2001 U. S. NATIONAL CHEMISTRY OLYMPIAD

NATIONAL EXAM—PART I

Prepared by the American Chemical Society Olympiad Examinations Task Force

OLYMPIAD EXAMINATIONS TASK FORCE

Arden P. Zipp, State University of New York, Cortland, NY
Chair

Jo A. Beran, Texas A&M University-Kingsville, TX

Peter E. Demmin (retired), Amherst Central High School, NY

Edward DeVillafranca (retired), Kent School, CT

Dianne H. Earle, Paul M. Dorman High School, SC

Alice Johnsen, Bellaire High School, TX

Patricia A. Metz, United States Naval Academy, MD

Ronald O. Ragsdale, University of Utah, UT

Diane D. Wolff, Western Virginia Community College, VA

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 22, 2001, 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.

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 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 22, 2001.

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
Avogadro constant	N_A	gas constant	R	Planck's constant	h
Celsius temperature	°C	gram	g	pressure	P
centi- prefix	c	heat capacity	C_p	rate constant	k
coulomb	C	hour	h	retention factor	R_f
electromotive force	E	joule	J	second	s
energy of activation	E_a	kelvin	K	speed of light	c
enthalpy	H	kilo- prefix	k	temperature, K	T
entropy	S	liter	L	time	t
				volt	V

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

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)		116 (289)		118 (293)

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 pencil. Make a heavy, full mark, but no stray marks. If you decide to change an answer, erase the unwanted mark ver
- 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 **wi 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 compounds is amphoteric?

I. $Al(OH)_3$ **II.** $Ba(OH)_2$ **III.** $Zn(OH)_2$

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

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

2. Calcium hydride reacts with excess water to form

(A) CaO and H_2 **(B)** $Ca(OH)_2$ and O_2

(C) $Ca(OH)_2$ only **(D)** $Ca(OH)_2$ and H_2

3. What is the most likely boiling point of an equimolar mixture of hexane, C_6H_{14}, and heptane, C_7H_{16}?

Boiling Point	
C_6H_{14}	69 °C
C_7H_{16}	98 °C

(A) below 69 °C **(B)** between 69 and 98 °C

(C) 69 °C **(D)** 98 °C

4. Which element melts at the highest temperature?

(A) aluminum **(B)** silicon

(C) phosphorus **(D)** sulfur

5. Which substance participates readily in both acid-base and oxidation-reduction reactions?

(A) Na_2CO_3 **(B)** KOH

(C) $KMnO_4$ **(D)** $H_2C_2O_4$

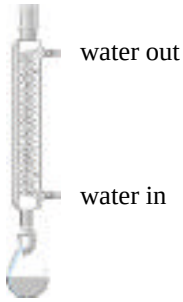
6. What mass of magnesium hydroxide is required to neutralize 125 mL of 0.136 M hydrochloric acid solution?

Substance	Molar Mass
$Mg(OH)_2$	58.33 g·mol^{-1}

(A) 0.248 g **(B)** 0.496 g

(C) 0.992 g **(D)** 1.98 g

7. What is the purpose of this apparatus?



(A) distilling **(B)** filtering

(C) refluxing **(D)** titrating

8. Calculate the mass of ammonia that can be produced from the decomposition of a sample of $(NH_4)_2PtCl_6$ containing 0.100 g Pt.

Substance	Molar Mass
$(NH_4)_2PtCl_6$	443.9 g·mol^{-1}

(A) 0.0811 g **(B)** 0.0766 g

(C) 0.0175 g **(D)** 0.00766 g

9. Assume 0.10 L of N_2 and 0.18 L of H_2, both at 50 atm and 450 °C, are reacted to form NH_3. Assuming the reaction goes to completion, identify the reagent that is in excess and determine the volume that remains at the same temperature and pressure.

(A) H_2, 0.02 L **(B)** H_2, 0.08 L

(C) N_2, 0.01 L **(D)** N_2, 0.04 L

10. Concentrated hydrochloric acid is 12.0 M and is 36.0% hydrogen chloride by mass. What is its density?

(A) 1.22 g·mL^{-1} **(B)** 1.10 g·mL^{-1}

(C) 1.01 g·mL^{-1} **(D)** 0.820 g·mL^{-1}

11. $C_7H_6O_3$ + $C_4H_6O_3$ → $C_9H_8O_4$ + $C_2H_4O_2$

salicylic acid + acetic anhydride → aspirin + acetic acid

What is the percent yield if 0.85 g of aspirin is formed in the reaction of 1.00 g of salicylic acid with excess acetic anhydride?

Substance	Molar Mass
$C_7H_6O_3$	138.12 g·mol^{-1}
$C_4H_6O_3$	102.09 g·mol^{-1}
$C_9H_8O_4$	180.15 g·mol^{-1}
$C_2H_4O_2$	60.05 g·mol^{-1}

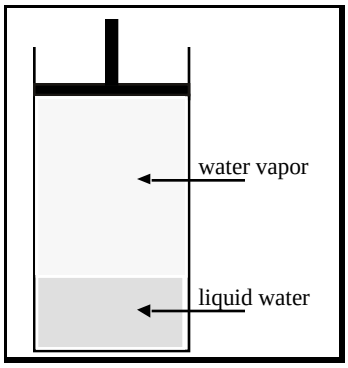
(A) 65 % **(B)** 77 % **(C)** 85 % **(D)** 91 %

12. The triple point of CO_2 occurs at 5.1 atm and –56 °C. Its critical temperature is 31 °C. Solid CO_2 is more dense than liquid CO_2. Under which combination of pressure and temperature is liquid CO_2 stable at equilibrium?

(A) 10 atm and –25 °C **(B)** 5.1 atm and –25 °C

(C) 10 atm and 33 °C **(D)** 5.1 atm and –100 °C

13. The vapor pressure of water at 20 °C is 17.54 mmHg. What will be the vapor pressure of the water in the apparatus shown after the piston is lowered, decreasing the volume of the gas above the liquid to one half of its initial volume? (Assume no temperature change.)



(A) 8.77 mmHg

(B) 17.54 mmHg

(C) 35.08 mmHg

(D) between 8.77 and 17.54 mmHg

14. What is the density of propane, C_3H_8, at 25 °C and 740. mmHg?

(A) 0.509 g·L^{-1} **(B)** 0.570 g·L^{-1}

(C) 1.75 g·L^{-1} **(D)** 1.96 g·L^{-1}

15. An unknown gas effuses through a small hole one half as fast as methane, CH_4, under the same conditions. What is the molar mass of the unknown gas?

(A) 4 g·mol^{-1} **(B)** 8 g·mol^{-1}

(C) 32 g·mol^{-1} **(D)** 64 g·mol^{-1}

16. What is the average velocity of H_2 [illegible]00 K relative to their velocity at 50 K?

(A) 2.00 times the velocity at 50 K

(B) 1.41 times the velocity at 50 K

(C) 0.71 times the velocity at 50 K

(D) 0.50 times the velocity at 50 K

17. What type of semiconductor results when highly purified silicon is doped with arsenic?

(A) *n*–type **(B)** *p*–type

(C) *q*–type **(D)** *s*–type

18. The heat of formation of NO from its elements is +90 kJ·mol^{-1}. What is the approximate bond dissociation energy of the bond in NO?

Bond	Bond Energy
N≡N	941 kJ·mol^{-1}
O=O	499 kJ·mol^{-1}

(A) 630 kJ·mol^{-1} **(B)** 720 kJ·mol^{-1}

(C) 765 kJ·mol^{-1} **(D)** 810 kJ·mol^{-1}

19. How much energy must be supplied to change 36 g of ice at 0 °C to water at room temperature, 25 °C?

Data for Water, H_2O	
ΔH^o_{fusion}	6.01 kJ·mol^{-1}
$C_{P,\,liquid}$	4.18 J·K^{-1}·g^{-1}

(A) 12 kJ **(B)** 16 kJ

(C) 19 kJ **(D)** 22 kJ

20. For a process that is both endothermic and spontaneous,

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

(C) $\Delta E = 0$ **(D)** $\Delta S > 0$

21. Consider the values for ΔH^o (in kJ·mol^{-1}) and for ΔS^o (in J·mol^{-1}·K^{-1}) given for four different reactions. For which reaction will ΔG^o increase the most (becoming more positive) when the temperature is increased from 0 °C to 25 °C?

(A) $\Delta H^o = 50$, $\Delta S^o = 50$

(B) $\Delta H^o = 90$, $\Delta S^o = 20$

(C) $\Delta H^o = -20$, $\Delta S^o = -50$

(D) $\Delta H^o = -90$, $\Delta S^o = -20$

22. A certain reaction is exothermic by 220 kJ and does 10 kJ of work. What is the change in the internal energy of the system at constant temperature?

(A) +230 kJ **(B)** +210 kJ

(C) –210 kJ **(D)** –230 kJ

23. $Fe_2O_3(s) + 3/2C(s) \rightarrow 3/2CO_2(g) + 2Fe(s)$ $\Delta H^o = +234.1$ kJ

$C(s) + O_2(g) \rightarrow CO_2(g)$ $\Delta H^o = -393.5$ kJ

Use these equations and ΔH^o values to calculate ΔH^o for this reaction.

$$4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$$

(A) –1648.7 kJ **(B)** –1255.3 kJ

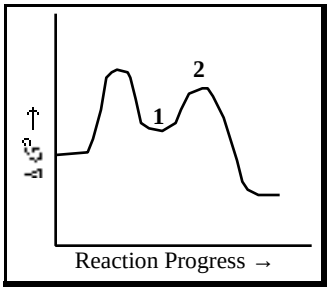
(C) –1021.2 kJ **(D)** –129.4 kJ

24. A large positive value of ΔG^o corresponds to which of these?

(A) small positive K **(B)** small negative K

(C) large positive K **(D)** large negative K

25. What names apply to chemical species corresponding to locations **1** and **2** on this reaction coordinate diagram?



	Location **1**	Location **2**
(A)	activated complex	activated complex
(B)	reaction intermediate	activated complex
(C)	activated complex	reaction intermediate
(D)	reaction intermediate	reaction intermediate

26. Gadolinium-153, which is used to detect osteoporosis, has a half-life of 242 days. Which value is closest to the percentage of the Gd-153 left in a patient's system after 2 years (730 days)?

(A) 33.0 % **(B)** 25.0 %

(C) 12.5 % **(D)** 6.25 %

27. Consider this reaction.

$$2NO_2(g) + O_3(g) \rightarrow N_2O_5(g)$$

The reaction of nitrogen dioxide and ozone is first order in $NO_2(g)$ and in $O_3(g)$. Which of the reaction mechanisms is consistent with the rate?

Mechanism **I**.
$NO_2 + O_3 \rightarrow NO_3 + O_2$ *slow*
$NO_3 + NO_2 \rightarrow N_2O_5$ *fast*

Mechanism **II**.
$O_3 \rightleftharpoons O_2 + O$ *fast*
$NO_2 + O \rightarrow NO_3$ *slow*
$NO_3 + NO_2 \rightarrow N_2O_5$ *fast*

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

(C) both **I** and **II** **(D)** neither **I** nor **II**

28. When the temperature of a reaction is raised from 300 K to 310 K, the reaction rate doubles. Determine the activation energy, E_a, associated with the reaction.

(A) 6.45 kJ·mol^{-1} **(B)** 23.3 kJ·mol^{-1}

(C) 53.6 kJ·mol^{-1} **(D)** 178 kJ·mol^{-1}

29. Use the experimental data in the table to determine the rat law for this reaction.

$$A + B \rightarrow AB$$

These data were obtained when the reaction was studied.

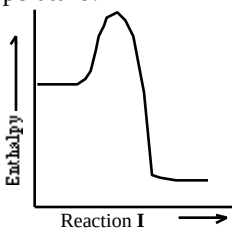
[A], M	[B], M	$\Delta[AB]/\Delta t$ mol·L^{-1}·s^{-1}
0.100	0.100	2.0×10^{-4}
0.200	0.100	2.0×10^{-4}
0.300	0.300	1.8×10^{-3}

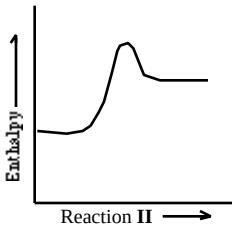
What is the rate equation for the reaction?

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

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

30. Which of the reactions represented in these diagrams will show the greatest increase in rate for a given increase in temperature?





(A) Reaction **I** forward **(B)** Reaction **I** reversed

(C) Reaction **II** forward **(D)** Reaction **II** reversed

Questions **31** and **32** should both be answered with reference to this equilibrium system.

$2NH_3(g) \rightleftharpoons N_2(g) + 3H_2(g) \qquad K_p = 80.0$ at 250 °C

31. What is K_p for this reaction?

$$1/2N_2(g) + 3/2H_2(g) \rightleftharpoons NH_3(g)$$

(A) 0.0125 **(B)** 0.112

(C) 8.94 **(D)** 40.0

32. What is the expression for K_c at 250 °C for this reaction?

$$2NH_3(g) \rightleftharpoons N_2(g) + 3H_2(g)$$

(A) $K_c = \dfrac{K_p}{(RT)^2}$ **(B)** $K_c = \dfrac{K_p}{RT}$

(C) $K_c = K_p(RT)^2$ **(D)** $K_c = K_p RT$

33. $HCOOH(aq) \rightleftharpoons H^+(aq) + HCOO^-(aq) \quad K_a = 1.7 \times 10^{-4}$

The ionization of formic acid is represented. Calculate $[H^+]$ of a solution initially containing 0.10 M HCOOH and 0.050 M HCOONa.

(A) 8.5×10^{-5} M **(B)** 3.4×10^{-4} M

(C) 4.1×10^{-3} M **(D)** 1.8×10^{-2} M

34. Which are strong acids?

I. $HClO_3$ **II.** H_2SeO_3 **III.** H_3AsO_4

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

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

35. Carbonic acid, H_2CO_3, is a diprotic acid for which $K_1 = 4.2 \times 10^{-7}$ and $K_2 = 4.7 \times 10^{-11}$. Which solution will produce a pH closest to 9?

(A) 0.1 M H_2CO_3 **(B)** 0.1 M Na_2CO_3

(C) 0.1 M $NaHCO_3$ **(D)** 0.1 M $NaHCO_3$ and 0.1 M Na_2CO_3

36. What is the pH of a saturated solution of magnesium hydroxide, $Mg(OH)_2$ at 25 °C? ($K_{sp} = 6.0 \times 10^{-12}$ at 25°C)

(A) 10.56 **(B)** 10.36

(C) 10.26 **(D)** 10.05

37. $P_4(s) + 3OH^-(aq) + 3H_2O(l) \rightarrow PH_3(g) + 3H_2PO_2^-(aq)$

For this reaction, the oxidizing and reducing agents are, respectively,

(A) P_4 and OH^- **(B)** OH^- and P_4

(C) P_4 and H_2O **(D)** P_4 and P_4

38. $Al^{3+}(aq) + 3e^- \rightarrow Al(s) \qquad E^o =$

$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s) \qquad E^o = +0.$

What voltage is produced under standard condit combining the half-reactions with these Standard Electrode Potentials?

(A) 1.32 V **(B)** 2.00 V **(C)** 2.30 V **(D)** 4.34 V

39. For which of these oxidation/reduction pairs will the reduction potential vary with pH?

I. AmO_2^{2+}/AmO_2^+ **II.** AmO_2^{2+}/Am^{4+} **III.** Am^{4+}/Am^{2+}

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

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

40. $2Ag^+(aq) + Cu(s) \rightarrow Cu^{2+}(aq) + 2Ag(s)$

The standard potential for this reaction is 0.46 V. Which change will increase the potential the most?

(A) doubling the $[Ag^+]$

(B) halving the $[Cu^{2+}]$

(C) doubling the size of the $Cu(s)$ electrode

(D) decreasing the size of the Ag electrode by one half

41. $10Cl^-(aq) + 2MnO_4^-(aq) + 16H^+(aq) \rightarrow 5Cl_2(g) + 2Mn^{2+}(aq) + 8H_2O(l)$

The value of E^o for this reaction at 25 °C is 0.15 V. What is the value of K for this reaction?

(A) 2.4×10^{25} **(B)** 4.9×10^{12}

(C) 1.2×10^5 **(D)** 3.4×10^2

42. When water is electrolyzed, hydrogen and oxygen gas are produced. If 1.008 g of H_2 is liberated at the cathode, what mass of O_2 is formed at the anode?

(A) 32.0 g **(B)** 16.0 g

(C) 8.00 g **(D)** 4.00 g

43. Which property of an element is most dependent on the shielding effect?

(A) atomic number

(B) atomic mass

(C) atomic radius

(D) number of stable isotopes

44. How many unpaired electrons are present in a ground state gaseous Ni^{2+} ion?

(A) 0 **(B)** 2 **(C)** 4 **(D)** 6

45. When the elements carbon, nitrogen and oxygen are arranged in order of increasing ionization energies, what is the correct order?

(A) C, N, O **(B)** O, N, C

(C) N, C, O **(D)** C, O, N

46. Given this set of quantum numbers for a multi-electron atom: 2, 0, 0, 1/2 and 2, 0, 0, –1/2. What is the next higher allowed set of *n* and *l* quantum numbers for this atom in its ground state?

(A) $n = 2, l = 0$ **(B)** $n = 2, l = 1$

(C) $n = 3, l = 0$ **(D)** $n = 3, l = 1$

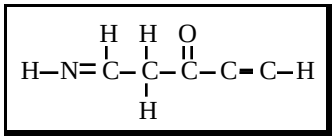
47. Which element will exhibit the photoelectric effect with light of the longest wavelength?

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

48. All these elements have common allotropes ***except***

(A) C **(B)** O **(C)** Kr **(D)** S

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



(A) 8 sigma and 7 pi **(B)** 8 sigma and 3 pi

(C) 11 sigma and 3 pi **(D)** 11 sigma and 4 pi

50. Which reaction involves a change in the electron-pair geometry for the underlined atom?

(A) $\underline{B}F_3 + F^- \rightarrow \underline{B}F_4$ **(B)** $\underline{N}H_3 + H^+ \rightarrow \underline{N}H_4^+$

(C) $2\underline{S}O_2 + O_2 \rightarrow 2\underline{S}O_3$ **(D)** $H_2\underline{O} + H^+ \rightarrow H_3\underline{O}^+$

51. Which compound has the largest lattice energy?

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

52. Which is the best description of a c

(A) Electrons are simultaneously attrac han one nucleus.

(B) Filled orbitals of two or more atoms over another.

(C) Unoccupied orbitals of two or more atoms overla one another.

(D) Oppositely-charged ions attract one another.

53. What is the formal charge on the chlorine atom in the oxyacid $HOClO_2$ if it contains only single bonds?

(A) –2 **(B)** –1 **(C)** +1 **(D)** +2

54. Which of these compounds is not adequately represented by a valence bond model?

I. CO_2 **II.** SO_2 **III.** SiO_2

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

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

55. Which compound is not correctly matched with its class name?

(A) HCOOH, acid

(B) C_6H_5CHO, aldehyde

(C) $C_2H_5COCH_3$, ether

(D) $CH_3CHOHCH_3$, secondary alcohol

56. How many toluene derivatives have the formula C_7H_7Cl?

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

57. When the compounds CH_3COOH, C_2H_5OH and C_6H_5OH are arranged in order of increasing acidity in aqueous solution, which order is correct?

(A) $C_2H_5OH < CH_3COOH < C_6H_5OH$

(B) $C_6H_5OH < CH_3COOH < C_2H_5OH$

(C) $CH_3COOH < C_6H_5OH < C_2H_5OH$

(D) $C_2H_5OH < C_6H_5OH < CH_3COOH$

58. Which can be used as a catalyst in an esterification reaction?

I. NaOH **II.** H_2SO_4

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

(C) both **I** and **II** **(D)** neither **I** nor **II**

59. Which term best describes a carbocation?

(A) electrophilic **(B)** free radical

(C) hydrophobic **(D)** nucleophilic

60. A racemic mixture has equal amou

(A) alkanes and alkenes.

(B) *cis* and *trans* isomers.

(C) functional group isomers.

(D) enantiomers.

END OF TEST

U. S. National Chemistry Olympiad – 2001
National Examination—Part I
SCORING KEY

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