid      (B) alcohol  
 (C) aldehyde      (D) alkene

60. What product, in addition to water, is produced by this reaction?



- (A)   
 (B)   
 (C)   
 (D)

END OF TEST



**US National Chemistry Olympiad – 2000  
National Examination—Part I  
SCORING KEY**

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