2004 U. S. NATIONAL CHEMISTRY OLYMPIAD

LOCAL SECTION EXAM

Prepared by the American Chemical Society Olympiad Examinations Task Force

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DIRECTIONS TO THE EXAMINER

This test is designed to be taken with an answer sheet on which the student records his or her responses. All answers are to be marked on that sheet, not written in the booklet. Each student should be provided with an answer sheet and scratch paper, both of which must be turned in with the test booklet at the end of the examination. Local Sections may use an answer sheet of their own choice.

The full examination consists of 60 multiple-choice questions representing a fairly wide range of difficulty. Students should be permitted to use non-programmable calculators. A periodic table and other useful information are provided on page two of this exam booklet for student reference.

Suggested Time: 60 questions—110 minutes

DIRECTIONS TO THE EXAMINEE

DO NOT TURN THE PAGE UNTIL DIRECTED TO DO SO.

This is a multiple-choice examination with four choices for each question. There is only *one* correct or best answer to each question. When you select your choice, blacken the corresponding space on the answer sheet with your pencil. Make a heavy full mark, but no stray marks. If you decide to change your answer, be certain to erase your original answer completely.

Not valid for use as an ACS Olympiad Local Section Exam after March 28, 2004. **STOCK CODE OL04**

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ABBREVIATIONS AND SYMBOLS					
ampere	A	Faraday constant	F	molal	m
atmosphere	atm	formula molar mass	M	molar	M
atomic mass unit	u	free energy	G	molar mass	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	temperature, K	T
enthalpy	H	kilo– prefix	k	time	t
entropy	S	liter	L	volt	V
equilibrium constant	K	milli– prefix	m		

CONSTANTS

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

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

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

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

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

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

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

$0\ °\mathrm{C} = 273.15\ \mathrm{K}$

$1\ \mathrm{atm} = 760\ \mathrm{mmHg}$

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	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1 **H** 1.008																	2 **He** 4.003
3 **Li** 6.941	4 **Be** 9.012											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.88	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.39	31 **Ga** 69.72	32 **Ge** 72.61	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.1	45 **Rh** 102.9	46 **Pd** 106.4	47 **Ag** 107.9	48 **Cd** 112.4	49 **In** 114.8	50 **Sn** 118.7	51 **Sb** 121.8	52 **Te** 127.6	53 **I** 126.9	54 **Xe** 131.3
55 **Cs** 132.9	56 **Ba** 137.3	57 **La** 138.9	72 **Hf** 178.5	73 **Ta** 180.9	74 **W** 183.8	75 **Re** 186.2	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.1	79 **Au** 197.0	80 **Hg** 200.6	81 **Tl** 204.4	82 **Pb** 207.2	83 **Bi** 209.0	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89 **Ac** (227)	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (263)	107 **Bh** (262)	108 **Hs** (265)	109 **Mt** (266)	110 (269)	111 (272)	112 (277)		114 (2??)				

58 **Ce** 140.1	59 **Pr** 140.9	60 **Nd** 144.2	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 152.0	64 **Gd** 157.3	65 **Tb** 158.9	66 **Dy** 162.5	67 **Ho** 164.9	68 **Er** 167.3	69 **Tm** 168.9	70 **Yb** 173.0	71 **Lu** 175.0
90 **Th** 232.0	91 **Pa** 231.0	92 **U** 238.0	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (262)

DIRECTIONS

- When you have selected your answer to each question, blacken the corresponding space on the answer sheet using a soft, #2 pencil. Make a heavy, full mark, but no stray marks. If you decide to change an answer, erase the unwanted mark very carefully.
- There is only one correct answer to each question. Any questions for which more than one response has been blackened **will not be counted**.
- Your score is based solely on the number of questions you answer correctly. **It is to your advantage to answer every question.**

1. Which element is a gas at 25 ˚C and 1 atm pressure?

(A) chlorine **(B)** phosphorus
(C) silicon **(D)** sulfur

2. Which combustion product is produced THE LEAST by gasoline-powered vehicles?

(A) CO_2 **(B)** H_2O **(C)** NO_2 **(D)** SO_2

3. Which element has the highest electrical conductivity at room temperature?

(A) Ge **(B)** Se **(C)** Sn **(D)** Te

4. How should a student prepare 100 mL of a 1.0 M H_2SO_4 solution from a 10. M H_2SO_4 solution?

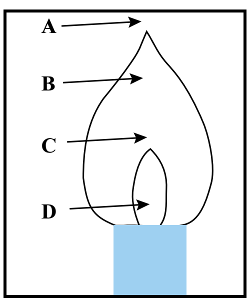
(A) Add 90 mL of H_2O to 10 mL of 10 M H_2SO_4.

(B) Add 10 mL of 10 M H_2SO_4 to 90 mL of H_2O.

(C) Add 10 mL of 10 M H_2SO_4 to 80 mL of H_2O, stir and dilute to 100 mL after allowing to cool.

(D) Add 80 mL of H_2O to 10 mL of 10 M H_2SO_4, stir and dilute to 100 mL after allowing to cool.

5. Which letter in the diagram depicts the hottest portion of a Bunsen burner flame?



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

6. What is the proper technique to test the odor of a vapor in a test tube?

(A) Hold the test tube near the nose and sniff.

(B) Use a micropipet to capture some of the gas and sniff that.

(C) Hold the test tube above the nose and pour the gas toward it.

(D) Hold the test tube near the nose and waft the gas toward it with a hand.

7. For which compound are the empirical and molecular formulas the same?

(A) C_6H_5COOH **(B)** $C_6H_4(COOH)_2$
(C) HOOCCOOH **(D)** CH_3COOH

8. What volume of liquid A has the same mass as 80.0 cm^3 of liquid B?

Density (g/cm^3)	
Liquid A	0.660
Liquid B	1.59

(A) 40.0 cm^3 **(B)** 97.0 cm^3
(C) 160. cm^3 **(D)** 193 cm^3

9. How many water molecules are in a 0.10 g sample of $CuSO_4{\cdot}5H_2O$ (MM = 249.7)?

(A) 1.2×10^{21} **(B)** 2.4×10^{21}
(C) 2.4×10^{22} **(D)** 1.2×10^{23}

10. Acetylene, C_2H_2, reacts with O_2 to produce CO_2 and H_2O. What is the O_2/C_2H_2 ratio in the balanced equation?

(A) 2/1 **(B)** 3/2 **(C)** 5/2 **(D)** 3/1

11. $Mg(OH)_2$ in the form of Milk of Magnesia is used to neutralize excess stomach acid. How many moles of stomach acid can be neutralized by 1.00 g of $Mg(OH)_2$?

Molar Mass (g/mol)	
$Mg(OH)_2$	58.33

(A) 0.0171 **(B)** 0.0343 **(C)** 0.686 **(D)** 1.25

12. A 25.00 mL sample of 0.1050 M H_2SO_4 is titrated with a NaOH solution of unknown concentration. The phenolphthalein endpoint was reached when 17.23 mL of the NaOH solution had been added. What is the concentration of the NaOH?

(A) 0.07617 M **(B)** 0.1447 M
(C) 0.1524 M **(D)** 0.3047 M

13. A sample of oxygen gas and a sample of an unknown gas are weighed separately in the same evacuated flask. Use the data given to find the molar mass of the unknown gas (assume experiments are carried out at the same pressure and temperature).

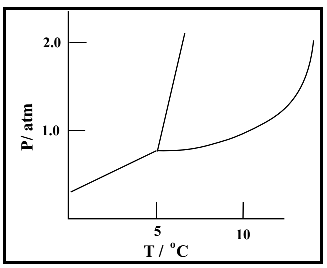
Mass of evacuated flask	124.46 g
Mass of flask + oxygen	125.10 g
Mass of flask + unknown gas	125.34 g

(A) 22 g/mol **(B)** 38 g/mol
(C) 44 g/mol **(D)** 84 g/mol

14. Which pair of gases has the same average rate of diffusion at 25 ˚C?

(A) He and Ne **(B)** N_2 and O_2
(C) N_2O and CO_2 **(D)** NH_3 and HCl

15. According to the phase diagram shown, in what state does the represented substance exist at 1.0 atm and 0.0 ˚C?



(A) solid only **(B)** liquid only
(C) gas only **(D)** solid and liquid only

16. What is the most effective way to condense a gas?

(A) Decrease the temperature and increase the pressure.
(B) Decrease the temperature and decrease the pressure.
(C) Increase the temperature and decrease the pressure.
(D) Increase the temperature and increase the pressure.

17. Which liquid has the highest vapor pressure at 25 ˚C?

(A) butane, C_4H_{10} **(B)** glycerol, $C_3H_5(OH)_3$
(C) octane, C_8H_{18} **(D)** propanol, C_3H_7OH

18. Which oxide has the highest melting point?

(A) H_2O **(B)** NO_2 **(C)** SO_2 **(D)** SiO_2

19. The enthalpy change of which reaction corresponds to ΔH°_f for Na_2CO_3(s) at 298 K?

(A) $2Na(s) + C(s) + 3/2O_2(g) \rightarrow Na_2CO_3(s)$
(B) $Na_2O(s) + CO_2(g) \rightarrow Na_2CO_3(s)$
(C) $2Na^+(aq) + CO_3^{2-}(aq) \rightarrow Na_2CO_3(s)$
(D) $2Na^+(aq) + 2OH^-(aq) + CO_2(aq) \rightarrow Na_2CO_3(s) + H_2O$

20. Which applies to any endothermic reaction?

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

21. When a bomb calorimeter is used to determine the heat of reaction, which property of the system under investigation is most likely to remain constant?

(A) number of molecules **(B)** pressure
(C) temperature **(D)** volume

22. For the reaction shown, which is closest to the value of ΔH?

	ΔH°_f (kJ·mol^{-1})
$Cr^{3+}(aq)$	-143
$Ni^{2+}(aq)$	-54

$2Cr^{3+}(aq) + 3Ni(s) \rightarrow 2Cr(s) + 3Ni^{2+}(aq)$

(A) 124 kJ **(B)** 89 kJ **(C)** -89 kJ **(D)** -124 kJ

23. An ice cube at 0.00 ˚C is placed in 200. g of distilled water at 25.00 ˚C. The final temperature after the ice is completely melted is 5.00 ˚C. What is the mass of the ice cube? (ΔH_{fus} = 340. J•g^{-1}, C_p = 4.18 J•g^{-1}•˚C^{-1})

(A) 23.6 g **(B)** 46.3 g **(C)** 50.0 g **(D)** 800. g

24. Which reaction occurs with the greatest increase in entropy?

(A) $2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$
(B) $2NO(g) \rightarrow N_2(g) + O_2(g)$
(C) $C(s) + O_2(g) \rightarrow CO_2(g)$
(D) $Br_2(g) + Cl_2(g) \rightarrow 2BrCl(g)$

25. For a rate law of the form; Rate = $k[A]^m[B]^n$, the exponents m and n are obtained from

(A) changes in rate with changing temperature.
(B) the coefficients of A and B in the balanced equation.
(C) the concentrations of A and B in a single experiment.
(D) changes in the reaction rate for different concentrations of A and B.

26. What is the order of a reaction for which the units of k are $L\cdot mol^{-1}\cdot s^{-1}$ and the units of the rate are $mol\cdot L^{-1}\cdot s^{-1}$?

(A) zero order **(B)** first order
(C) second order **(D)** some other order

27. For the reaction $A + B \rightarrow C$,
the rate law is: $\text{Rate} = k[A]^2$.
Which change(s) will increase the rate of the reaction?

I	Increasing the concentration of A
II	Increasing the concentration of B

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

28. Which does NOT change with time for a first-order reaction?

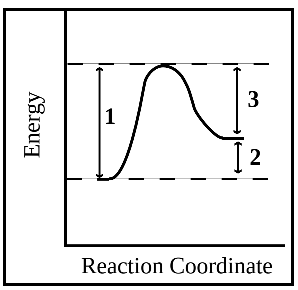
(A) the amount of reactant that disappears in each half-life
(B) the concentration of the reactant
(C) the length of each half-life
(D) the rate of the reaction

29. The rates of which reactions are increased when the temperature is raised?

I	endothermic reactions
II	exothermic reactions

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

30. When a catalyst is added to the system represented by this energy-reaction coordinate diagram, which dimensions in the diagram are changed?



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

31. Which statement is true for a reaction at equilibrium?

(A) All reaction ceases.
(B) The reaction has gone to completion.
(C) The rates of the forward and reverse reactions are equal.
(D) The amount of product equals the amount of reactant.

32. For the hypothetical reaction, $2A(s) + B(g) \rightleftharpoons 3C(g)$ what is the equilibrium expression?

(A) $K = \dfrac{[C]^3}{[A]^2[B]}$ **(B)** $K = \dfrac{3[C]}{2[A][B]}$

(C) $K = \dfrac{[C]^3}{[A]^2 + [B]}$ **(D)** $K = \dfrac{[C]^3}{[B]}$

33. Acetylsalicylic acid (aspirin) behaves as an acid according to the equation shown. Calculate K_b for the $C_9H_7O_4^-$(aq) ion. ($K_a = 3.0 \times 10^{-4}$)
$HC_9H_7O_4(aq) + H_2O \rightleftharpoons H_3O^+(aq) + C_9H_7O_4^-(aq)$

(A) 3.0×10^{-17} **(B)** 3.3×10^{-11}
(C) 9.0×10^{-8} **(D)** 3.3×10^{3}

34. What will happen to the pH of a buffer solution when a small amount of a strong base is added? The pH will

(A) increase slightly
(B) decrease slightly
(C) remain exactly the same
(D) become 7.0

35. When a solution of NH_3 ($K_b = 1.8 \times 10^{-5}$) is titrated with a strong acid the indicator used should change color near a pH of

(A) 1 **(B)** 5 **(C)** 9 **(D)** 13

36. When solid silver chloride (MM = 143.4) is added to 100. mL of H_2O, 1.9×10^{-4} grams dissolves. What is the K_{sp} for silver chloride?

(A) 1.3×10^{-5} **(B)** 3.7×10^{-6}
(C) 3.7×10^{-8} **(D)** 1.8×10^{-10}

37. In which species does the underlined element have an oxidation number of +2?

(A) $\underline{S}O_2Cl_2$ **(B)** $\underline{Fe}(CN)_6^{4-}$
(C) $H\underline{N}O_2$ **(D)** $\underline{Ni}(CO)_4$

38. Which transformation is an oxidation?

(A) $VO_3^- \rightarrow VO_2^+$
(B) $CrO_2^- \rightarrow CrO_4^{2-}$
(C) $SO_3 \rightarrow SO_4^{2-}$
(D) $NO_3^- \rightarrow NO_2^-$

39. $\_Sn^{2+}(aq) + \_NO_3^-(aq) + \_H^+(aq) \rightarrow \_Sn^{4+}(aq) + \_NO(g) + \_H_2O$

What is the coefficient for $H^+(aq)$ when the equation above is balanced correctly with the smallest integer coefficients?

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

40. In electrochemical cells the cathode is always the electrode where

(A) oxidation occurs.

(B) reduction occurs.

(C) positive ions are formed.

(D) negative ions are formed.

41. $2Ga(s) + 6H^+(aq) \rightarrow 2Ga^{3+}(aq) + 3H_2(g)$

The potential of the cell for the reaction given is 0.54 V. If the concentrations of the ions are 1.0 M and the pressure of $H_2(g)$ is 1 atm, what is E° for the half-reaction $Ga^{3+}(aq) + 3e^- \rightarrow Ga(s)$

(A) -0.54 V **(B)** -0.27 V

(C) 0.27 V **(D)** 0.54 V

42. All of the following affect the number of moles of metal deposited during electrolysis EXCEPT the

(A) current used **(B)** electrolysis time

(C) charge on the ion **(D)** molar mass

43. The emission spectrum of hydrogen in the visible region consists of

(A) a continuous band of light.

(B) a series of equally spaced lines.

(C) a series of lines that are closer at low energies.

(D) a series of lines that are closer at high energies.

44. Which atom in its ground state has the most unpaired electrons?

(A) Ge **(B)** As **(C)** Se **(D)** Br

45. An monoatomic ion that has 18 electrons and a +2 charge

(A) has 16 protons. **(B)** has the symbol Ar^{2+}.

(C) has 18 neutrons. **(D)** is isoelectronic with Ar.

46. Which atom has the largest atomic radius?

(A) Li **(B)** K **(C)** As **(D)** Br

47. What is the maximum number of electrons that occupy the n = 3 level?

(A) 6 **(B)** 8 **(C)** 10 **(D)** 18

48. How does the reducing ability of the elements vary across the period from Na to Ar? It

(A) decreases steadily.

(B) increases steadily.

(C) decreases then increases.

(D) increases then decreases.

49. Which species contains only covalent bonds?

(A) H_2SO_4 **(B)** NH_4NO_3

(C) NaOCl **(D)** K_2CrO_4

50. How many valence electrons are in the pyrophosphate ion, $P_2O_7^{4-}$?

(A) 48 **(B)** 52 **(C)** 54 **(D)** 56

51. Which species has the largest F-A-F bond angle where A is the central atom?

(A) BF_3 **(B)** CF_4 **(C)** NF_3 **(D)** OF_2

52. The triple bond in carbon monoxide consists of

(A) 3 sigma bonds

(B) 2 sigma bonds and 1 pi bond

(C) 1 sigma bond and 2 pi bonds

(D) 3 pi bonds

53. The boiling points of the halogens, F_2, Cl_2, Br_2 and I_2, increase in that order. This is best attributed to differences in

(A) covalent bond strengths.

(B) dipole forces.

(C) London dispersion forces.

(D) colligative forces.

54. Which species is polar?

(A) CO_2 **(B)** SO_2 **(C)** SO_3 **(D)** O_2

55. Which formula represents n-butane?

(A) $CH_3CH_2CH_2CH_3$ **(B)** $CH_2{=}CHCH_2CH_3$

(C) $(CH_3)_2CHCH_3$ **(D)** $(CH_3)_3CH$

56. How many structural isomers have the formula $C_3H_6Cl_2$?

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

57. What is the hybridization of the carbon atom in a carboxyl group?

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

58. A reaction in which a carboxylic acid reacts with an alcohol to form an organic compound and water is called

(A) esterification **(B)** hydrolysis

(C) neutralization **(D)** saponification

59. What substance is formed when $CF_2{=}CF_2$ is polymerized?

(A) Polyethylene **(B)** Polyurethane

(C) PVC **(D)** Teflon

60. Most enzymes are a type of

(A) carbohydrate **(B)** lipid

(C) nucleic acid **(D)** protein

END OF TEST

Olympiad 2004 Local Section

KEY

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