



# 2015 U.S. NATIONAL CHEMISTRY OLYMPIAD LOCAL SECTION EXAM



Prepared by the American Chemical Society Chemistry Olympiad Examinations Task Force

## OLYMPIAD EXAMINATIONS TASK FORCE

Seth N. Brown, **Chair**, *University of Notre Dame*, Notre Dame, IN

James Ayers, *Mesa State College*, Grand Junction, CO  
Mark DeCamp, *University of Michigan*, Dearborn, MI (retired)  
Xu Duan, *Holton-Arms School*, Bethesda, MD  
Valerie Ferguson, *Moore HS*, Moore, OK  
Julie Furstenau, *Thomas B. Doherty HS*, Colorado Springs, CO  
Kimberly Gardner, *United States Air Force Academy*, CO  
Paul Groves, *South Pasadena HS*, South Pasadena, CA  
David W. Hostage, *Taft School*, Watertown, CT  
Dennis Kliza, *Kincaid School*, Houston, TX  
John Kotz, *State University of New York*, Oneonta, NY (retired)  
Adele Mouakad, *St. John's School*, San Juan, PR  
Jane Nagurney, *Scranton Preparatory School*, Scranton, PA  
Ronald Ragsdale, *University of Utah*, Salt Lake City, UT (retired)

### 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. A periodic table and other useful information are provided on page two of this exam booklet for student reference.

Only non-programmable calculators are to be used on the ACS local section exam. The use of a programmable calculator, cell phone, or any other device that can access the internet or make copies or photographs during the exam is grounds for disqualification.

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.

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

CONSTANTS
$R = 8.314 \text{ J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$
$R = 0.0821 \text{ L}\cdot\text{atm}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$
$F = 96,500 \text{ C}\cdot\text{mol}^{-1}$
$F = 96,500 \text{ J}\cdot\text{V}^{-1}\cdot\text{mol}^{-1}$
$N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$
$h = 6.626 \times 10^{-34} \text{ J}\cdot\text{s}$
$c = 2.998 \times 10^8 \text{ m}\cdot\text{s}^{-1}$
$0^{\circ}\text{C} = 273.15 \text{ K}$
$1 \text{ atm} = 760 \text{ mm Hg}$
Specific heat capacity of $\text{H}_2\text{O} = 4.184 \text{ J}\cdot\text{g}^{-1}\cdot\text{K}^{-1}$

### EQUATIONS

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

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

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

## PERIODIC TABLE OF THE ELEMENTS

1	PERIODIC TABLE OF THE ELEMENTS																18
1A																	8A
1	2											13	14	15	16	17	2
H	He											3A	4A	5A	6A	7A	He
1.008	4.003											5	6	7	8	9	10
3	4											5	6	7	8	9	10
Li	Be											B	C	N	O	F	Ne
6.941	9.012											10.81	12.01	14.01	16.00	19.00	20.18
11	12	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Na	Mg	3B	4B	5B	6B	7B	8B	8B	8B	1B	2B	Al	Si	P	S	Cl	Ar
22.99	24.31											26.98	28.09	30.97	32.07	35.45	39.95
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
39.10	40.08	44.96	47.88	50.94	52.00	54.94	55.85	58.93	58.69	63.55	65.39	69.72	72.61	74.92	78.96	79.90	83.80
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
85.47	87.62	88.91	91.22	92.91	95.94	(98)	101.1	102.9	106.4	107.9	112.4	114.8	118.7	121.8	127.6	126.9	131.3
55	56	57	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
132.9	137.3	138.9	178.5	180.9	183.8	186.2	190.2	192.2	195.1	197.0	200.6	204.4	207.2	209.0	(209)	(210)	(222)
87	88	89	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	(Uut)	Fl	(Uup)	Lv	(Uus)	(Uuo)
(223)	(226)	(227)	(261)	(262)	(263)	(262)	(265)	(266)	(281)	(272)	(285)	(284)	(289)	(288)	(293)	(294)	(294)

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

---

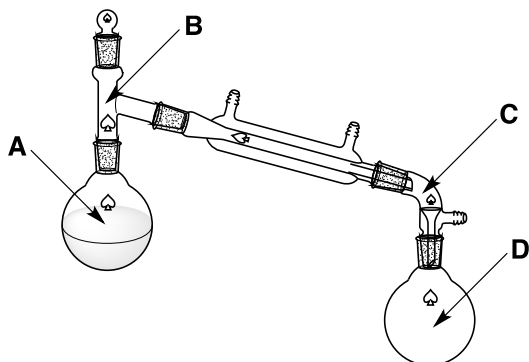
---

**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.**

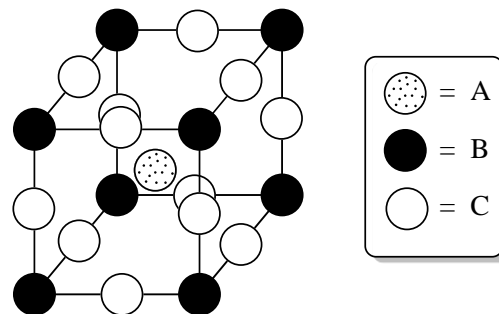
1. Benzene,  $C_6H_6$ , reacts with oxygen,  $O_2$ , to form  $CO_2$  and  $H_2O$ . How much  $O_2$  is required for the complete combustion of 1.0 mol  $C_6H_6$ ?  
(A) 6.0 mol (B) 7.5 mol  
(C) 9.0 mol (D) 12 mol
2. A 10.00 g sample of a soluble barium salt is treated with an excess of sodium sulfate to precipitate 11.21 g  $BaSO_4$  ( $M = 233.4$ ). Which barium salt is it?  
(A)  $BaCl_2$  ( $M = 208.2$ )  
(B)  $Ba(O_2CH)_2$  ( $M = 227.3$ )  
(C)  $Ba(NO_3)_2$  ( $M = 261.3$ )  
(D)  $BaBr_2$  ( $M = 297.1$ )
3. What is the concentration of nitrate ion in a 425 mL solution containing 32.0 g of  $Mg(NO_3)_2$  ( $M = 148.3$ )?  
(A) 0.216 M (B) 0.432 M  
(C) 0.508 M (D) 1.02 M
4. The formula for terbium phosphate is  $TbPO_4$ . The formula for terbium sulfate is  
(A)  $Tb_2SO_4$  (B)  $TbSO_4$   
(C)  $Tb_2(SO_4)_3$  (D)  $Tb(SO_4)_2$
5. A 25.0 mL sample of 0.15 M silver nitrate,  $AgNO_3$ , is reacted with a 3.58 g sample of calcium chloride,  $CaCl_2$  ( $M = 111.0$ ). Which of the following statements is true?  
(A) Silver nitrate is the limiting reactant and calcium nitrate precipitates.  
(B) Silver nitrate is the limiting reactant and silver chloride precipitates.  
(C) Calcium chloride is the limiting reactant and calcium nitrate precipitates.  
(D) Calcium chloride is the limiting reactant and silver chloride precipitates.
6. Which aqueous solution exhibits the largest freezing point depression?  
(A) 1.0 *m* KBr (B) 0.75 *m*  $C_6H_{12}O_6$   
(C) 0.5 *m*  $MgCl_2$  (D) 0.25 *m*  $Ga_2(SO_4)_3$
7. Which calcium compound is not appreciably more soluble in 0.1 M hydrochloric acid than it is in pure water?  
(A) Limestone,  $CaCO_3$   
(B) Slaked lime,  $Ca(OH)_2$   
(C) Gypsum,  $CaSO_4 \cdot 2 H_2O$   
(D) Hydroxyapatite,  $Ca_5(OH)(PO_4)_3$
8. Which metal reacts most vigorously with water at 25 °C?  
(A) Na (B) Mg (C) K (D) Ca
9. Each of the following forms a colored aqueous solution EXCEPT  
(A)  $Cr(NO_3)_3$  (B)  $Co(NO_3)_2$   
(C)  $Cu(NO_3)_2$  (D)  $Zn(NO_3)_2$
10. A student wishes to measure 37 mL of a liquid. Which apparatus would be most suitable?  
(A) 50 mL graduated cylinder  
(B) 50 mL volumetric pipet  
(C) 50 mL beaker  
(D) 50 mL Erlenmeyer flask
11. A 2.0 mL sample of a colorless solution, when treated with a few drops of 2 M hydrochloric acid, forms a white precipitate which dissolves when the solution is heated to boiling. The original solution could have contained which of the following cations?  
I. 0.1 M  $Ag^+$  II. 0.1 M  $Pb^{2+}$   
(A) I only (B) II only  
(C) Either I or II (D) Neither I nor II
12. Which compound has the lowest normal boiling point?  
(A) HF (B) HCl (C) HBr (D) HI
13. Which of the following would lead to an increase in the vapor pressure of a liquid?  
I. Increasing the temperature II. Adding a nonvolatile solute  
(A) I only (B) II only  
(C) Both I and II (D) Neither I nor II

14. A student is separating  $\text{CHCl}_3$  (bp =  $61^\circ\text{C}$ ) from  $\text{CHCl}_2\text{CHCl}_2$  (bp =  $146^\circ\text{C}$ ) by distillation. She has just begun to collect the first distillate in the receiving flask. At what position in the apparatus will the temperature be  $61^\circ\text{C}$ ?



- (A) A      (B) B      (C) C      (D) D
15. How is the enthalpy of vaporization of a substance related to its enthalpy of fusion?
- (A) The enthalpy of vaporization is greater than the enthalpy of fusion.  
 (B) The enthalpy of vaporization is equal to the enthalpy of fusion.  
 (C) The enthalpy of vaporization is less than the enthalpy of fusion.  
 (D) There is no general relationship between a substance's enthalpy of vaporization and enthalpy of fusion.
16. A 3.0 L sample of helium gas is stored in a rigid, sealed container at  $25^\circ\text{C}$  and 1.0 atm pressure. The temperature is increased to  $125^\circ\text{C}$ . What is the new pressure of the gas?
- (A) 0.20 atm      (B) 0.75 atm  
 (C) 1.3 atm      (D) 5.0 atm
17. Diamond is an example of what kind of solid?
- (A) Ionic      (B) Metallic  
 (C) Molecular      (D) Network covalent
18. Which of the following is a mathematical statement of the first law of thermodynamics?
- (A)  $\Delta V = (nR/P)\Delta T$       (B)  $\Delta E = q + w$   
 (C)  $\Delta H = \Delta E + P\Delta V$       (D)  $\Delta G = \Delta H - T\Delta S$

19. The cubic unit cell of a perovskite structure containing atoms of types A, B, and C is illustrated below. What is the empirical formula of this substance?



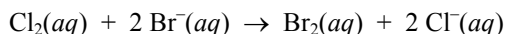
- (A) ABC      (B)  $\text{ABC}_3$       (C)  $\text{AB}_4\text{C}_6$       (D)  $\text{AB}_8\text{C}_{12}$
20. The enthalpy change under standard conditions for which of the reactions below would be equal to the  $\Delta H^\circ_f$  of  $\text{NaOH}(s)$ ?
- (A)  $\text{Na}(s) + \text{H}_2\text{O}(l) \rightarrow \text{NaOH}(s) + \frac{1}{2} \text{H}_2(g)$   
 (B)  $\text{Na}(s) + \frac{1}{2} \text{O}_2(g) + \frac{1}{2} \text{H}_2(g) \rightarrow \text{NaOH}(s)$   
 (C)  $\text{Na}(s) + \frac{1}{2} \text{H}_2\text{O}_2(l) \rightarrow \text{NaOH}(s)$   
 (D)  $\text{Na}^+(aq) + \text{OH}^-(aq) \rightarrow \text{NaOH}(s)$
21. A 37.5 g piece of gold at  $83.0^\circ\text{C}$  is added to 100. g  $\text{H}_2\text{O}$  at  $22.0^\circ\text{C}$  in a well-insulated cup. What is the temperature after the system comes to equilibrium? (The specific heat capacity of Au is  $0.129 \text{ J}\cdot\text{g}^{-1}\cdot\text{K}^{-1}$ )
- (A)  $22.7^\circ\text{C}$       (B)  $23.0^\circ\text{C}$   
 (C)  $25.0^\circ\text{C}$       (D)  $52.5^\circ\text{C}$
22. Which of these reactions has  $\Delta S^\circ > 0$ ?
- (A)  $\text{S}_8(l) \rightarrow \text{S}_8(s, \text{monoclinic})$   
 (B)  $\text{H}_2(g) + \text{O}_2(g) \rightarrow \text{H}_2\text{O}_2(aq)$   
 (C)  $\text{H}_2(g) + 2 \text{Ag}^+(aq) \rightarrow 2 \text{H}^+(aq) + 2 \text{Ag}(s)$   
 (D)  $\text{PCl}_5(g) \rightarrow \text{PCl}_3(g) + \text{Cl}_2(g)$
23. Given the enthalpy changes:
- $\text{A} + \text{B} \rightarrow \text{C} \quad \Delta H = -35 \text{ kJ}\cdot\text{mol}^{-1}$   
 $\text{A} + \text{D} \rightarrow \text{E} + \text{F} \quad \Delta H = +20 \text{ kJ}\cdot\text{mol}^{-1}$   
 $\text{F} \rightarrow \text{C} + \text{E} \quad \Delta H = +15 \text{ kJ}\cdot\text{mol}^{-1}$
- What is  $\Delta H$  for the reaction  $2\text{A} + \text{B} + \text{D} \rightarrow 2\text{F}$ ?
- (A)  $0 \text{ kJ}\cdot\text{mol}^{-1}$       (B)  $-30 \text{ kJ}\cdot\text{mol}^{-1}$   
 (C)  $-40 \text{ kJ}\cdot\text{mol}^{-1}$       (D)  $-70 \text{ kJ}\cdot\text{mol}^{-1}$

24. The  $K_a$  of phosphoric acid,  $\text{H}_3\text{PO}_4$ , is  $7.6 \times 10^{-3}$  at  $25^\circ\text{C}$ . For the reaction



$\Delta H^\circ = -14.2 \text{ kJ/mol}$ . What is the  $K_a$  of  $\text{H}_3\text{PO}_4$  at  $60^\circ\text{C}$ ?

- (A)  $4.2 \times 10^{-3}$  (B)  $6.8 \times 10^{-3}$   
 (C)  $8.5 \times 10^{-3}$  (D)  $1.8 \times 10^{-2}$
25. For the reaction
- $$5 \text{O}_2(g) + 4 \text{NH}_3(g) \rightarrow 4 \text{NO}(g) + 6 \text{H}_2\text{O}(g)$$
- if  $\text{NH}_3$  is being consumed at a rate of  $0.50 \text{ M}\cdot\text{s}^{-1}$ , at what rate is  $\text{H}_2\text{O}$  being formed?
- (A)  $0.33 \text{ M}\cdot\text{s}^{-1}$  (B)  $0.50 \text{ M}\cdot\text{s}^{-1}$   
 (C)  $0.75 \text{ M}\cdot\text{s}^{-1}$  (D)  $3.0 \text{ M}\cdot\text{s}^{-1}$
26. The rate of decomposition of hydrogen peroxide is first order in  $\text{H}_2\text{O}_2$ . At  $[\text{H}_2\text{O}_2] = 0.150 \text{ M}$ , the decomposition rate was measured to be  $4.83 \times 10^{-6} \text{ M}\cdot\text{s}^{-1}$ . What is the rate constant for the reaction?
- (A)  $2.15 \times 10^{-4} \text{ s}^{-1}$  (B)  $3.22 \times 10^{-5} \text{ s}^{-1}$   
 (C)  $4.83 \times 10^{-6} \text{ s}^{-1}$  (D)  $7.25 \times 10^{-7} \text{ s}^{-1}$
27. In the reaction  $\text{A} \rightarrow \text{B}$ , a plot of  $1/[\text{A}]$  vs.  $t$  is found to be linear. What is the reaction order in A?
- (A) Zeroth order (B) First order  
 (C) Second order (D) Third order
28. The half-life of iodine-131 is 8.02 days. How long will it take for 80.% of the sample to decay?
- (A) 2.6 days (B) 13 days  
 (C) 19 days (D) 32 days
29. For the reaction



which of the following could be used to monitor the rate?

I. pH meter II. Spectrophotometer

- (A) I only (B) II only  
 (C) Either I or II (D) Neither I nor II
30. For a reversible exothermic reaction, what is the effect of increasing temperature on the equilibrium constant ( $K_{\text{eq}}$ ) and on the forward rate constant ( $k_f$ )?
- (A)  $K_{\text{eq}}$  and  $k_f$  both increase  
 (B)  $K_{\text{eq}}$  and  $k_f$  both decrease  
 (C)  $K_{\text{eq}}$  increases and  $k_f$  decreases  
 (D)  $K_{\text{eq}}$  decreases and  $k_f$  increases

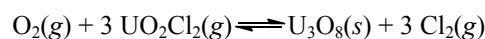
31. When 0.10 M solutions of ammonium acetate, barium acetate, and sodium acetate are ranked from least basic to most basic, what is the correct ordering?

- (A)  $\text{NH}_4\text{C}_2\text{H}_3\text{O}_2 < \text{NaC}_2\text{H}_3\text{O}_2 < \text{Ba}(\text{C}_2\text{H}_3\text{O}_2)_2$   
 (B)  $\text{Ba}(\text{C}_2\text{H}_3\text{O}_2)_2 < \text{NH}_4\text{C}_2\text{H}_3\text{O}_2 < \text{NaC}_2\text{H}_3\text{O}_2$   
 (C)  $\text{NaC}_2\text{H}_3\text{O}_2 < \text{Ba}(\text{C}_2\text{H}_3\text{O}_2)_2 < \text{NH}_4\text{C}_2\text{H}_3\text{O}_2$   
 (D)  $\text{NaC}_2\text{H}_3\text{O}_2 < \text{NH}_4\text{C}_2\text{H}_3\text{O}_2 < \text{Ba}(\text{C}_2\text{H}_3\text{O}_2)_2$

32. What is the solubility of  $\text{MgF}_2$  ( $K_{\text{sp}} = 6.8 \times 10^{-9}$ ) in pure water?

- (A)  $6.8 \times 10^{-9} \text{ mol}\cdot\text{L}^{-1}$  (B)  $5.8 \times 10^{-5} \text{ mol}\cdot\text{L}^{-1}$   
 (C)  $8.2 \times 10^{-5} \text{ mol}\cdot\text{L}^{-1}$  (D)  $1.2 \times 10^{-3} \text{ mol}\cdot\text{L}^{-1}$

33. What is the ratio  $K_c/K_p$  for the following reaction at  $723^\circ\text{C}$ ?

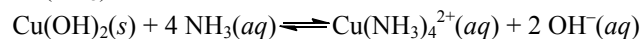


- (A) 0.0122 (B) 1.00 (C) 59.4 (D) 81.8

34. What is  $[\text{H}_3\text{O}^+]$  in a solution formed by dissolving 1.00 g  $\text{NH}_4\text{Cl}$  ( $M = 53.5$ ) in 30.0 mL of 3.00 M  $\text{NH}_3$  ( $K_b = 1.8 \times 10^{-5}$ )?

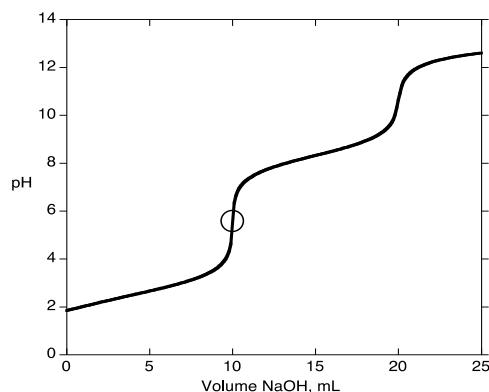
- (A)  $2.7 \times 10^{-9} \text{ M}$  (B)  $5.5 \times 10^{-10} \text{ M}$   
 (C)  $1.2 \times 10^{-10} \text{ M}$  (D)  $1.4 \times 10^{-12} \text{ M}$

35. Copper(II) hydroxide,  $\text{Cu}(\text{OH})_2$ , has  $K_{\text{sp}} = 2.2 \times 10^{-20}$ . For the reaction below,  $K_{\text{eq}} = 4.0 \times 10^{-7}$ . What is  $K_f$  for  $\text{Cu}(\text{NH}_3)_4^{2+}$ ?



- (A)  $8.8 \times 10^{-27}$  (B)  $5.5 \times 10^{-14}$   
 (C)  $1.8 \times 10^{13}$  (D)  $1.1 \times 10^{26}$

36. A 0.100 M aqueous solution of  $\text{H}_2\text{SeO}_3$  is titrated with 1.000 M  $\text{NaOH}$  solution. At the point marked with a circle on the titration curve, which species represent at least 10% of the total selenium in solution?



- (A)  $\text{H}_2\text{SeO}_3$  only (B) Both  $\text{H}_2\text{SeO}_3$  and  $\text{HSeO}_3^-$   
 (C)  $\text{HSeO}_3^-$  only (D) Both  $\text{HSeO}_3^-$  and  $\text{SeO}_3^{2-}$

37. What is the oxidation number of C in formaldehyde,  $\text{CH}_2\text{O}$ ?  
 (A) -2 (B) 0 (C) +2 (D) +4
38. In a galvanic cell in which the following spontaneous reaction takes place, what process occurs at the cathode?  
 $3 \text{Ce}^{4+}(\text{aq}) + \text{Cr}(\text{s}) \rightarrow 3 \text{Ce}^{3+}(\text{aq}) + \text{Cr}^{3+}(\text{aq})$   
 (A) Reduction of  $\text{Cr}^{3+}(\text{aq})$   
 (B) Reduction of  $\text{Ce}^{4+}(\text{aq})$   
 (C) Oxidation of  $\text{Cr}(\text{s})$   
 (D) Oxidation of  $\text{Ce}^{3+}(\text{aq})$
39. Which two half reactions, when coupled, will make a galvanic cell that will produce the largest voltage under standard conditions?  
 I.  $\text{Cu}^{2+}(\text{aq}) + 2 \text{e}^- \rightarrow \text{Cu}(\text{s}) \quad E^\circ = +0.34 \text{ V}$   
 II.  $\text{Pb}^{2+}(\text{aq}) + 2 \text{e}^- \rightarrow \text{Pb}(\text{s}) \quad E^\circ = -0.13 \text{ V}$   
 III.  $\text{Ag}^+(\text{aq}) + \text{e}^- \rightarrow \text{Ag}(\text{s}) \quad E^\circ = +0.80 \text{ V}$   
 IV.  $\text{Al}^{3+}(\text{aq}) + 3 \text{e}^- \rightarrow \text{Al}(\text{s}) \quad E^\circ = -1.66 \text{ V}$   
 (A) I and II (B) I and IV  
 (C) II and IV (D) III and IV
40. An electrolysis cell is operated for 3000 s using a current of 1.50 A. From which 1.0 M solution will the greatest mass of metal be deposited?  
 (A)  $\text{TlNO}_3$  (B)  $\text{Pb}(\text{NO}_3)_2$   
 (C)  $\text{ZnCl}_2$  (D)  $\text{In}(\text{NO}_3)_3$
41. The reduction of  $\text{O}_2$  to  $\text{H}_2\text{O}$  in acidic solution has a standard reduction potential of +1.23 V. What is the effect on the half-cell potential at 25 °C when the pH of the solution is increased by one unit?  
 $\text{O}_2(\text{g}) + 4 \text{H}^+(\text{aq}) + 4 \text{e}^- \rightarrow 2 \text{H}_2\text{O}(\text{l})$   
 (A) The half-cell potential decreases by 59 mV.  
 (B) The half-cell potential increases by 59 mV.  
 (C) The half-cell potential decreases by 236 mV.  
 (D) The half-cell potential increases by 236 mV.
42. Given the two standard reduction potentials below, what is the  $K_{\text{sp}}$  of  $\text{Ag}_2\text{CrO}_4$  at 25 °C?  
 $\text{Ag}_2\text{CrO}_4(\text{s}) + 2 \text{e}^- \rightarrow 2 \text{Ag}(\text{s}) + \text{CrO}_4^{2-}(\text{aq}) \quad E^\circ = +0.446 \text{ V}$   
 $\text{Ag}^+(\text{aq}) + \text{e}^- \rightarrow \text{Ag}(\text{s}) \quad E^\circ = +0.799 \text{ V}$   
 (A)  $8.64 \times 10^{11}$  (B)  $1.08 \times 10^{-6}$   
 (C)  $1.16 \times 10^{-12}$  (D)  $1.11 \times 10^{-39}$
43. What is the value of the quantum number  $l$  for a 5p orbital?  
 (A) 1 (B) 2 (C) 3 (D) 4
44. Which element has chemical properties most similar to those of P?  
 (A) N (B) Al (C) S (D) As
45. Which metal has the lowest melting point?  
 (A) Li (B) Na (C) K (D) Rb
46. Which gas-phase atom has no unpaired electrons in its ground state?  
 (A) Li (B) Be (C) B (D) C
47. Which halogen atom has the greatest electron affinity?  
 (A) F (B) Cl (C) Br (D) I
48. Which electronic transition in atomic hydrogen corresponds to the emission of visible light?  
 (A)  $n = 5 \rightarrow n = 2$  (B)  $n = 1 \rightarrow n = 2$   
 (C)  $n = 3 \rightarrow n = 4$  (D)  $n = 3 \rightarrow n = 1$
49. Which species are linear?  
 I.  $\text{NO}_2^+$  II.  $\text{I}_3^-$   
 (A) I only (B) II only  
 (C) Both I and II (D) Neither I nor II
50. The peroxymonosulfate anion,  $\text{HSO}_5^-$ , has  
 (A) five sulfur-oxygen bonds and no oxygen-oxygen bonds.  
 (B) four sulfur-oxygen bonds and one oxygen-oxygen bond.  
 (C) three sulfur-oxygen bonds and two oxygen-oxygen bonds.  
 (D) one sulfur-oxygen bond and four oxygen-oxygen bonds.
51. Which statement about bonding is correct?  
 (A) A  $\sigma$  bond has cylindrical symmetry about the bonding axis.  
 (B) A  $\pi$  bond is twice as strong as a  $\sigma$  bond.  
 (C) A double bond consists of two  $\pi$  bonds.  
 (D) A  $\pi$  bond results from the sideways overlap of hybridized orbitals.

- 
- 
52. What is the geometry of the chlorate ion,  $\text{ClO}_3^-$ ?
- (A) trigonal planar      (B) trigonal pyramidal  
(C) T-shaped      (D) zigzag
53. What is the bond order in  $\text{NO}$ ?
- (A) 1.0      (B) 1.5      (C) 2.0      (D) 2.5
54. In the Lewis structure of ozone,  $\text{O}_3$ , what is the formal charge on the central oxygen?
- (A) 2-      (B) 1-      (C) 0      (D) 1+
55. Hydrogenation of an alkene converts it to an
- (A) alkane.      (B) alkyne.  
(C) alcohol.      (D) aldehyde.
56. What is the relationship between the two compounds below?
- $\text{CH}_3\text{CH}_2\text{CH}(\text{CH}_3)\text{CH}_2\text{CH}_3$      $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}(\text{CH}_3)\text{CH}_3$
- (A) Identical      (B) Stereoisomers  
(C) Geometric isomers      (D) Structural isomers
57. Which class of organic compounds does NOT contain oxygen?
- (A) Alcohol      (B) Amide  
(C) Amine      (D) Ketone
58. Compared to ionic compounds of similar molar mass, hydrocarbons typically have
- I. Higher water solubility      II. Higher melting points
- (A) I only      (B) II only  
(C) Both I and II      (D) Neither I nor II
59. Which of the following compounds could contain exactly one triple bond?
- (A)  $\text{C}_5\text{H}_{10}$       (B)  $\text{C}_5\text{H}_{12}$       (C)  $\text{C}_6\text{H}_{10}$       (D)  $\text{C}_6\text{H}_{12}$
60. Which of the following is NOT classified as a biopolymer?
- (A) Collagen      (B) Glucose  
(C) Cellulose      (D) Chitin

---

**END OF TEST**

---

---

---

**Olympiad 2015**  
**USNCO Local Section Exam**  
**KEY**

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