



# 2011 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. Each Local Section may use an answer sheet of its 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	<i>n</i>	Faraday constant	<i>F</i>	molar mass	<i>M</i>
ampere	<i>A</i>	free energy	<i>G</i>	mole	mol
atmosphere	atm	frequency	$\nu$	Planck's constant	<i>h</i>
atomic mass unit	<i>u</i>	gas constant	<i>R</i>	pressure	<i>P</i>
Avogadro constant	$N_A$	gram	<i>g</i>	rate constant	<i>k</i>
Celsius temperature	°C	hour	<i>h</i>	reaction quotient	<i>Q</i>
centi- prefix	<i>c</i>	joule	<i>J</i>	second	<i>s</i>
coulomb	<i>C</i>	kelvin	<i>K</i>	speed of light	<i>c</i>
density	<i>d</i>	kilo- prefix	<i>k</i>	temperature, K	<i>T</i>
electromotive force	<i>E</i>	liter	<i>L</i>	time	<i>t</i>
energy of activation	$E_a$	measure of pressure mm Hg		vapor pressure	VP
enthalpy	<i>H</i>	milli- prefix	<i>m</i>	volt	<i>V</i>
entropy	<i>S</i>	molal	<i>m</i>	volume	<i>V</i>
equilibrium constant	<i>K</i>	molar	<i>M</i>		

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

### 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																		18																	
1A																		8A																	
1	2												13	14	15	16	17	2																	
H	He												B	C	N	O	F	He																	
1.008	4.003												10.81	12.01	14.01	16.00	19.00	20.18																	
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)	(Uuq)	(Uup)	(Uuh)	(Uus)	(Uuo)																		
(223)	(226)	(227)	(261)	(262)	(266)	(264)	(277)	(268)	(281)	(272)	(277)	(Uut)	(Uuq)	(Uup)	(Uuh)	(Uus)	(Uuo)																		

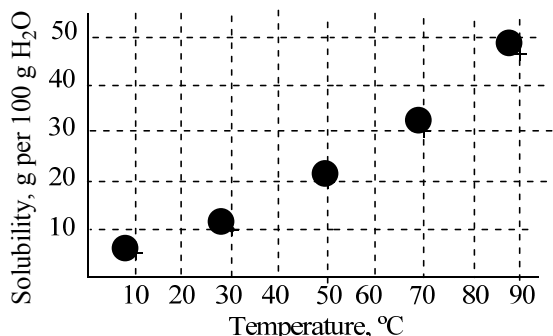
58	59	60	61	62	63	64	65	66	67	68	69	70	71
Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
140.1	140.9	144.2	(145)	150.4	152.0	157.3	158.9	162.5	164.9	167.3	168.9	173.0	175.0
90	91	92	93	94	95	96	97	98	99	100	101	102	103
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
232.0	231.0	238.0	(237)	(244)	(243)	(247)	(247)	(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. A student is asked to dispense 24.70 mL of a solution with an uncertainty of less than 0.05 mL. Which item should be used for this task?  
(A) 50 mL beaker  
(B) 50 mL buret  
(C) 50 mL Erlenmeyer flask  
(D) 50 mL graduated cylinder
2. Oxygen gas can be produced by the decomposition of all of the following substances EXCEPT  
(A) calcium oxide.            (B) hydrogen peroxide.  
(C) mercury(II) oxide.        (D) ozone.
3. Which gaseous product is formed when dilute nitric acid reacts with silver metal in the absence of air?  
(A) H<sub>2</sub>        (B) O<sub>2</sub>        (C) NH<sub>3</sub>        (D) NO
4. How many of the following gases are characterized by BOTH color AND a distinctive odor?  
Cl<sub>2</sub>        CH<sub>4</sub>        NO<sub>2</sub>  
(A) none        (B) one        (C) two        (D) three
5. Which action should be taken immediately if concentrated sulfuric acid is spilled on the skin?  
(A) It should be rinsed off with large quantities of running water.  
(B) It should be neutralized with solid CaCO<sub>3</sub>.  
(C) It should be neutralized with concentrated NaOH.  
(D) The area of the spill should be wrapped tightly with cloth and shown to a health provider.

6. The solubility of KClO<sub>3</sub> at several temperatures is shown in the accompanying diagram.



A student mixes 10.0 g of KClO<sub>3</sub> with 45.0 g of H<sub>2</sub>O and stirs it for a long time at 60 °C until the solution is completely clear then allows it to cool slowly to 20 °C where it remains clear. Which statement about the final clear mixture at 20 °C is correct?

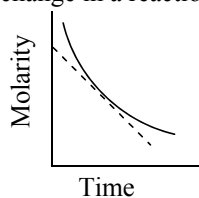
- (A) It is a saturated solution.
  - (B) It is an unsaturated solution and can be made saturated by decreasing the temperature.
  - (C) It is an unsaturated solution and can be made saturated by increasing the temperature.
  - (D) It is a supersaturated solution.
7. A 65.25 g sample of CuSO<sub>4</sub>•5H<sub>2</sub>O (*M* = 249.7) is dissolved in enough water to make 0.800 L of solution. What volume of this solution must be diluted with water to make 1.00 L of 0.100 M CuSO<sub>4</sub>?  
(A) 3.27 mL                                (B) 81.6 mL  
(C) 209 mL                                 (D) 306 mL
  8. How many moles of O<sub>2</sub> are required for the complete combustion of 2.2 g of C<sub>3</sub>H<sub>8</sub> to form CO<sub>2</sub> and H<sub>2</sub>O?  
(A) 0.050        (B) 0.15        (C) 0.25        (D) 0.50
  9. A typical polyethylene bag from a grocery store weighs 12.4 g. How many molecules of ethylene, C<sub>2</sub>H<sub>4</sub>, must be polymerized to make such a bag?  
(A) 1.36 × 10<sup>24</sup>                                (B) 6.02 × 10<sup>23</sup>  
(C) 5.33 × 10<sup>23</sup>                                (D) 2.67 × 10<sup>23</sup>

10. In the titration of a monoprotic acid with a solution of sodium hydroxide of known concentration, what quantities are equal at the equivalence point?
- (A) the concentrations of hydroxide and hydronium ions  
 (B) the number of moles of hydroxide ion added and the number of moles of hydronium ion initially present  
 (C) the volume of sodium hydroxide solution added and the volume of acid solution initially present  
 (D) the number of moles of hydroxide ion added and the number of moles of monoprotic acid initially present
11. When a nonvolatile solute is dissolved in a volatile solvent, which characteristic is greater for the solution than for the solvent?
- (A) boiling point (B) freezing point  
 (C) rate of evaporation (D) vapor pressure
12. What is the concentration of nitrate ion in a solution made by mixing 100 mL of a 0.200 M  $\text{HNO}_3$  solution with 200 mL of a 0.100 M solution of  $\text{Mg}(\text{NO}_3)_2$ ?
- (A) 0.133 M (B) 0.150 M  
 (C) 0.167 M (D) 0.200 M
13. The phase transition from gas to solid is called
- (A) condensation. (B) evaporation.  
 (C) polymerization. (D) sublimation.
14. A sample of gas occupies a volume of 9.23 L at 345 K and 1.40 atm. What is its volume at 525 K and 3.20 atm?
- (A) 2.65 L (B) 6.14 L (C) 13.9 L (D) 32.1 L
15. Which substance has the strongest London dispersion forces?
- (A)  $\text{H}_2\text{O}$  (B)  $\text{H}_2\text{S}$  (C)  $\text{H}_2\text{Se}$  (D)  $\text{H}_2\text{Te}$
16. When the substances Si, KCl,  $\text{CH}_3\text{OH}$ , and  $\text{C}_2\text{H}_6$  are arranged in order of increasing melting point, what is the correct order?
- (A) Si, KCl,  $\text{CH}_3\text{OH}$ ,  $\text{C}_2\text{H}_6$   
 (B)  $\text{CH}_3\text{OH}$ ,  $\text{C}_2\text{H}_6$ , Si, KCl  
 (C) KCl, Si,  $\text{C}_2\text{H}_6$ ,  $\text{CH}_3\text{OH}$   
 (D)  $\text{C}_2\text{H}_6$ ,  $\text{CH}_3\text{OH}$ , KCl, Si
17. According to the following information, in what physical state(s) does bromine exist at  $-7.4^\circ\text{C}$  and 400 mm Hg?  
 [Triple point  $-7.3^\circ\text{C}$ , 44 mm Hg  
 Liquid density  $3.1\text{ g}\cdot\text{cm}^{-3}$ , Solid density  $3.4\text{ g}\cdot\text{cm}^{-3}$ ]
- (A) solid only (B) liquid only  
 (C) liquid and solid only (D) gas, liquid, and solid
18. A gas mixture at  $27^\circ\text{C}$  and 1 atm contains equal masses of He,  $\text{H}_2$ ,  $\text{CO}_2$ , and  $\text{CH}_4$ . How do their molecular velocities compare?
- (A)  $\text{He} = \text{H}_2 = \text{CO}_2 = \text{CH}_4$  (B)  $\text{He} < \text{H}_2 < \text{CO}_2 < \text{CH}_4$   
 (C)  $\text{H}_2 < \text{He} < \text{CH}_4 < \text{CO}_2$  (D)  $\text{CO}_2 < \text{CH}_4 < \text{He} < \text{H}_2$
19. The energies of the bonds broken in a certain reaction are greater than the energies of the bonds formed. Which one of the following statements about this reaction must be true?
- (A) The reaction is endothermic.  
 (B) The reaction is exothermic.  
 (C) The reaction is spontaneous.  
 (D) The reaction is non-spontaneous.
20. How much heat is required to convert 5.0 g of ice at  $-10.0^\circ\text{C}$  to liquid water at  $15.0^\circ\text{C}$ ? (Assume heat capacities are independent of temperature.)
- |                                 |   |
|---------------------------------|---|
| Enthalpy of fusion              | $6.00\text{ kJ}\cdot\text{mol}^{-1}$                        |
| Specific heat capacity of ice   | $37.8\text{ J}\cdot\text{mol}^{-1}\cdot^\circ\text{C}^{-1}$ |
| Specific heat capacity of water | $76.0\text{ J}\cdot\text{mol}^{-1}\cdot^\circ\text{C}^{-1}$ |
- (A)  $4.2 \times 10^2\text{ J}$  (B)  $2.1 \times 10^3\text{ J}$   
 (C)  $9.3 \times 10^3\text{ J}$  (D)  $3.8 \times 10^4\text{ J}$
21. What is the standard enthalpy of formation of ethylene,  $\text{C}_2\text{H}_4$ , if its standard enthalpy of combustion is  $-1411\text{ kJ}\cdot\text{mol}^{-1}$ ?
- |                                |   |
|--------------------------------|---|
| substance                      | $\Delta\text{H}_f^\circ, \text{kJ}\cdot\text{mol}^{-1}$ |
| $\text{CO}_2(\text{g})$        | -394  |
| $\text{H}_2\text{O}(\text{l})$ | -286  |
- (A)  $1411\text{ kJ}\cdot\text{mol}^{-1}$  (B)  $51\text{ kJ}\cdot\text{mol}^{-1}$   
 (C)  $-337\text{ kJ}\cdot\text{mol}^{-1}$  (D)  $-445\text{ kJ}\cdot\text{mol}^{-1}$
22. At the triple point of water how do the entropies of solid, liquid, and gas compare?
- (A)  $S^\circ_{\text{solid}} < S^\circ_{\text{liquid}} < S^\circ_{\text{gas}}$  (B)  $S^\circ_{\text{solid}} = S^\circ_{\text{liquid}} < S^\circ_{\text{gas}}$   
 (C)  $S^\circ_{\text{gas}} < S^\circ_{\text{solid}} < S^\circ_{\text{liquid}}$  (D)  $S^\circ_{\text{solid}} = S^\circ_{\text{liquid}} = S^\circ_{\text{gas}}$
23. "A perfect crystalline substance has an entropy of zero at absolute zero" is a statement of
- (A) Hess's Law.  
 (B) The First Law of Thermodynamics.  
 (C) The Second Law of Thermodynamics.  
 (D) The Third Law of Thermodynamics.

24. Which one of the following sets of conditions would result in a reaction that is spontaneous at high temperatures but non-spontaneous at low temperatures?

- (A)  $\Delta H > 0, \Delta S > 0$       (B)  $\Delta H > 0, \Delta S < 0$   
(C)  $\Delta H < 0, \Delta S < 0$       (D)  $\Delta H < 0, \Delta S > 0$

25. What quantity is represented by the slope of the dashed line in the accompanying diagram for the concentration change in a reaction?



- (A) instantaneous reaction rate  
(B) rate constant  
(C) reaction order for that reactant  
(D) activation energy
26. Changes in which factors affect both the rate and the rate constant of a first order reaction?  
I temperature    II concentration
- (A) I only      (B) II only  
(C) Both I and II      (D) Neither I nor II

27. Consider the hypothetical reaction:  
 $A + 2B \rightarrow C$   
The rate remains constant when the concentration of A is doubled and the concentration of B is held constant. The reaction rate doubles when the concentration of B is doubled and the concentration of A is held constant. What are the orders of A and B in this reaction?

(A) A = 0, B = 1      (B) A = 0, B = 2  
(C) A = 1, B = 2      (D) A = 1, B = 0

28. Which statement is true about a reactant that appears in the balanced equation for a reaction but does not appear in the rate equation?

(A) It is an inhibitor.  
(B) It is not part of the reaction.  
(C) Its concentration is too low to be important.  
(D) It takes part in the reaction after the rate-determining step.

29. Introduction of two drops of concentrated sulfuric acid,  $H_2SO_4$ , speeds up an esterification reaction. Introduction of a piece of platinum metal, Pt, speeds up the reaction of  $H_2$  and  $O_2$  gas. Which of the following statements is true?

- (A) Pt is a homogeneous catalyst;  $H_2SO_4$  is a heterogeneous catalyst.  
(B) Pt is a heterogeneous catalyst;  $H_2SO_4$  is a homogeneous catalyst.  
(C) Pt and  $H_2SO_4$  are both heterogeneous catalysts.  
(D) Pt and  $H_2SO_4$  are both homogeneous catalysts.
30. Which change will decrease the rate of the reaction between  $I_2(s)$  and  $H_2(g)$ ?
- (A) Increasing the partial pressure of  $H_2(g)$   
(B) Adding the  $I_2(s)$  as one piece rather than as several small ones  
(C) Heating the reaction mixture  
(D) Adding a catalyst for the reaction

31. For the equilibrium system:  
 $CO(g) + 2 H_2(g) \rightleftharpoons CH_3OH(l)$   
what is  $K_c$ ?

- (A)  $K_c = \frac{[CH_3OH]}{2[CO][H_2]}$       (B)  $K_c = \frac{[CH_3OH]}{[CO][H_2]^2}$   
(C)  $K_c = \frac{1}{2[CO][H_2]}$       (D)  $K_c = \frac{1}{[CO][H_2]^2}$

32. Consider the system at equilibrium:  
 $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$   
for which  $\Delta H < 0$ . Which change(s) will increase the yield of  $SO_3(g)$ ?

I Increasing the temperature  
II Increasing the volume of the container

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

33. When 0.10 M solutions of HF, HCl, KF, and KCl are arranged in order of increasing pH which order is correct?

(A) HF, HCl, KF, KCl      (B) HCl, HF, KF, KCl  
(C) HCl, HF, KCl, KF      (D) HF, HCl, KCl, KF

34. Which one of the following mixtures creates a buffer solution?
- (A) 10.0 mL 0.10 M NaOH, 10.0 mL 0.10 M HF  
 (B) 20.0 mL 0.10 M NaOH, 15.0 mL 0.10 M HF  
 (C) 15.0 mL 0.10 M NaOH, 20.0 mL 0.10 M HF  
 (D) 10.0 mL 0.10 M NaOH, 5.0 mL 0.20 M HF
35. The solubility of  $\text{AgBrO}_3$  in aqueous solution depends on the presence of other substances in solution. Relative to its solubility in  $\text{H}_2\text{O}$  the solubility of  $\text{AgBrO}_3$  is higher in 0.10 M \_\_\_\_\_ and lower in 0.10 M \_\_\_\_\_.
- (A)  $\text{NH}_3$ ,  $\text{KBrO}_3$                       (B)  $\text{KBrO}_3$ ,  $\text{NH}_3$   
 (C)  $\text{HNO}_3$ ,  $\text{NH}_3$                         (D)  $\text{NH}_3$ ,  $\text{HNO}_3$
36. A 0.015 M solution of a weak acid has a pH of 3.52. What is the value of the  $K_a$  for this acid?
- (A)  $2.0 \times 10^{-2}$                         (B)  $6.2 \times 10^{-6}$   
 (C)  $9.1 \times 10^{-8}$                         (D)  $1.4 \times 10^{-9}$
37. All of the reactions below represent oxidation-reduction processes EXCEPT the
- (A) combustion of tin in chlorine gas.  
 (B) decomposition of potassium chlorate.  
 (C) neutralization of sodium hydroxide.  
 (D) reaction of magnesium with hydrochloric acid.
38. Which expression gives the correct value for the standard potential for a gold-rhodium voltaic cell?
- | Half-reaction   | $E^\circ$ , V |
|---|---------------|
| $\text{Rh}^{3+}(\text{aq}) + 3\text{e}^- \rightarrow \text{Rh}(\text{s})$ | 0.76          |
| $\text{Au}^+(\text{aq}) + \text{e}^- \rightarrow \text{Au}(\text{s})$     | 1.69          |
- (A)  $1.69 + 0.76$                         (B)  $1.69 - 0.76$   
 (C)  $3(1.69) + 0.76$                     (D)  $3(1.69) - 0.76$
39. When potassium permanganate,  $\text{KMnO}_4$ , is added to an acidified solution of oxalic acid,  $\text{H}_2\text{C}_2\text{O}_4$ , the products are  $\text{CO}_2$  gas and  $\text{Mn}^{2+}$  ions. What is the reducing agent in this reaction?
- (A)  $\text{KMnO}_4$                                 (B)  $\text{H}_2\text{C}_2\text{O}_4$   
 (C)  $\text{H}_3\text{O}^+$                                  (D)  $\text{CO}_2$
40. Which term represents the charge on one mole of electrons?
- (A) one Ampere                            (B) one Coulomb  
 (C) one Faraday                          (D) one Volt
41. Consider a voltaic cell in which the reaction below occurs in two half-cells connected by a salt bridge and an external circuit.
- $$2\text{Cr}(\text{s}) + 3\text{Sn}^{2+}(\text{aq}) \rightarrow 3\text{Sn}(\text{s}) + 2\text{Cr}^{3+}(\text{aq}) \quad E^\circ = 0.603 \text{ V}$$
- Which change will cause the voltage to increase?
- (A) Increasing the amount of  $\text{Sn}(\text{s})$  in its half-cell  
 (B) Increasing the amount of  $\text{Cr}(\text{s})$  in its half-cell  
 (C) Diluting the solution in the anode compartment  
 (D) Diluting the solution in the cathode compartment
42. How long must a current of 4.00 A be applied to a solution of  $\text{Cu}^{2+}(\text{aq})$  to produce 2.0 grams of copper metal?
- (A)  $2.4 \times 10^4 \text{ s}$                             (B)  $1.5 \times 10^3 \text{ s}$   
 (C)  $7.6 \times 10^2 \text{ s}$                             (D)  $3.8 \times 10^2 \text{ s}$
43. Which element has atoms with exactly four valence electrons in its ground state?
- (A) Ca                      (B) Cr                      (C) Si                      (D) S
44. Gas-phase atoms of which element have an occupied 5d orbital in their ground state?
- (A) Ag ( $Z = 47$ )                            (B) Ba ( $Z = 56$ )  
 (C) Eu ( $Z = 63$ )                            (D) Ir ( $Z = 77$ )
45. Which gas-phase atom in its ground state could have an electron with the quantum numbers:  $n = 3$ ,  $l = 2$ ,  $m_l = 0$ ,  $m_s = -1/2$ ?
- (A) Na                      (B) Mg                      (C) P                      (D) Ti
46. Properties of the alkaline earth metals that increase from Be to Ba include which of the following?  
 I Atomic radius II Ionization energy III Nuclear charge
- (A) I and II only                            (B) I and III only  
 (C) II and III only                          (D) I, II, and III
47. In which list are the ions arranged in order of decreasing size?
- (A)  $\text{S}^{2-}$ ,  $\text{Br}^-$ ,  $\text{K}^+$ ,  $\text{Ca}^{2+}$                       (B)  $\text{Br}^-$ ,  $\text{S}^{2-}$ ,  $\text{K}^+$ ,  $\text{Ca}^{2+}$   
 (C)  $\text{K}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{S}^{2-}$ ,  $\text{Br}^-$                       (D)  $\text{Ca}^{2+}$ ,  $\text{K}^+$ ,  $\text{S}^{2-}$ ,  $\text{Br}^-$
48. The element Lawrencium was first synthesized by the reaction:  ${}_{98}^{252}\text{Cf} + {}_5^{11}\text{B} \rightarrow {}_{103}^{258}\text{Lr} + \underline{\hspace{1cm}}$   
 What products are needed to balance this equation?
- (A)  $4\alpha + {}_0^1\text{n}$                                 (B)  $5\alpha + {}_0^1\text{n}$   
 (C)  $5\alpha + {}_0^1\text{n}$                                 (D)  $5\alpha + {}_0^1\text{n}$

49. What is the oxidation number of rhenium in  $\text{Ca}(\text{ReO}_4)_2$ ?  
(A) +1 (B) +3 (C) +6 (D) +7
50. Which species has the largest bond angle?  
(A)  $\text{NO}_2^+$  (B)  $\text{NO}_2$  (C)  $\text{NO}_2^-$  (D)  $\text{NO}_3^-$
51. Which species is planar?  
(A)  $\text{CO}_3^{2-}$  (B)  $\text{SO}_3^{2-}$  (C)  $\text{ClO}_3^-$  (D)  $\text{BF}_4^-$
52. Given the reactions  
 $\text{CH}_4(\text{g}) \rightarrow \text{C}(\text{g}) + 4\text{H}(\text{g}) \quad \Delta H^\circ = 1656 \text{ kJ}\cdot\text{mol}^{-1}$   
 $\text{HC}\equiv\text{CH}(\text{g}) \rightarrow 2\text{C}(\text{g}) + 2\text{H}(\text{g}) \quad \Delta H^\circ = 1648 \text{ kJ}\cdot\text{mol}^{-1}$   
what is the estimated  $\text{C}\equiv\text{C}$  bond energy in  $\text{kJ}\cdot\text{mol}^{-1}$ ?  
(A) 414 (B) 820 (C) 1234 (D) 1664
53. Which bonds are formed by a carbon atom with  $\text{sp}^2$  hybridization?  
(A) 4  $\pi$  bonds  
(B) 2  $\pi$  bonds and 2  $\sigma$  bonds  
(C) 1  $\pi$  bond and 3  $\sigma$  bonds  
(D) 4  $\sigma$  bonds
54. How many resonance forms can be written for the nitrate ion,  $\text{NO}_3^-$ ?  
(A) 1 (B) 2 (C) 3 (D) 4
55. The boiling points of  $\text{CH}_3\text{COCH}_3$ ,  $\text{CH}_3\text{COC}_2\text{H}_5$ , and  $\text{CH}_3\text{COC}_3\text{H}_7$  are  $56^\circ\text{C}$ ,  $80^\circ\text{C}$ , and  $102^\circ\text{C}$ , respectively. This increase is best attributed to an increase in which of the following?  
I dipole-dipole interactions  
II dispersion forces  
III hydrogen bonding  
(A) I only (B) II only  
(C) III only (D) II and III only
56. How many isomeric compounds have the formula  $\text{C}_3\text{H}_8\text{O}$ ?  
(A) 1 (B) 2 (C) 3 (D) 4
57. How many sigma bonds does propyne,  $\text{C}_3\text{H}_4$ , have?  
(A) 2 (B) 4 (C) 6 (D) 8
58. Which of the compounds below will react readily with chlorine by addition?  
I  $\text{C}_2\text{H}_2$  (ethyne) II  $\text{C}_2\text{H}_4$  (ethene) III  $\text{C}_6\text{H}_6$  (benzene)  
(A) I only (B) I and II only  
(C) II and III only (D) I, II, and III
59. The smell of rancid butter is due to the presence of butyric (butanoic) acid. What is the formula for this compound?  
(A)  $\text{C}_4\text{H}_8\text{O}_2$  (B)  $\text{C}_4\text{H}_{10}\text{O}$   
(C)  $\text{C}_5\text{H}_{10}\text{O}_2$  (D)  $\text{C}_5\text{H}_{12}\text{O}$
60. In a double helix of DNA, adenine is paired with  
(A) adenine. (B) cytosine.  
(C) guanine. (D) thymine.

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**END OF TEST**

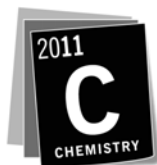
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**Olympiad 2011**  
**USNCO Local Section Exam**  
**KEY**

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