2010 U.S. NATIONAL CHEMISTRY OLYMPIAD
LOCAL SECTION EXAM

Prepared by the American Chemical Society Chemistry Olympiad Examinations Task Force

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.

PERIODIC TABLE OF THE ELEMENTS

1 1A																	18 8A
1 **H** 1.008	2 2A											13 3A	14 4A	15 5A	16 6A	17 7A	2 **He** 4.003
3 **Li** 6.941	4 **Be** 9.012											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.31	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.88	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.39	31 **Ga** 69.72	32 **Ge** 72.61	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.1	45 **Rh** 102.9	46 **Pd** 106.4	47 **Ag** 107.9	48 **Cd** 112.4	49 **In** 114.8	50 **Sn** 118.7	51 **Sb** 121.8	52 **Te** 127.6	53 **I** 126.9	54 **Xe** 131.3
55 **Cs** 132.9	56 **Ba** 137.3	57 **La** 138.9	72 **Hf** 178.5	73 **Ta** 180.9	74 **W** 183.8	75 **Re** 186.2	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.1	79 **Au** 197.0	80 **Hg** 200.6	81 **Tl** 204.4	82 **Pb** 207.2	83 **Bi** 209.0	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89 **Ac** (227)	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (266)	107 **Bh** (264)	108 **Hs** (277)	109 **Mt** (268)	110 **Ds** (281)	111 **Rg** (272)	112 Uub (277)	113 (Uut)	114 (Uuq)	115 (Uup)	116 (Uuh)	117 (Uus)	118 (Uuo)

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

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 completely.

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. A student is asked to measure 30.0 g of methanol (d = 0.7914 g/mL at 25˚C) but has only a graduated cylinder with which to measure it. What volume of methanol should the student use to obtain the required 30.0 g?

   (A) 23.7 mL   (B) 30.0 mL

   (C) 32.4 mL   (D) 37.9 mL

2. A flame test was performed to confirm the identity of a metal ion in solution. The result was a green flame. Which of the following metal ions is indicated?

   (A) copper   (B) sodium

   (C) strontium   (D) zinc

3. When phenolphthalein is added to an aqueous solution containing one of the following solutes the solution turns pink. Which solute is present?

   (A) NaCl   (B) $KC_2H_3O_2$

   (C) LiBr   (D) NH_4NO_3

4. Solid camphor is insoluble in water but is soluble in vegetable oil. The best explanation for this behavior is that camphor is a(n)

   (A) ionic solid   (B) metallic solid

   (C) molecular solid (D) network solid

5. A student performed an experiment to determine the ratio of H_2O to $CuSO_4$ in a sample of hydrated copper(II) sulfate by heating it to drive off the water and weighing the solid before and after heating. The formula obtained experimentally was $CuSO_4 \cdot 5.5H_2O$ but the accepted formula is $CuSO_4 \cdot 5H_2O$. Which error best accounts for the difference in results?

   (A) During heating some of the hydrated copper(II) sulfate was lost.

   (B) The hydrated sample was not heated long enough to drive off all the water.

   (C) The student weighed out too much sample initially.

   (D) The student used a balance that gave weights that were consistently too high by 0.10 g.

6. An aqueous solution is known to contain Ag^+, Mg^{2+}, and Sr^{2+} ions. Which reagent should be used to selectively precipitate the Ag^+?

   (A) 0.20 M NaCl   (B) 0.20 M NaOH

   (C) 0.20 M Na_2SO_4 (D) 0.20 M Na_3PO_4

7. What is the coefficient for O_2 when the following reaction

   $$\_\_As_2S_3 + \_\_O_2 \rightarrow \_\_ As_2O_3 + \_\_SO_2$$

   is correctly balanced with the smallest integer coefficients?

   (A) 5   (B) 6   (C) 8   (D) 9

8. Which compound contains the highest percentage of nitrogen by mass?

   (A) NH_2OH ($M = 33.0$)   (B) NH_4NO_2 ($M = 64.1$)

   (C) N_2O_3 ($M = 76.0$)   (D) $NH_4NH_2CO_2$ ($M = 78.1$)

9. How many neutrons are in 0.025 mol of the isotope $_{24}^{54}Cr$?

   (A) 1.5×10^{22} (B) 3.6×10^{23}

   (C) 4.5×10^{23} (D) 8.1×10^{23}

10. Magnesium chloride dissolves in water to form

    (A) hydrated $MgCl_2$ molecules

    (B) hydrated Mg^{2+} ions and hydrated Cl^- ions

    (C) hydrated Mg^{2+} ions and hydrated Cl_2^{2-} ions

    (D) hydrated Mg atoms and hydrated Cl_2 molecules

11. Enzymes convert glucose ($M = 180.2$) to ethanol ($M = 46.1$) according to the equation

    $$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$$

    What is the maximum mass of ethanol that can be made from 15.5 kg of glucose?

    (A) 0.256 kg   (B) 0.512 kg

    (C) 3.96 kg   (D) 7.93 kg

12. Commercial vinegar is a 5.00% by mass aqueous solution of acetic acid, CH_3CO_2H ($M = 60.0$). What is the molarity of acetic acid in vinegar? [density of vinegar = 1.00 g/mL]

(A) 0.833 M (B) 1.00 M

(C) 1.20 M (D) 3.00 M

13. A 2.00 L balloon at 20.0°C and 745 mmHg floats to an altitude where the temperature is 10.0°C and the air pressure is 700 mmHg. What is the new volume of the balloon?

(A) 0.94 L   (B) 1.06 L   (C) 2.06 L   (D) 2.20 L

14. Which family of elements has solid, liquid and gaseous members at 25°C and 1 atm pressure?

(A) alkali metals (Li – Cs)   (B) pnictogens (N – Bi)

(C) chalcogens (O – Te)   (D) halogens (F – I)

15. A gas diffuses one-third as fast as O_2 at 100 °C. This gas could be

(A) He ($M = 4$)   (B) C_2H_5F ($M = 48$)

(C) C_7H_{12} ($M = 96$)   (D) C_5F_{12} ($M = 288$)

16. Moist air is less dense than dry air at the same temperature and barometric pressure. Which is the best explanation for this observation?

(A) H_2O is a polar molecule but N_2 and O_2 are not.

(B) H_2O has a higher boiling point than N_2 or O_2.

(C) H_2O has a lower molar mass than N_2 or O_2.

(D) H_2O has a higher heat capacity than N_2 or O_2.

17. Under certain conditions CO_2 melts rather than sublimes. To which transition in the phase diagram does this change correspond?
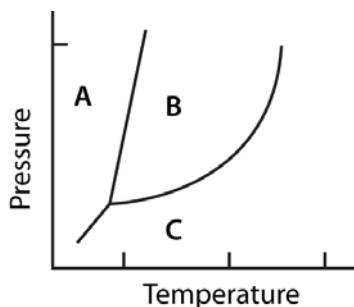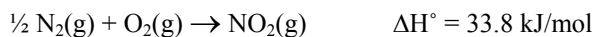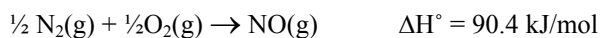

(A) A → B   (B) A → C   (C) B → C   (D) C → B

18. The critical temperature of water is the

(A) temperature at which solid, liquid and gaseous water coexist.

(B) temperature at which water vapor condenses.

(C) maximum temperature at which liquid water can exist.

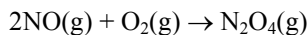(D) minimum temperature at which water vapor can exist.

19. Which process is exothermic?

(A) condensation   (B) fusion

(C) sublimation   (D) vaporization

20. Use the thermodynamic information:

$\frac{1}{2} N_2(g) + \frac{1}{2}O_2(g) \rightarrow NO(g)$ $\Delta H° = 90.4$ kJ/mol

$\frac{1}{2} N_2(g) + O_2(g) \rightarrow NO_2(g)$ $\Delta H° = 33.8$ kJ/mol

$2NO_2(g) \rightarrow N_2O_4(g)$ $\Delta H° = -58.0$ kJ/mol

to calculate $\Delta H°$ in kJ/mol for the reaction:

$2NO(g) + O_2(g) \rightarrow N_2O_4(g)$

(A) –171.2   (B) –114.6   (C) 114.6   (D) 171.2

21. Determine the enthalpy change for the reaction of 5.00 g of Fe_2O_3 with aluminum metal according to the equation $Fe_2O_3(s) + 2Al(s) \rightarrow Al_2O_3(s) + 2Fe(l)$

Substance	$\Delta H_f°$ kJ/mol
$Fe_2O_3(s)$	–825.5
$Al_2O_3(s)$	–1675.7
Fe(l)	12.4

(A) –25.8 kJ   (B) –26.2 kJ

(C) –52.4 kJ   (D) –77.9 kJ
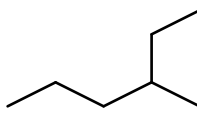
22. Which reaction has the most positive entropy change under standard conditions?

(A) $H_2O(g) + CO(g) \rightarrow H_2(g) + CO_2(g)$

(B) $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

(C) $NH_3(g) \rightarrow NH_3(aq)$

(D) $C_8H_{18}(l) \rightarrow C_8H_{18}(s)$

23. What are the signs of ΔH and ΔS for a reaction that is spontaneous only at low temperatures?

(A) ΔH is positive, ΔS is positive

(B) ΔH is positive, ΔS is negative

(C) ΔH is negative, ΔS is negative

(D) ΔH is negative, ΔS is positive

24. Which substance has a non-zero standard free energy of formation?

(A) Pb(s) (B) Hg(l) (C) $Cl_2(g)$ (D) $O_3(g)$

25. Factors that can affect the rate of a chemical reaction between a solid and a solution include all of the following EXCEPT the

(A) concentration of the reactants in solution.

(B) volume of the container.

(C) size of the solid particles.

(D) temperature.

26. The commercial production of ammonia is represented by the equation $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$.
If the rate of disappearance of $H_2(g)$ is 1.2×10^{-3} mol/min, what is the rate of appearance of $NH_3(g)$?

(A) 2.4×10^{-3} mol/min (B) 1.8×10^{-3} mol/min

(C) 1.2×10^{-3} mol/min (D) 8.0×10^{-4} mol/min

27. A reaction is endothermic with $\Delta H = 100.$ kJ/mol.
If the activation enthalpy of the forward reaction is 140. kJ/mol, what is the activation enthalpy of the reverse reaction?

(A) 40. kJ/mol (B) 100. kJ/mol

(C) 140. kJ/mol (D) 240. kJ/mol

28. The first-order disappearance of a substance has a half-life of 34.0 s. How long does it take for the concentration of that substance to fall to 12.5% of its initial value?

(A) 11 s (B) 68 s (C) 102 s (D) 272 s

29. The reaction $C_3H_7I + Cl^- \rightarrow C_3H_7Cl + I^-$ is thought to occur in the polar solvent CH_3OH by the mechanism:

Step 1 $C_3H_7I \rightarrow C_3H_7^+ + I^-$ (slow)

Step 2 $C_3H_7^+ + Cl^- \rightarrow C_3H_7Cl$ (fast)

Which species is an intermediate in this reaction?

(A) CH_3OH (B) $C_3H_7^+$ (C) I^- (D) Cl^-

30. The times listed are those recorded at 25˚C for the reaction below to produce a measurable amount of $I_2(aq)$:

$$S_2O_8^{2-}(aq) + 2I^-(aq) \rightarrow I_2(aq) + 2SO_4^{2-}(aq)$$

Experiment	Initial $[S_2O_8^{2-}]$, M	Initial $[I^-]$, M	Time (sec)
1	0.0400	0.0800	39
2	0.0400	0.0400	78
3	0.0100	0.0800	156
4	0.0200	0.0200	?

What is the expected time for experiment 4?

(A) 156 sec (B) 234 sec

(C) 312 sec (D) 624 sec

31. What is the equilibrium expression, K_c, for the reaction: $2S(s) + 3O_2(g) \rightleftharpoons 2SO_3(g)$?

(A) $K_c = 2[SO_3]/(2[S]+3[O_2])$ (B) $K_c = 2[SO_3]/3[O_2]$

(C) $K_c = [SO_3]^2/[S]^2[O_2]^3$ (D) $K_c = [SO_3]^2/[O_2]^3$

32. In which reaction at equilibrium will the amount of reactants present increase with an increase in the container volume?

(A) $C(s) + CO_2(g) \rightleftharpoons 2CO(g)$

(B) $H_2(g) + F_2(g) \rightleftharpoons 2 HF(g)$

(C) $CO(g) + NO_2(g) \rightleftharpoons CO_2(g) + NO(g)$

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

33. What is the pH of a solution made by mixing 200. mL of 0.0657 M NaOH, 140. mL of 0.107 M HCl, and 160. mL of H_2O?

(A) 3.04 (B) 2.74 (C) 2.43 (D) 2.27

34. What is the percentage ionization of HCOOH molecules in a 0.10 M solution? $[K_a = 1.8 \times 10^{-4}]$

(A) 4.2% (B) 2.7% (C) 1.8% (D) 1.3%

35. What is the pH of a solution that is 0.20 M in HF and 0.40 M in NaF? $[K_a = 7.2 \times 10^{-4}]$

(A) 1.92 (B) 2.84 (C) 3.14 (D) 3.44

36. A 500. mL saturated solution of $MgCO_3$ ($M = 84$) is reduced to 120. mL by evaporation. What mass of solid $MgCO_3$ is formed? $[K_{sp} = 4.0 \times 10^{-5}]$

(A) 0.0013 g (B) 0.064 g

(C) 0.20 g (D) 0.27 g

37. Consider the following reactions:

$X(NO_3)_2 + Y \rightarrow X + Y(NO_3)_2$

$X(NO_3)_2 + Z \rightarrow X + Z(NO_3)_2$

$Y(NO_3)_2 + Z \rightarrow$ No reaction

What is the correct order of increasing activity for the metals; X, Y, Z?

(A) $X < Y < Z$ (B) $X < Z < Y$

(C) $Z < Y < X$ (D) $Z < X < Y$

38. For the cell

$Zn(s) + 2H^+(aq) \rightarrow Zn^{2+}(aq) + H_2(g)$ $E° = 0.76$ V

Which change will increase the voltage of the cell?

(A) Increasing the size of the Zn electrode.

(B) Increasing the $[Zn^{2+}]$.

(C) Increasing the $[H^+]$.

(D) Increasing the pressure of the $H_2(g)$.

39. When the half-reaction $NO_3^- \rightarrow NO$ is balanced for one NO_3^- in acid solution, ____ electron(s) is (are) _____.

(A) 3 gained (B) 1 gained

(C) 1 lost (D) 3 lost

40. In the reaction
$ClO_3^-(aq) + 5Cl^-(aq) + 6H^+(aq) \rightarrow 3Cl_2(g) + 3H_2O(l)$
the oxidizing and reducing agents are, respectively,

(A) $Cl^-(aq)$ and $ClO_3^-(aq)$ (B) $ClO_3^-(aq)$ and $Cl^-(aq)$

(C) $ClO_3^-(aq)$ and $H^+(aq)$ (D) $Cl^-(aq)$ and $H^+(aq)$

41. $Ag^+(aq) + e^- \rightarrow Ag(s) \qquad E° = 0.80 \text{ V}$

$Co^{2+}(aq) + 2e^- \rightarrow Co(s) \quad E° = -0.28 \text{ V}$

Use the standard reduction potentials to determine the standard potential for the reaction:

$Co(s) + 2Ag^+(aq) \rightarrow Co^{2+}(aq) + 2Ag(s)$

(A) 0.52V (B) 0.66V (C) 1.08V (D) 1.88V

42. What mass of copper is deposited when a current of 10.0A is passed through a solution of copper(II) nitrate for 30.6 seconds?

(A) 0.101g (B) 0.201g (C) 0.403g (D) 6.04g

43. Which statement concerning visible light is correct?

(A) The product of wavelength and frequency is a constant for visible light in a vacuum.

(B) As the wavelength of light increases the energy of a photon increases.

(C) As the wavelength of light increases its amplitude also increases.

(D) Green light has a higher frequency than blue light.

44. Ernest Rutherford's scattering experiment demonstrated the existence of the

(A) alpha particle. (B) electron.

(C) neutron. (D) nucleus.

45. The removal of an electron from which gaseous atom requires the greatest amount of energy?

(A) Na (B) Cl (C) K (D) Br

46. For which pair of species is the difference in radii the greatest?

(A) Li and F (B) Li^+ and F^-

(C) Li^+ and O^{2-} (D) O^{2-} and F^-

47. The electron configuration of cobalt (Z = 27) is $1s^2 2s^2 2p^6 3s^2 3p^6 3d^7 4s^2$. How many unpaired electrons are in a gaseous Co^{3+} ion in its ground state?

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

48. Which element has the greatest electrical conductivity?

(A) As (B) Ge (C) P (D) Sn

49. How many valence electrons are in a persulfate ion, SO_5^{2-}?

(A) 32 (B) 34 (C) 36 (D) 38

50. Which diatomic molecule contains the strongest bond?

(A) H–Cl (B) H–F (C) Cl–Cl (D) F–F

51. The O–N–O bond angles in the nitrate ion, NO_3^-, are best described as being

(A) all 120° (B) all 109.5°

(C) all 90° (D) two 90°, one 180°

52. Which molecule has no permanent dipole moment?

(A) BCl_3 (B) NCl_3 (C) $CHCl_3$ (D) PCl_3

53. When the compounds HF, H_2O, NH_3, and CH_4 are listed in order of increasing boiling point, which order is correct?

(A) $CH_4 < NH_3 < H_2O < HF$

(B) $NH_3 < CH_4 < H_2O < HF$

(C) $HF < CH_4 < H_2O < NH_3$

(D) $CH_4 < NH_3 < HF < H_2O$

54. Which ionic solid has the greatest lattice energy?

(A) NaCl (B) MgO (C) KBr (D) SrS

55. What is the IUPAC name for the molecule below?

(A) heptane (B) 2-ethylpentane

(C) 3-methylhexane (D) 4-ethylpentane

56. How many different aldehydes have the formula $C_5H_{10}O$?

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

57. Which compound will rapidly decolorize bromine in $CHCl_3$?

   (A) benzene   **(B)** cyclohexane

   (C) hexane   **(D)** 1-hexene

58. Which combination of reactants produces an ester?

   (A) acid and alcohol   **(B)** acid and aldehyde

   (C) alcohol and aldehyde   **(D)** aldehyde and potassium permanganate

59. Which element is used to form cross-links between the strands of latex rubber?

   (A) Fe   **(B)** N   **(C)** P   **(D)** S

60. The classification of a fat as saturated or unsaturated is based on whether

   (A) it can be metabolized by humans.

   (B) it contains carbon – carbon double bonds.

   (C) it has twenty or more carbon atoms.

   (D) it is of animal origin.

END OF TEST

2010 U.S. National Chemistry Olympiad
Local Section Exam

KEY

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