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Home Instruction Packet for AP Chemistry

Name of Teacher and Class: Mr. Bangs - AP Chemistry

In this packet are materials and directions for students to complete in their preparation for the AP Exam.

This work will be reviewed as a class following the re-opening of school.

I am available to support you during the hours 7:50am-2:50 pm to answer any of your questions. I will be responding to your emails through the following contact: rbangs@rpsd.org

Lesson:	Assignment Directions
Week 1-	Please review the description sheet attached to Learning from Home Lesson Plan which has been distributed to students.
Week 2:	Please review the description sheet attached to Learning from Home Lesson Plan which has been distributed to students.
Week 3:	Complete AP Chemistry 2016 Free Response; All Questions Complete 2012 ACS Chemistry Olympiad; All questions
Week 4:	Complete full length Practice Exam

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Learning from Home Lesson Plans

Class	Weeks	Electronic Assignments	Paper Assignments
	Week 1		a) Complete AP Chemistry 2013 Free Response All Questions b) Complete 2013 ACS Chemistry olympiad All Questions
	Week 2		a) Complete AP chemistry 2015 Free Response All Questions b) Complete 2009 ACS Chemistry olympiad All Questions c) Complete Sweet 16 chemistry of Gases

AP chemistry (Mr. Bangs)

Comments:

1) Scoring Guidelines are attached for the 2013 & 2015 Free Response Questions

2) Answers keys are attached for the 2013 & 2009 ACS chemistry olympiad Questions
Students should mark any questions for which they require assistance in understanding. These specific questions will be discussed as a class upon our return to school.

3) Utilize Acellus, Khan Academy, Bozemanscience.com, and other on-line resources to strengthen skills in preparation for AP Exam

2009 U. S. NATIONAL CHEMISTRY OLYMPIAD

LOCAL SECTION EXAM

Prepared by the American Chemical Society Olympiad Examinations Task Force

OLYMPIAD EXAMINATIONS TASK FORCE

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Ronald Ragsdale, *University of Utah*, Salt Lake City, UT

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 31, 2009. STOCK CODE OL09

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

CONSTANTS
$R = 8.314\ \text{J·mol}^{-1}\text{·K}^{-1}$
$R = 0.0821\ \text{L·atm·mol}^{-1}\text{·K}^{-1}$
$1\ F = 96{,}500\ \text{C·mol}^{-1}$
$1\ F = 96{,}500\ \text{J·V}^{-1}\text{·mol}^{-1}$
$N_A = 6.022 \times 10^{23}\ \text{mol}^{-1}$
$h = 6.626 \times 10^{-34}\ \text{J·s}$
$c = 2.998 \times 10^{8}\ \text{m·s}^{-1}$
$0\ °\text{C} = 273.15\ \text{K}$

EQUATIONS

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

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 **Ds** (269)	111 **Rg** (272)	112 **Uub** (277)		114 **Uuq** (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 salt is colorless?

   (A) $KMnO_4$ (B) $BaSO_4$
   (C) Na_2CrO_4 (D) $CoCl_2$

2. Which 0.10 M aqueous solution exhibits the lowest electrical conductivity?

   (A) NH_4Cl (B) $CuBr_2$
   (C) Na_2CO_3 (D) C_2H_5OH

3. Which element is a liquid at 25°C and 1 atm?

   (A) fluorine (B) chlorine
   (C) bromine (D) iodine

4. Mixing which combination produces a gaseous product?

   (A) solid ammonium nitrate and solid calcium hydroxide
   (B) copper metal and 0.10 M hydrochloric acid
   (C) solutions of barium hydroxide and 0.10 M sulfuric acid
   (D) solutions of aluminum nitrate and sodium chloride

5. Which technique can be used to determine the number of components in a plant pigment?

   (A) calorimetry (B) chromatography
   (C) colorimetry (D) gravimetry

6. In the determination of the molar mass of a solid acid by titrating it with a standardized base, which procedural error will yield a molar mass that is smaller than the actual value?

   (A) adding the standardized base to a buret containing drops of water
   (B) dissolving the weighed solid acid in twice the recommended volume of water
   (C) using half as many drops of indicator as suggested
   (D) weighing out half of the recommended mass of solid acid

7. The mass of one atom of an element is 1.71×10^{-22} g. What is the atomic mass of this element in $g\cdot mol^{-1}$?

   (A) 101 (B) 103 (C) 105 (D) 107

8. What is the percent by mass of nitrogen in ammonium carbonate, $(NH_4)_2CO_3$?

   (A) 14.53% (B) 27.83%
   (C) 29.16% (D) 33.34%

9. How many moles of water will be produced from the complete combustion of 4.4 g of C_3H_8?

   (A) 0.10 (B) 0.25 (C) 0.40 (D) 0.80

10. A 10.0 g sample of an oxide of copper forms metallic copper and 1.26 g of water when heated in a stream of hydrogen. What is the mass percent of copper in this oxide?

    (A) 11.2% (B) 66.6% (C) 79.9% (D) 88.8%

11. A 49.9 g sample of barium hydroxide octahydrate, $Ba(OH)_2\cdot8H_2O$, is dissolved in water and the solution is diluted to give a final volume of 2.50 L. What is the concentration of the hydroxide ion in this solution?

Molar Mass / $g\cdot mol^{-1}$	
$Ba(OH)_2\cdot8H_2O$	315

    (A) 0.0634 M (B) 0.127 M
    (C) 0.190 M (D) 0.634 M

12. What volume (in mL) of 0.0500 M phosphoric acid is needed to titrate completely 25.0 mL of 0.150 M barium hydroxide solution to a phenolphthalein end point?

$$3Ba(OH)_2 + 2H_3PO_4 \rightarrow Ba_3(PO_4)_2 + 6H_2O$$

    (A) 50.0 (B) 75.0 (C) 100. (D) 150.

13. A sample of gas at 273 K has a pressure of P_1 and a volume of V_1. When the pressure is changed to P_2, what is the volume V_2? (Assume the temperature remains constant.)

    (A) $\frac{P_1P_2}{V_1}$ (B) $\frac{P_1V_1}{P_2}$
    (C) $\frac{P_2V_1}{P_1}$ (D) $\frac{P_2}{P_1V_1}$

14. How do the number of molecules, n, in 1.0 L of each of the following gases; CH_4, N_2, CO_2, compare at 1 atm and 25 °C?

(A) $n_{CH_4} < n_{CO_2} < n_{N_2}$ (B) $n_{N_2} < n_{CO_2} < n_{CH_4}$

(C) $n_{CO_2} < n_{CH_4} < n_{N_2}$ (D) $n_{CH_4} = n_{CO_2} = n_{N_2}$

15. Solid sodium acetate, $NaC_2H_3O_2$, is what type of solid?

(A) ionic (B) metallic

(C) molecular (D) network covalent

16. Which substance has the highest vapor pressure at 25°C?

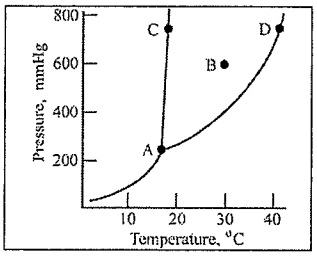
(A) methanol, CH_3OH

(B) ethanol, CH_3CH_2OH

(C) 1-propanol, $CH_3CH_2CH_2OH$

(D) 1-butanol, $CH_3CH_2CH_2CH_2OH$

17. Which point on the phase diagram represents the normal boiling point?



(A) point A (B) point B

(C) point C (D) point D

18. What types of intermolecular forces are exerted by CH_3Cl molecules in the liquid phase?

I.	dipole-dipole forces
II.	hydrogen bonding
III.	London dispersion forces

(A) I only (B) II only

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

19. A 22.0 g piece of metal is heated to 100.0°C and placed in 75.0 g H_2O at 25.0°C. If the final temperature of the metal and water is 27.8°C, what is the specific heat capacity of the metal in $J \cdot g^{-1} \cdot {}^\circ C^{-1}$? (Assume no heat is lost/gained by the surroundings.)

	C_p / $J \cdot g^{-1} \cdot {}^\circ C^{-1}$
H_2O	4.18

(A) 0.038 (B) 0.16 (C) 0.55 (D) 5.0

20. Which change(s) is(are) accompanied by an increase in entropy of the system?

I.	conversion of $O_2(g)$ to $O_3(g)$
II.	freezing of water
III.	sublimation of iodine

(A) I only (B) III only

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

21. $NO(g) \rightarrow \frac{1}{2}N_2(g) + \frac{1}{2}O_2(g)$ ΔH_1°

$2NO(g) \rightarrow N_2O(g) + \frac{1}{2}O_2(g)$ ΔH_2°

Which relationship is correct?

(A) $\Delta H_1^\circ = \Delta H_2^\circ$

(B) ΔH_f° for $NO(g) = \Delta H_1^\circ$

(C) ΔH_f° for $N_2O(g) = \Delta H_2^\circ$

(D) ΔH_f° for $N_2O(g) = \Delta H_2^\circ - 2\Delta H_1^\circ$

22. When 2.74 g of Ba(s) reacts with $O_2(g)$ at 298 K and 1 atm to form BaO(s), 11,100 J of heat is released. What is ΔH_f° for BaO(s) in $kJ \cdot mol^{-1}$?

(A) 556 (B) 221 (C) –221 (D) –556

23. A reaction has $\Delta H^\circ > 0$ and $\Delta G^\circ > 0$ at 25°C. This reaction

(A) is at equilibrium at 25°C.

(B) could not be spontaneous under standard conditions at any temperature.

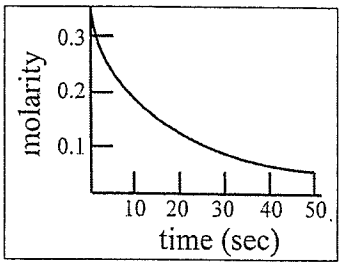
(C) could be spontaneous under standard conditions at temperatures above 25°C.

(D) could be spontaneous under standard conditions at temperatures below 25°C.

24. An ionic compound has a solubility of 1 $mol \cdot L^{-1}$ in water at 25 °C and its solubility increases as the temperature is raised. What are the signs of ΔH° and ΔS° for the dissolving process?

	ΔH°	ΔS°
(A)	+	+
(B)	+	–
(C)	–	+
(D)	–	–

25. For the reaction represented by the accompanying diagram, which reaction rate is the greatest?



(A) average rate (B) final rate

(C) initial rate (D) rate at 20 seconds

26. Which units are appropriate for a reaction rate?

(A) $mol \cdot L^{-1} \cdot s^{-1}$ (B) $mol \cdot L^{-1}$

(C) $mol \cdot L \cdot s^{-1}$ (D) $L \cdot mol^{-1} \cdot s^{-1}$

27. What is the rate equation for a reaction, A + B → products, based on the rate data?

$[A]_0$, mol·L^{-1}	$[B]_0$, mol·L^{-1}	Rate
0.15	0.10	x
0.30	0.20	4x
0.30	0.40	16x

(A) Rate = $k[A]^2$ (B) Rate = $k[B]^2$

(C) Rate = $k[A][B]$ (D) Rate = $k[A][B]^2$

28. The effect of temperature on the rates of chemical reactions is primarily a result of the

(A) size of the colliding molecules.

(B) orientation of the colliding molecules.

(C) enthalpies of the reactants and products.

(D) kinetic energies of the colliding molecules.

29. The value of the rate constant for a gas phase reaction can be changed by increasing the

(A) amount of product.

(B) pressure of the reactant.

(C) temperature of the reaction vessel.

(D) volume of the reaction vessel.

30. What is the half life of the irreversible first order reaction, A → B, if 75% of A is converted to B in 60 minutes?

(A) 30 minutes (B) 45 minutes

(C) 60 minutes (D) 80 minutes

31. What is the K_{eq} expression for the reaction, $C(s) + CO_2(g) \rightleftharpoons 2CO(g)$?

(A) $K_{eq} = \frac{2[CO]}{[CO_2]}$ (B) $K_{eq} = \frac{2[C][CO]}{[CO_2]}$

(C) $K_{eq} = \frac{[CO]^2}{[CO_2]}$ (D) $K_{eq} = \frac{[C][CO]^2}{[CO_2]}$

32. The equilibrium system $N_2O_4(g) \rightleftharpoons 2NO_2(g)$ has $K_p = 11$ and $\Delta H^\circ = 57$ kJ·mol^{-1} at 25 °C. Which action will **not** cause a change in the position of the equilibrium?

(A) increasing the temperature

(B) adding $NO_2(g)$

(C) adding xenon gas to increase the pressure

(D) increasing the container volume

33. Which is not a conjugate acid/base pair?

(A) H_2CO_3 & CO_3^{2-} (B) HSO_4^- & SO_4^{2-}

(C) $H_2PO_4^-$ & HPO_4^{2-} (D) H_3O^+ & H_2O

34. What is the $[OH^-]$ in an aqueous solution which has a pH = 11.70?

(A) 7.1×10^{-2} M (B) 5.0×10^{-3} M

(C) 1.4×10^{-6} M (D) 2.0×10^{-12} M

35. Equal volumes of 0.25 M HNO_2 and 0.25 M HNO_3 are titrated separately with 0.25 M KOH. Which would be the same for both titrations?

(A) initial pH

(B) pH halfway to the equivalence point

(C) pH at the equivalence point

(D) pH when 5 mL excess KOH has been added

36. For which salt is the molar solubility, s, equal to 4×10^{-6} M?

(A) $AgC_2H_3O_2$ $K_{sp} = 2\times10^{-3}$

(B) TlBr $K_{sp} = 4\times10^{-6}$

(C) $MnCO_3$ $K_{sp} = 2\times10^{-11}$

(D) $Zn(OH)_2$ $K_{sp} = 3\times10^{-17}$

37. Which substance can act only as a reducing agent?

(A) I_2 (B) BrCl (C) NaBr (D) HIO_4

38. When the equation
$Sn^{2+}(aq) + IO_3^-(aq) + H^+(aq) \rightarrow Sn^{4+}(aq) + I_2(aq) + H_2O(l)$
is balanced, what is the $Sn^{2+}(aq)$ / IO_3^- (aq) mole ratio?

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

39. Given the standard reduction potentials, which statement is correct?

$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	$E^\circ = 0.34$ V
$2H^+(aq) + 2e^- \rightarrow H_2(g)$	$E^\circ = 0.00$ V
$Cr^{3+}(aq) + 3e^- \rightarrow Cr(s)$	$E^\circ = -0.73$ V

(A) Cr(s) will react with acid.

(B) Cu(s) will react with acid.

(C) $Cu^{2+}(aq)$ will react with acid.

(D) Cu(s) will react with $Cr^{3+}(aq)$.

40. Use the standard reduction potentials given to calculate the standard potential for the reaction;

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

$Ag^+(aq) + e^- \rightarrow Ag(s)$	$E^\circ = 0.80$ V
$Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$	$E^\circ = -0.13$ V

(A) 1.73 V (B) 0.93 V (C) 0.67V (D) 0.54 V

41. For the voltaic cell represented,

$Ni(s)|Ni^{2+}(aq)||Ag^+(aq)|Ag(s)$

which change will increase the cell potential?

(A) increasing the $[Ag^+]$ (B) increasing the $[Ni^{2+}]$

(C) adding Ni(s) (D) removing Ag(s)

42. The deposition of 1.0 g of which element from its molten chloride requires the shortest time at a current of 1 A?

(A) Na (B) Mg (C) Al (D) Ba

43. Which properties of electromagnetic radiation are inversely related?

(A) amplitude and frequency

(B) energy and wavelength

(C) energy and frequency

(D) wavelength and amplitude

44. Which electronic transition in a hydrogen atom releases the greatest amount of energy?

(A) $n = 3 \rightarrow n = 2$ (B) $n = 5 \rightarrow n = 3$

(C) $n = 6 \rightarrow n = 5$ (D) $n = 3 \rightarrow n = 6$

45. Which must represent an atom in an excited state?

(A) $1s^22s^22p^1$ (B) $1s^22s^22p^2$

(C) $1s^22s^22p^23s^1$ (D) $1s^22s^22p^5$

46. Which quantum numbers represent the orbitals being filled in the ground state for the elements Sc (21) to Zn (30)?

(A) $n = 3, l = 1$ (B) $n = 3, l = 2$

(C) $n = 4, l = 1$ (D) $n = 4, l = 2$

47. Which pair consists of species that are isoelectronic?

(A) Na^+, K^+ (B) Cl, Cl^-

(C) Fe^{2+}, Mn^{2+} (D) Ar, Ca^{2+}

48. In which series are the species listed in order of increasing size?

(A) N, O, F (B) Na, Mg, K

(C) Cr, Cr^{2+}, Cr^{3+} (D) Cl, Cl^-, S^{2-}

49. In which molecule does the chlorine have the most positive partial charge?

(A) HCl (B) BrCl (C) OCl_2 (D) SCl_2

50. Which molecule contains the shortest carbon-carbon bonds?

(A) C_2H_2 (B) C_2H_4 (C) C_3H_8 (D) C_6H_{12}

51. How many valence electrons are in one ion of thiosulfate, $S_2O_3^{2-}$?

(A) 26 (B) 28 (C) 30 (D) 32

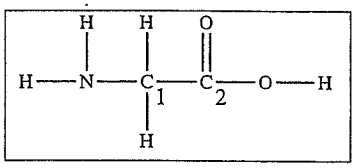
52. Which substance has the highest melting point?

(A) CO (B) CO_2 (C) SiO_2 (D) P_2O_5

53. Which species has exactly five pairs of electrons around the central atom?

(A) ClF_5 (B) SF_4 (C) SF_5^- (D) XeF_4

54. What are the hybridizations of the carbon atoms labeled C_1 and C_2, respectively, in glycine?



	C_1	C_2
(A)	sp^2	sp^2
(B)	sp^2	sp^3
(C)	sp^3	sp^2
(D)	sp^3	sp^3

55. The formula, H_3CCOCH_3, represents a(n)

(A) aldehyde. (B) ester.

(C) ether. (D) ketone.

56. Which suffix is used to designate a carbohydrate?

(A) –ase (B) –ate (C) –one (D) –ose

57. Which compound has the largest molar mass?

(A) hexane (B) 1-hexene

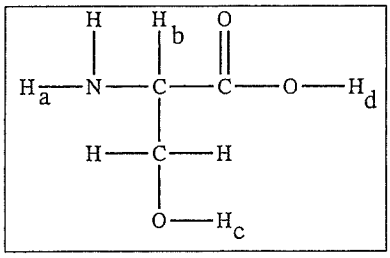
(C) 1-hexyne (D) benzene

58. Which functional group is not commonly found in proteins?

(A) alcohol (B) aldehyde

(C) amide (D) amine

59. Which hydrogen is the most acidic in the molecule shown?



(A) H_a (B) H_b (C) H_c (D) H_d

60. The gentle oxidation of ethanol, CH_3CH_2OH, produces

(A) ethanal, CH_3CHO.

(B) ethanoic acid, CH_3CO_2H.

(C) carbon monoxide, CO.

(D) carbon dioxide, CO_2.

END OF TEST

Olympiad 2009 Local Section

KEY

Number	Answer
1.	B
2.	D
3.	C
4.	A
5.	B
6.	A
7.	B
8.	C
9.	C
10.	D
11.	B
12.	A
13.	B
14.	D
15.	A
16.	A
17.	D
18.	C
19.	C
20.	B
21.	D
22.	D
23.	C
24.	A
25.	C
26.	A
27.	B
28.	D
29.	C
30.	A

Number	Answer
31.	C
32.	C
33.	A
34.	B
35.	D
36.	C
37.	C
38.	D
39.	A
40.	B
41.	A
42.	D
43.	B
44.	A
45.	C
46.	B
47.	D
48.	D
49.	C
50.	A
51.	D
52.	C
53.	B
54.	C
55.	D
56.	D
57.	A
58.	B
59.	D
60.	A

2012 U.S. NATIONAL CHEMISTRY OLYMPIAD

LOCAL SECTION EXAM

Prepared by the American Chemical Society Chemistry 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.

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ABBREVIATIONS AND SYMBOLS

amount of substance	n	Faraday constant	F	molar mass	M
ampere	A	free energy	G	mole	mol
atmosphere	atm	frequency	ν	Planck's constant	h
atomic mass unit	u	gas constant	R	pressure	P
Avogadro constant	N_A	gram	g	rate constant	k
Celsius temperature	°C	hour	h	reaction quotient	Q
centi– prefix	c	joule	J	second	s
coulomb	C	kelvin	K	speed of light	c
density	d	kilo– prefix	k	temperature, K	T
electromotive force	E	liter	L	time	t
energy of activation	E_a	measure of pressure mm Hg		vapor pressure	VP
enthalpy	H	milli– prefix	m	volt	V
entropy	S	molal	m	volume	V
equilibrium constant	K	molar	M		

CONSTANTS

$R = 8.314\ \text{J•mol}^{-1}\text{•K}^{-1}$

$R = 0.0821\ \text{L•atm•mol}^{-1}\text{•K}^{-1}$

$1\ F = 96{,}500\ \text{C•mol}^{-1}$

$1\ F = 96{,}500\ \text{J•V}^{-1}\text{•mol}^{-1}$

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

$h = 6.626 \times 10^{-34}\ \text{J•s}$

$c = 2.998 \times 10^{8}\ \text{m•s}^{-1}$

0 °C = 273.15 K

1 atm = 760 mm Hg

EQUATIONS

$$E = E^\circ - \frac{RT}{nF}\ln Q$$

$$\ln K = \left(\frac{-\Delta H}{R}\right)\left(\frac{1}{T}\right) + \text{constant}$$

$$\ln\left(\frac{k_2}{k_1}\right) = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

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 **Ds** (281)	111 **Rg** (272)	112 **Cn** (285)	113 (Uut) (284)	114 (Uuq) (289)	115 (Uup) (288)	116 (Uuh) (293)	117 (Uus) (294)	118 (Uuo) (294)

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)

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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. How many atoms are in 4.0×10^{-5} grams of Al?

(A) 8.9×10^{17} **(B)** 2.4×10^{19}
(C) 6.5×10^{20} **(D)** 2.0×10^{22}

2. How many moles of sulfate ions are in 100 mL of a solution of 0.0020 M $Fe_2(SO_4)_3$?

(A) 2.0×10^{-4} **(B)** 6.0×10^{-4}
(C) 2.0×10^{-1} **(D)** 6.0×10^{-1}

3. The value of which concentration unit for a solution changes with temperature?

(A) molarity **(B)** molality
(C) mole fraction **(D)** mass percentage

4. How many moles of water are produced by the complete combustion of 14.4 g of C_5H_{12}?

$$C_5H_{12} + 8O_2 \rightarrow 5CO_2 + 6H_2O$$

(A) 0.200 **(B)** 0.600 **(C)** 1.20 **(D)** 2.40

5. A solution of $Ba(OH)_2$ is standardized with potassium acid phthalate (abbreviated KHP), $KHC_8H_8O_4$ ($M = 204$). If 1.530 g of KHP is titrated with 34.50 mL of the $Ba(OH)_2$ solution, what is the molarity of $Ba(OH)_2$?

(A) 0.0217 M **(B)** 0.0435 M
(C) 0.109 M **(D)** 0.217 M

6. 30.0 mL of 0.10 M $Ca(NO_3)_2$ and 15.0 mL of 0.20 M Na_3PO_4 solutions are mixed. After the reaction is complete, which of these ions has the lowest concentration in the final solution?

(A) Na^+ **(B)** NO_3^- **(C)** Ca^{2+} **(D)** PO_4^{3-}

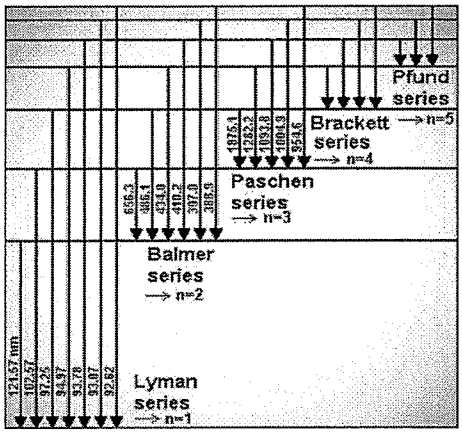
7. A dilute solution of which acid is most likely to produce a reduction product other than H_2 when it reacts with a metal?

(A) HF **(B)** HCl **(C)** HNO_3 **(D)** H_2SO_4

8. Which two substances react spontaneously?

(A) Ag and Cu **(B)** Ag^+ and Cu
(C) Ag and Cu^{2+} **(D)** Ag^+ and Cu^{2+}

9. Which spectral series for hydrogen contains lines in the visible region of the spectrum?



(A) Lyman series **(B)** Balmer series
(C) Paschen series **(D)** Brackett series

10. Which piece of laboratory apparatus is not used for the purpose listed?

	Apparatus	Purpose
(A)	aspirator	measure height
(B)	buret	measure volume
(C)	calorimeter	measure thermal energy change
(D)	desiccator	store samples in dry conditions

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

11. Which transformation demonstrates that the bonds between water molecules are weaker than the bonds within a water molecule?

(A) freezing water **(B)** electrolysis of water
(C) boiling water **(D)** reaction of water with Na(s)

12. The molar mass of an unknown organic liquid ($M \sim 100$) is determined by placing 5 mL of the liquid in a weighed 125-mL conical flask fitted with a piece of Al foil with a pin hole in it. The flask is heated in a boiling water bath until the liquid evaporates to expel the air and fill the flask with the unknown vapor at atmospheric pressure. After cooling to room temperature the flask and its contents are reweighed. The uncertainty in which piece of apparatus causes the largest percentage error in the molar mass?

(A) balance ($\pm$0.01 g) **(B)** barometer ($\pm$0.2 mm Hg)
(C) flask ($\pm$1.0 mL) **(D)** thermometer ($\pm$0.2 °C)

13. At the molecular level, the factor that determines whether a substance will be a solid, liquid, or gas is the balance between the

(A) kinetic energies of the molecules and their intermolecular forces.

(B) potential energies of the molecules and their intermolecular forces.

(C) kinetic energies of the molecules and their intramolecular forces.

(D) potential energies of the molecules and their intramolecular forces.

14. A gas sample in a flexible container is maintained at constant pressure while its temperature is increased from 25 °C to 75 °C. If the initial volume of the gas is 4.2 L, what is the change in volume due to the temperature increase?

(A) 0.7 L (B) 4.9 L (C) 8.4 L (D) 12.6 L

15. The critical temperature of carbon dioxide is 304.3 K. Which statement is true about the behavior of carbon dioxide above this temperature?

(A) Solid, liquid and gaseous carbon dioxide are in equilibrium above this temperature.

(B) Liquid and gaseous carbon dioxide are in equilibrium above this temperature.

(C) Liquid carbon dioxide does not exist above this temperature.

(D) Carbon dioxide molecules do not exist above this temperature.

16. Which substance is matched incorrectly with the type of solid it forms?

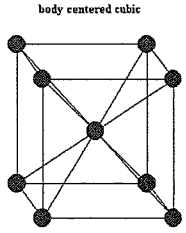
(A) ammonium sulfate-ionic solid

(B) lead-metallic solid

(C) potassium chloride-ionic solid

(D) silicon dioxide-molecular solid

17. Metallic sodium has a body-centered cubic unit cell. How many atoms are contained in one unit cell?



(A) 1 (B) 2 (C) 5 (D) 9

18. Which substance has the lowest boiling point?

(A) H_2O (B) H_2S (C) H_2Se (D) H_2Te

19. The combustion of 1.00 mole of methane, CH_4, produces carbon dioxide and water and releases 802 $kJ \cdot mol^{-1}$. When 3.00 mol of oxygen react with a stoichiometric quantity of methane, what is ΔH for the reaction?

(A) -1.20×10^3 kJ (B) -8.02×10^2 kJ

(C) 8.02×10^2 kJ (D) 1.20×10^3 kJ

20. What is the final temperature when 20.0 g of water (specific heat capacity 4.184 $J \cdot g^{-1} \cdot K^{-1}$) at 80.0 °C is mixed with 30.0 g of water at 20.0 °C in an insulated container?

(A) 32 °C (B) 44 °C (C) 50 °C (D) 56 °C

21. $PCl_5(s)$ reacts with $H_2O(l)$ according to the equation:

$$PCl_5(s) + 4H_2O(l) \rightarrow H_3PO_4(aq) + 5HCl(aq)$$

What is $\Delta H°$ for this reaction in $kJ \cdot mol^{-1}$?

Substance	$PCl_5(s)$	$H_2O(l)$	$H_3PO_4(aq)$	$HCl(aq)$
$\Delta H_f°$, kJ/mol	–443.5	–285.8	–1284.4	–167.1

(A) –722.2 (B) –533.2 (C) 533.2 (D) 722.2

22. Which is a statement of the Second Law of Thermodynamics?

(A) The energy of the universe is conserved.

(B) The energy of the universe is decreasing.

(C) The entropy of the universe is conserved.

(D) The entropy of the universe is increasing.

23. For which signs of ΔH and ΔS will a reaction always be spontaneous?

(A) $\Delta H +, \Delta S +$ (B) $\Delta H +, \Delta S -$

(C) $\Delta H -, \Delta S -$ (D) $\Delta H -, \Delta S +$

24. What is correct about the signs and magnitudes of the free energy, $\Delta G°$, and the equilibrium constant, K, for a thermodynamically spontaneous reaction under standard conditions?

(A) $\Delta G° < 0, K < 0$ (B) $\Delta G° = 0, K > 0$

(C) $\Delta G° < 0, K = 0$ (D) $\Delta G° < 0, K > 0$

25. The rate of a stoichiometric reaction between a solid and a gas in a container may be increased by increasing all of the following factors EXCEPT the

(A) pressure of the gas.

(B) temperature of the gas.

(C) volume of the container.

(D) surface area of the solid.

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26. The gas phase decomposition of dinitrogen pentoxide is represented by this equation.

$$2N_2O_5(g) \rightarrow 4NO_2(g) + O_2(g)$$

What is the rate of formation of oxygen gas (in $mol \cdot L^{-1} \cdot s^{-1}$) in an experiment where 0.080 mol of N_2O_5 is consumed in a 4.0 L container every 0.20 seconds?

(A) 0.020 **(B)** 0.050 **(C)** 0.10 **(D)** 0.20

27. Which accounts for the increase in the rate of a reaction when a catalyst is added to a chemical system?

(A) a decrease in the enthalpy change between the reactants and products

(B) an increase in the potential energy of the reactants

(C) a decrease in the potential energy of the activated complex

(D) a decrease in the entropy of the activated complex

28. For this first-order isomerization reaction,

$$CH_3NC \rightarrow CH_3CN,$$

how do the properties of the reaction in the table below vary as the reaction proceeds?

	Rate of reaction $-\frac{\Delta[CH_3NC]}{\Delta t}$, ($M \cdot s^{-1}$)	Half-life, (s)
(A)	remains the same	decreases
(B)	decreases	remains the same
(C)	remains the same	remains the same
(D)	decreases	decreases

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

29. The rate of a reaction between A and B follows the rate law Rate = $k[A]^2[B]$.

Determine the rate of Experiment Two in the table below at the same temperature as Experiment One.

Experiment	[A], M	[B], M	Observed Rate, $mol \cdot L^{-1} \cdot s^{-1}$
1	0.10	0.10	R
2	0.30	0.20	?

(A) 3R **(B)** 6R **(C)** 12R **(D)** 18R

30. One proposed mechanism for the hydrolysis of an ester is shown below.

$$RCOOR' + H_3O^+ \rightarrow RCOHOR'^+ + H_2O$$
$$RCOHOR'^+ + H_2O \rightarrow RC(OH)OR'(OH_2)^+$$
$$RC(OH)OR'(OH_2)^+ + H_2O \rightarrow RCOOH + R'OH + H_3O^+$$

Which species is considered an intermediate?

(A) $RCOHOR'^+$ **(B)** H_3O^+

(C) $RCOOR'$ **(D)** $R'OH$

31. Which statement(s) characterize(s) a chemical system at equilibrium?

I The rate of the forward reaction is equal to the rate of the reverse reaction.

II The concentrations of the reactants and products are equal.

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

(C) Both I and II **(D)** Neither I nor II

32. What is the solubility in pure water of $Ba(IO_3)_2$ in moles per liter at 25 °C? [K_{sp} (25 °C) = 6.0×10^{-10}]

(A) 1.2×10^{-5} **(B)** 1.7×10^{-5}

(C) 5.3×10^{-4} **(D)** 8.4×10^{-4}

33. $$C(s) + H_2O(g) \rightleftharpoons CO(g) + H_2(g) \quad \Delta H > 0$$

For the system above at equilibrium, which changes will increase the amount of $H_2(g)$?

I Adding C(s)

II Increasing the volume of the container

III Increasing the temperature

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

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

34. Determine the volume of 0.125 M NaOH required to titrate to the equivalence point 25.0 mL of a 0.175 M solution of a monoprotic weak acid that is 20% ionized.

(A) 7.00 mL **(B)** 17.9 mL

(C) 28.0 mL **(D)** 35.0 mL

35. A 75 mL solution that is 0.10 M in $HC_2H_3O_2$ and 0.10 M in $NaC_2H_3O_2$ has a pH of 4.74. Which of the following actions will change the pH of this solution?

I Adding 15 mL of 0.10 M HCl

II Adding 0.010 mol of $NaC_2H_3O_2$

III Diluting the solution from 75 mL to 125 mL

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

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

36. Which acid-base indicator will give the best results for the titration of an aqueous ammonia solution with 0.10 M HCl?

Indicator	Color change	pH range
Methyl violet	red → blue	0 → 2
Methyl red	red → yellow	4 → 6
Cresol red	yellow → purple	7 → 9
Phenolphthalein	colorless → pink	8 → 10

(A) Methyl violet **(B)** Methyl red

(C) Cresol red **(D)** Phenolphthalein

37. Which species has an atom with an oxidation number of +3?

(A) ClO_2^- **(B)** PO_4^{3-} **(C)** $S_2O_3^{2-}$ **(D)** NO_2^+

38. According to the reduction potentials in the table below, which statement is true at standard conditions?

Reaction	E°, V
$L^{2+} + 2e^- \rightarrow L$	–0.13
$M^{2+} + 2e^- \rightarrow M$	–0.44
$N^{2+} + 2e^- \rightarrow N$	–0.76

(A) L^{2+} ions oxidize M metal.

(B) M metal reduces N^{2+} ions.

(C) M is a better reducing agent than N.

(D) M^{2+} ions are better oxidizing agents than L^{2+} ions.

39. How many H^+ ions are required when the equation below is balanced with the smallest whole number coefficients?

$Cu(s) + NO_3^-(aq) + H^+(aq) \rightarrow Cu^{2+}(aq) + NO(g) + H_2O(l)$

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

40.

$$Ag^+ + e^- \rightarrow Ag \qquad E° = 0.80\ V$$
$$Co^{2+} + 2e^- \rightarrow Co \qquad E° = -0.28\ V$$

What is the E° value for the voltaic cell using the half-reactions above at standard conditions?

(A) 0.52 V **(B)** 1.08 V **(C)** 1.32 V **(D)** 1.88 V

41.

$$Sn(s) \mid Sn^{2+}(aq) \parallel Cu^{2+}(aq) \mid Cu(s)$$

For the voltaic cell represented above, which change will increase the voltage?

(A) increasing the size of the Sn electrode

(B) increasing the size of the Cu electrode

(C) increasing the $[Sn^{2+}]$

(D) increasing the $[Cu^{2+}]$

42. For how many seconds must a current of 5.00 A flow in order to deposit 1.30 g of nickel from a solution of nickel(II) nitrate? (Coulombs = Amperes × seconds)

(A) 2.14×10^2 **(B)** 4.28×10^2

(C) 8.55×10^2 **(D)** 4.28×10^3

43. The isotope ^{14}C undergoes radioactive decay slowly. Which mode of decay is most likely?

(A) alpha emission **(B)** beta emission

(C) positron emission **(D)** electron capture

44. The quantum numbers, $n = 4$, $l = 1$, $m_l = 0$ could represent a valence electron in which atom in its ground state?

(A) Fe **(B)** In **(C)** Pd **(D)** Se

45. A gas phase atom with the electron configuration

$$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^6$$

loses three electrons. What is the electron configuration of the resulting gas phase ion?

(A) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5$

(B) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1\ 3d^4$

(C) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^3$

(D) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5\ 4s^1\ 3d^5$

46. Which existing element would the chemistry of element 119 most resemble?

(A) Rn (Z = 86) **(B)** Fr (Z= 87)

(C) Ra (Z = 88) **(D)** Ac (Z = 89)

47. Which atom has the largest atomic radius?

(A) S **(B)** Cl **(C)** Se **(D)** Br

48. Of the elements listed, which has the highest first ionization energy?

(A) Li **(B)** Be **(C)** Na **(D)** Mg

49. Which species contains only covalent bonds?

(A) AlF_3 **(B)** NH_4NO_3

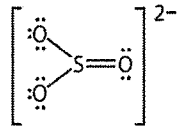
(C) H_2SO_4 **(D)** $K_2Cr_2O_7$

50. In which species can we describe the central atom as having sp^2 hybridization?

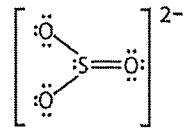
(A) BeF_2 **(B)** CO_2 **(C)** KrF_2 **(D)** SO_2

51. Which Lewis dot structure is a valid representation for the sulfite ion, $[SO_3^{2-}]$?

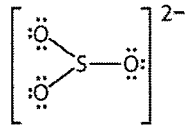
(A)



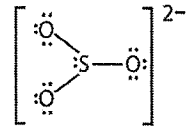
(B)



(C)



(D)



52. In which species does sulfur have the lowest oxidation state?

(A) SCl_2 (B) OSF_2 (C) H_2SO_3 (D) SF_6

53. A triple bond is found in which of the following species?

I CO II C_2H_2 III CN^-

(A) I only (B) II only

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

54. Which of the following compounds has a non-zero dipole moment?

(A) CO_2 (B) AsH_3 (C) CCl_4 (D) PF_5

55. Which molecule contains the fewest hydrogen atoms?

(A) cyclopropane (B) propane

(C) propene (D) propyne

56. What is the difference between 2-chloropentane and 3-chloropentane?

(A) the number of carbon atoms in the molecule

(B) the number of chlorine atoms in the molecule

(C) the position of the chlorine atom in the molecule

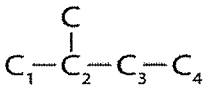
(D) the geometry of the carbon chain

57. Alanine is a(n)

(A) amino acid. (B) ester.

(C) nucleic acid. (D) sugar.

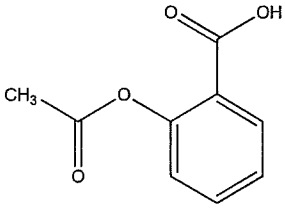
58. A secondary alcohol results from the attachment of a hydroxyl group to which carbon atom?



(A) C_1 (B) C_2 (C) C_3 (D) C_4

59. Aspirin has the structural formula below. Which functional groups does this molecule contain?

I acid II alcohol III ester IV ether



(A) I and III (B) II and III

(C) II and IV (D) I, II, III and IV

60. Which substance yields the most energy per gram of sample upon metabolism?

(A) carbohydrate (B) fat

(C) protein (D) vitamin

END OF TEST

Olympiad 2012
USNCO Local Exam
KEY

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

2013 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.

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ABBREVIATIONS AND SYMBOLS					
amount of substance	n	Faraday constant	F	molar mass	M
ampere	A	free energy	G	mole	mol
atmosphere	atm	frequency	ν	Planck's constant	h
atomic mass unit	u	gas constant	R	pressure	P
Avogadro constant	N_A	gram	g	rate constant	k
Celsius temperature	°C	hour	h	reaction quotient	Q
centi– prefix	c	joule	J	second	s
coulomb	C	kelvin	K	speed of light	c
density	d	kilo– prefix	k	temperature, K	T
electromotive force	E	liter	L	time	t
energy of activation	E_a	measure of pressure mm Hg		vapor pressure	VP
enthalpy	H	milli– prefix	m	volt	V
entropy	S	molal	m	volume	V
equilibrium constant	K	molar	M		

CONSTANTS
$R = 8.314\ \text{J•mol}^{-1}\text{•K}^{-1}$
$R = 0.0821\ \text{L•atm•mol}^{-1}\text{•K}^{-1}$
$1\ F = 96{,}500\ \text{C•mol}^{-1}$
$1\ F = 96{,}500\ \text{J•V}^{-1}\text{•mol}^{-1}$
$N_A = 6.022 \times 10^{23}\ \text{mol}^{-1}$
$h = 6.626 \times 10^{-34}\ \text{J•s}$
$c = 2.998 \times 10^{8}\ \text{m•s}^{-1}$
0 °C = 273.15 K
1 atm = 760 mm Hg

EQUATIONS

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

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 **Ds** (281)	111 **Rg** (272)	112 **Cn** (285)	113 (Uut) (284)	114 (Uuq) (289)	115 (Uup) (288)	116 (Uuh) (293)	117 (Uus) (294)	118 (Uuo) (294)

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)

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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. When this equation is balanced using the smallest possible integers, what is the sum of the coefficients?

$$__(NH_4)_3PO_4(aq) + __CaCl_2(aq) \rightarrow __Ca_3(PO_4)_2(s) + __NH_4Cl(aq)$$

(A) 8 **(B)** 9 **(C)** 11 **(D)** 12

2. A solution of KNO_3 in water is prepared for which the following data have been obtained:
masses of solute and solvent
molar masses of solute and solvent
Which of these quantitative descriptions of the solution can be determined?
I. molarity II. molality III. density of solution

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

3. What mass of the compound CrO_3 ($M = 100.0$) contains 4.5×10^{23} oxygen atoms?

(A) 2.25 g **(B)** 12.0 g **(C)** 25.0 g **(D)** 75.0 g

4. An 18.5 g sample of tin ($M = 118.7$) combines with 10.0 g of sulfur ($M = 32.07$) to form a compound. What is the empirical formula of this compound?

(A) SnS **(B)** SnS_2 **(C)** Sn_2S **(D)** Sn_2S_3

5. A mixture is prepared by adding 50.0 mL of 0.200 M NaOH to 75.0 mL of 0.100 M NaOH. What is the $[OH^-]$ in the mixture?

(A) 0.0600 M **(B)** 0.0800 M
(C) 0.140 M **(D)** 0.233 M

6. What mass of $NaHCO_3$ ($M = 84.0$) is required to completely neutralize 25.0 mL of 0.125 M H_2SO_4?

(A) 0.131 g **(B)** 0.262 g
(C) 0.525 g **(D)** 1.05 g

7. A solid can be separated from a liquid by all the following means EXCEPT

(A) decantation **(B)** distillation
(C) filtration **(D)** hydration

8. A student determined the density of a solid to be 2.90, 2.91 and 2.93 $g \cdot cm^{-3}$. If the actual density of this solid is 2.70 $g \cdot cm^{-3}$, how should the student's results be described?

(A) high accuracy and high precision
(B) low accuracy and high precision
(C) high accuracy and low precision
(D) low accuracy and low precision

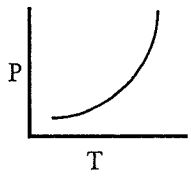
9. Which cation forms an insoluble chloride and an insoluble sulfide?

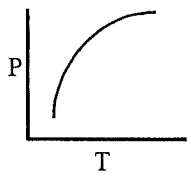
(A) Ba^{2+} **(B)** Cu^{2+} **(C)** Mn^{2+} **(D)** Pb^{2+}

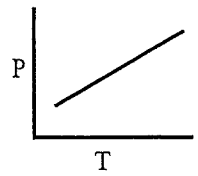
10. Which 0.10 M aqueous solution exhibits the lowest electrical conductivity?

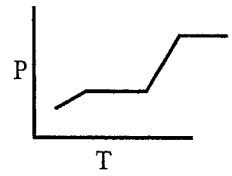
(A) $HC_2H_3O_2(aq)$ **(B)** $HNO_3(aq)$
(C) $NH_4C_2H_3O_2(aq)$ **(D)** $Ca(NO_3)_2(aq)$

11. Which graph best represents the vapor pressure of water as a function of temperature from 0 °C to 100 °C?

(A)


(B)


(C)


(D)


12. The table below shows the data for three titrations to determine the concentration of a NaOH solution with standard 0.200 M HCl solution using phenolphthalein as the indicator.

Trial	Vol HCl, mL	Vol NaOH, mL	M_{NaOH}, calc.
1	21.43	19.26	0.223
2	18.57	16.73	0.222
3	22.20	21.14	0.210

Which explanation best accounts for the lower value of the NaOH M in Trial 3?

(A) Some of the neutralized solution from Trial 2 was left in the flask for Trial 3.

(B) The number of drops of phenolphthalein was doubled in Trial 3.

(C) The HCl concentration was used as 0.250 M in the NaOH molarity calculation.

(D) A few drops of NaOH solution were spilled on the desktop in Trial 3.

13. A sample of an ideal gas has a volume of 0.500 L at 25 °C and 1.20 atm pressure. What is its volume at 75 °C and 3.60 atm?

(A) 0.143 L (B) 0.195 L

(C) 0.500 L (D) 1.75 L

14. In a mixture of N_2 and O_2 gases, the mol fraction of N_2 is found to be 0.700. The total pressure of the mixture is 1.42 atm. What is the partial pressure of O_2 in the mixture?

(A) 0.211 atm (B) 0.426 atm

(C) 0.493 atm (D) 0.994 atm

15. The substances below have molar masses that are the same within ± 2 g/mol. Which substance has the lowest boiling point?

(A) $CH_3CH_2CH_3$ (B) CH_3OCH_3

(C) CH_3CH_2OH (D) CH_3CHO

16. Which statement is correct about the critical point of a phase diagram?

(A) Solid, liquid and gas are present in equilibrium.

(B) Liquid and vapor are indistinguishable from one another.

(C) Liquid can be produced by a change in pressure.

(D) Vapor can be produced by a change in temperature.

17. When equal volumes of the following pairs of liquids are mixed thoroughly and allowed to stand, which pair is most likely to separate into two layers?

(A) ethanol and methanol

(B) carbon tetrachloride and methanol

(C) hexane and pentane

(D) carbon tetrachloride and hexane

18. For the same atoms at the lattice points, which lattice exhibits the lowest density?

(A) body-centered cubic (B) face-centered cubic

(C) hexagonal (D) simple cubic

19. A sample of NaOH(s) was added to water in a calorimeter. The temperature was monitored as the NaOH dissolved to give the data below. Determine the heat released during the solution process. (Assume the solution specific heat is 4.18 $J \cdot g^{-1} \cdot K^{-1}$)

Mass of water	100.00 g
Mass of NaOH(*s*)	10.00 g
Initial Temperature of water	24.0 °C
Final Temperature of solution	48.2 °C

(A) 1.01×10^3 Joules (B) 2.66×10^3 Joules

(C) 1.01×10^4 Joules (D) 1.11×10^4 Joules

20. For which of the reactions below is(are) the heat of reaction equal to the heat of formation?

I. $1/2\ N_2(g) + O_2(g) \rightarrow NO_2(g)$ $\Delta H > 0$

II. $SO_2(g) + 1/2\ O_2(g) \rightarrow SO_3(g)$ $\Delta H < 0$

(A) I. only (B) II. only

(C) Both I. and II. (D) Neither I. nor II.

21. $CH_4(g) + Cl_2(g) \rightarrow CH_2Cl_2(g) + 2\ HCl(g)$

Use the data in the table below to calculate the standard enthalpy, ΔH°, for the reaction above.

Substance	$CH_4(g)$	$CH_2Cl_2(g)$	$HCl(g)$
ΔH_f°, $kJ \cdot mol^{-1}$	–74.6	–95.4	–92.3

(A) $-205\ kJ \cdot mol^{-1}$ (B) $-113\ kJ \cdot mol^{-1}$

(C) $113\ kJ \cdot mol^{-1}$ (D) $205\ kJ \cdot mol^{-1}$

22. $C_2H_5OH(l) + 3\ O_2(g) \rightarrow 2\ CO_2(g) + 3\ H_2O(g)$

During an experiment 10.00 g of ethanol is completely burned in air to release $CO_2(g)$ and $H_2O(g)$ as shown in the equation above. During the combustion, 296.6 kJ of heat energy is released. What is the molar enthalpy of combustion, ΔH°_{comb}?

(A) $-2966\ kJ \cdot mol^{-1}$ (B) $-1366\ kJ \cdot mol^{-1}$

(C) $-64.36\ kJ \cdot mol^{-1}$ (D) $-29.66\ kJ \cdot mol^{-1}$

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23. Which reaction has the greatest positive change in entropy, ΔS?

(A) $2\ Mg(s) + O_2(g) \rightarrow 2\ MgO(s)$

(B) $2\ C_2H_2(g) + 5\ O_2(g) \rightarrow 4\ CO_2(g) + 2\ H_2O(l)$

(C) $2\ KClO_3(s) \rightarrow 2\ KCl(s) + 3\ O_2(g)$

(D) $2\ SO_2(g) + O_2(g) \rightarrow 2\ SO_3(g)$

24. Which statement is correct for the reaction represented below?

$2\ NOCl(g) \rightarrow 2\ NO(g) + Cl_2(g) \quad \Delta H^\circ_{rxn} > 0$

This reaction is

(A) spontaneous at all temperatures.

(B) spontaneous only at high temperatures.

(C) spontaneous only at low temperatures.

(D) not spontaneous at any temperature.

25. For the reaction:
$2\ A + 3\ B \rightarrow C$, [A] is found to decrease at a rate of $2.0\ M{\bullet}s^{-1}$. If the rate law is rate = k[A], how fast does [B] decrease under the same conditions?

(A) $0.66\ M{\bullet}s^{-1}$ (B) $1.3\ M{\bullet}s^{-1}$

(C) $2.0\ M{\bullet}s^{-1}$ (D) $3.0\ M{\bullet}s^{-1}$

26. What are the units for the rate constant of a second-order reaction?

(A) s^{-1} (B) $M^{-1}{\bullet}s^{-1}$ (C) $M^{-2}{\bullet}s^{-1}$ (D) $M^{2}{\bullet}s^{-1}$

27. A sample containing a radioactive isotope produces 2000 counts per minute in a Geiger counter. After 120 hours, the sample produces 250 counts per minute. What is the half-life of the isotope?

(A) 15 h (B) 30 h (C) 40 h (D) 60 h

28. In the rate-limiting approximation for a two-step reaction, the overall rate of the reaction is always equal to the rate of the _____ step in the reaction mechanism.

(A) first (B) second

(C) fastest (D) slowest

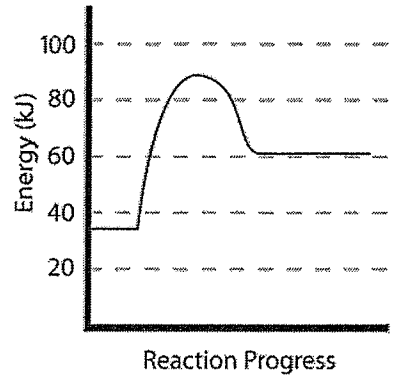
29. Which of the following examples demonstrate homogeneous catalysis?

I. Pt(s) catalyzing the reaction of $O_2(g)$ with CO(g)
II. Cl(g) catalyzing the decomposition of $O_3(g)$
III. $H_2O_2(aq)$ decomposition catalyzed by $Br^-(aq)$

(A) I. only (B) II. only

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

30.



The diagram above represents the energy profile for the reaction: $A + B \rightarrow C + D$. What is the value of the activation energy for the reaction: $C + D \rightarrow A + B$?

(A) 25 kJ (B) 55 kJ (C) 85 kJ (D) –30 kJ

31. What is the equilibrium expression for this reaction?

$2\ HgO(s) \rightleftharpoons 2\ Hg(l) + O_2(g)$

(A) $K = [Hg][O_2]/[HgO]$

(B) $K = [Hg]^2[O_2]/[HgO]^2$

(C) $K = [Hg]^2[O_2]$

(D) $K = [O_2]$

32. For the exothermic reaction

$4\ NH_3(g) + 7\ O_2(g) \rightleftharpoons 4\ NO_2(g) + 6\ H_2O(g)$

which change will increase the quantity of NO_2 in the mixture?

(A) increasing temperature

(B) decreasing container volume

(C) adding Ne(g)

(D) adding $H_2O(g)$

33. Weak acids include which of the following?

I. HF(aq) II. HI(aq) III. $HNO_2(aq)$

(A) I. only (B) II. only

(C) III. only (D) I. and III. only

34. $H_2CO_3(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + H_3O^+(aq)$
$HCO_3^-(aq) + H_2O(l) \rightleftharpoons CO_3^{2-}(aq) + H_3O^+(aq)$
According to the equations above, what is the conjugate base of HCO_3^-?

(A) $H_2CO_3(aq)$ (B) $H_2O(l)$

(C) $H_3O^+(aq)$ (D) $CO_3^{2-}(aq)$

35. A saturated solution of which salt will have the highest $[Ag^+]$?

(A) AgCl ($K_{sp} = 1.8 \times 10^{-10}$)

(B) Ag_2CrO_4 ($K_{sp} = 1.1 \times 10^{-12}$)

(C) Ag_3PO_4 ($K_{sp} = 1.8 \times 10^{-18}$)

(D) Ag_2S ($K_{sp} = 6.0 \times 10^{-51}$)

36. A saturated solution of manganese(II) carbonate ($M = 114.95$) contains 5.44×10^{-5} g of $MnCO_3$ per100 mL at 25 °C. What is its K_{sp} at this temperature?

(A) 4.7×10^{-6} (B) 3.0×10^{-9}

(C) 2.2×10^{-11} (D) 2.2×10^{-13}

37. Three metals, A, B and C, with solutions of their respective cations are tested in a voltaic cell with the following results;

A and B: A is the cathode
B and C: C is the cathode
A and C: A is the anode

What is the order of the reduction potentials from highest to lowest for the cations of these metals?

(A) A > B > C (B) B > C > A

(C) C > A > B (D) B > A > C

38. In which pair of substances do the nitrogen atoms have the same oxidation state?

(A) HNO_3 and N_2O_5 (B) NO and HNO_2

(C) N_2 and N_2O (D) HNO_2 and HNO_3

39. In the equation below, which species acts as the oxidizing agent? $Pb(s) + PbO_2(s) + 2\ H^+(aq) + 2\ HSO_4^-(aq) \rightarrow 2\ PbSO_4(s) + 2\ H_2O(l)$

(A) Pb(s) (B) $PbO_2(s)$

(C) $H^+(aq)$ (D) $HSO_4^-(aq)$

40. A standard voltaic cell is constructed using Cu metal in 1.0 M $Cu(NO_3)_2(aq)$ and an unknown metal in a 1.0 M solution of its nitrate salt. The cell voltage is 0.47 V when the Cu half-cell is the cathode. What is the standard reduction potential of the unknown metal? [$E°_{Cu} = 0.34$ V]

(A) –0.81 V (B) –0.13 V (C) 0.13 V (D) 0.81 V

41. A voltaic cell is constructed with the overall reaction:

$Sn^{2+}(aq) + 2\ Ag^+(aq) \rightleftharpoons Sn^{4+}(aq) + 2\ Ag(s)$.

Which change will increase the voltage of the cell?

(A) increasing $[Sn^{2+}]$ (B) increasing $[Sn^{4+}]$

(C) decreasing $[Ag^+]$ (D) reducing the size of the Ag electrode

42. Use the standard reduction potentials to determine what is observed at the cathode during the electrolysis of a 1.0 M solution of KBr that contains phenolphthalein. What observation(s) is(are) made?

$O_2(g) + 4\ H^+(aq) + 4\ e^- \rightarrow 2\ H_2O(l)$	E° = 1.23 V
$Br_2(l) + 2e^- \rightarrow 2\ Br^-(aq)$	E° = 1.07 V
$2\ H_2O(l) + 2\ e^- \rightarrow H_2(g) + 2\ OH^-$	E° = –0.80 V
$K^+(aq) + e^- \rightarrow K(s)$	E° = –2.92 V

(A) Solid metal forms.

(B) Bubbles form and a pink color appears.

(C) Dark red $Br_2(aq)$ forms.

(D) Bubbles form and the solution remains colorless.

43. To whom is the discovery of the nuclear atom attributed?

(A) Neils Bohr (B) Louis deBroglie

(C) Robert Millikan (D) Ernest Rutherford

44. Each of the following atomic orbitals is possible except

(A) 1*s*. (B) 2*p*. (C) 3*f*. (D) 4*d*.

45. The ion $^{55}Mn^{2+}$ contains which combination of protons, neutrons and electrons?

	protons	neutrons	electrons
A	25	30	23
B	25	55	23
C	27	30	25
D	30	25	28

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

46. What is the characteristic color of the flame test for potassium?

(A) yellow (B) red (C) green (D) violet

47. Which atom has the highest electronegativity?

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

48. In which set are both elements metalloids?

(A) Cr and Mo (B) Ge and As

(C) Sn and Pb (D) Se and Br

49. The silicon-oxygen bonds in SiO_2 are best described as

(A) coordinate covalent. (B) ionic.

(C) nonpolar covalent. (D) polar covalent.

50. Which bond is strongest?

(A) C=C (B) C=N (C) C=O (D) C=S

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51. What is the relationship between the two species shown below?

They are

(A) geometric isomers. (B) enantiomers.

(C) resonance forms. (D) structural isomers.

52. If A represents the central atom, in which molecule is the F-A-F angle the smallest?

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

53. On the basis of VSEPR theory, what geometry is predicted for the central sulfur atom in $SOCl_2$?

(A) bent (B) T-shaped

(C) trigonal planar (D) trigonal pyramidal

54. How many sigma (σ) and pi (π) bonds are in a molecule of ethyne (acetylene), HCCH?

(A) 1 σ and 1 π (B) 2 σ and 1 π

(C) 2 σ and 3 π (D) 3 σ and 2 π

55. What is the number of structural isomers with the molecular formula C_6H_{14}?

(A) three (B) four (C) five (D) six

56. All of the following are condensation polymers except

(A) nylon (B) polyethylene

(C) protein (D) starch

57. Methanol can be gently oxidized with hot copper metal. What is(are) the product(s) of this oxidation?

(A) acetic acid (B) carbon dioxide + water

(C) ethanol (D) methanal

58. Which statement does not describe benzene, C_6H_6?

(A) It is an aromatic hydrocarbon.

(B) It exists in two isomeric forms.

(C) It undergoes substitution reactions.

(D) It can react to form three different products with the formula $C_6H_4Cl_2$.

59. All of the following atoms comprise part of a peptide functional group except

(A) hydrogen. (B) nitrogen.

(C) oxygen. (D) phosphorus.

60. Which vitamin is the most soluble in water?

(A) A (B) K (C) C (D) D

END OF TEST

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KEY

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