



# 2009 U. S. NATIONAL CHEMISTRY OLYMPIAD

## NATIONAL EXAM – PART I



Prepared by the American Chemical Society Olympiad Examinations Task Force

### OLYMPIAD EXAMINATIONS TASK FORCE

Arden P. Zipp, **Chair**, *State University of New York*, Cortland, NY

James Ayers, *Mesa State College*, Grand Junction, CO

Paul Groves, *South Pasadena HS*, South Pasadena, CA

Sherry Berman-Robinson, *Consolidated HS*, Orland Park, IL (retired) Preston Hays, *Glenbrook South HS*, Glenbrook, IL

Seth Brown, *University of Notre Dame*, Notre Dame, IN

David Hostage, *Taft School*, Watertown, CT

Peter Demmin, *Amherst HS*, Amherst, NY (retired)

Adele Mouakad, *St. John's School*, San Juan, PR

Marian Dewane, *Centennial HS*, Boise, ID

Jane Nagurney, *Scranton Preparatory School*, Scranton, PA

Valerie Ferguson, *Moore HS*, Moore, OK

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

Kimberly Gardner, *US Air Force Academy*, Colorado Springs, CO

#### DIRECTIONS TO THE EXAMINER—PART I

**Part I** of this test is designed to be taken with a Scantron® answer sheet on which the student records his or her responses. Only this Scantron sheet is graded for a score on **Part I**. Testing materials, scratch paper, and the Scantron sheet should be made available to the student *only* during the examination period. All testing materials including scratch paper should be turned in and kept secure until April 29, 2009, after which tests can be returned to students and their teachers for further study.

Allow time for the student to read the directions, ask questions, and fill in the requested information on the Scantron sheet. The answer sheet must be completed using a pencil, not pen. When the student has completed **Part I**, or after **one hour and thirty minutes** has elapsed, the student must turn in the Scantron sheet, **Part I** of the testing materials, and all scratch paper.

There are three parts to the National Olympiad Examination. You have the option of administering the three parts in any order, and you are free to schedule rest-breaks between parts.

<b>Part I</b>	<b>60 questions</b>	<b>single-answer multiple-choice</b>	<b>1 hour, 30 minutes</b>
<b>Part II</b>	<b>8 questions</b>	<b>problem-solving, explanations</b>	<b>1 hour, 45 minutes</b>
<b>Part III</b>	<b>2 lab problems</b>	<b>laboratory practical</b>	<b>1 hour, 30 minutes</b>

A periodic table and other useful information are provided on page 2 for student reference. Students should be permitted to use non-programmable calculators.

#### DIRECTIONS TO THE EXAMINEE—PART I

**DO NOT TURN THE PAGE UNTIL DIRECTED TO DO SO.** Answers to questions in **Part I** must be entered on a Scantron answer sheet to be scored. Be sure to write your name on the answer sheet; an ID number is already entered for you. **Make a record of this ID number because you will use the same number on both Parts II and III.** Each item in **Part I** consists of a question or an incomplete statement that is followed by four possible choices. Select the single choice that best answers the question or completes the statement. Then use a pencil to blacken the space on your answer sheet next to the same letter as your choice. You may write on the examination, but the test booklet will not be used for grading. Scores are based on the number of correct responses. When you complete **Part I** (or at the end of one hour and 30 minutes), you *must* turn in all testing materials, scratch paper, and your Scantron answer sheet. Do not forget to turn in your U.S. citizenship statement before leaving the testing site today.

**Not valid for use as an USNCO Olympiad National Exam after April 29, 2009.**

Distributed by the ACS DivCHED Examinations Institute, Iowa State University, Ames, IA.

All rights reserved. Printed in U.S.A.

ABBREVIATIONS AND SYMBOLS					
amount of substance	<i>n</i>	Faraday constant	<i>F</i>	molar	<i>M</i>
ampere	<i>A</i>	free energy	<i>G</i>	molar mass	<i>M</i>
atmosphere	atm	frequency	$\nu$	mole	mol
atomic mass unit	<i>u</i>	gas constant	<i>R</i>	Planck's constant	<i>h</i>
atomic molar mass	<i>A</i>	gram	<i>g</i>	pressure	<i>P</i>
Avogadro constant	$N_A$	hour	<i>h</i>	rate constant	<i>k</i>
Celsius temperature	°C	joule	<i>J</i>	reaction quotient	<i>Q</i>
centi- prefix	<i>c</i>	kelvin	<i>K</i>	second	<i>s</i>
coulomb	<i>C</i>	kilo- prefix	<i>k</i>	speed of light	<i>c</i>
electromotive force	<i>E</i>	liter	<i>L</i>	temperature, K	<i>T</i>
energy of activation	$E_a$	measure of pressure	mmHg	time	<i>t</i>
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>				

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

### 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	18
H	He											B	C	N	O	F	Ne
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						
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Uub						
(223)	(226)	(227)	(261)	(262)	(263)	(262)	(265)	(266)	(269)	(272)	(277)						

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. Which oxide produces an acidic solution when mixed with water?

- (A)  $\text{Al}_2\text{O}_3$     (B)  $\text{CaO}$     (C)  $\text{CO}$     (D)  $\text{SO}_2$

2. Which gas should not be collected over water due to its high solubility in water?

- (A)  $\text{H}_2$     (B)  $\text{N}_2$     (C)  $\text{NH}_3$     (D)  $\text{CH}_4$

3. Which procedure(s) will allow a student to differentiate between solid sodium sulfate and solid sodium sulfite?

- I.** Make solutions of each and look for a precipitate when added to 0.10 M  $\text{Ba}(\text{NO}_3)_2$ .
- II.** Add crystals of each to 0.10 M  $\text{HCl}$  and watch for bubbles.
- III.** Make solutions of each and test with a pH indicator.

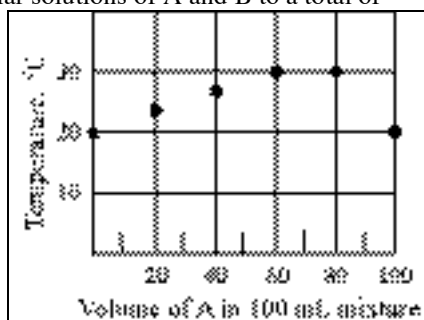
- (A) I only                                    (B) III only  
 (C) I and II only                            (D) II and III only

4. A student gets fingerprints on a cuvette before using it to determine the concentration of a colored species using its known extinction coefficient. What is the effect on the absorbance and reported concentration?

**absorbance                    reported concentration**

- (A) increased                    too low  
 (B) increased                    too high  
 (C) decreased                    too low  
 (D) decreased                    too high

5. Chemicals A and B each initially at 20 °C react exothermically. A graph of the final temperature reached by mixing equimolar solutions of A and B to a total of 100 mL is given to the right. According to this graph, in what mole ratio do A and B react?



- (A) 2:1    (B) 3:1    (C) 4:1    (D) 3:2

6. What color does the strontium ion produce in a flame test?

- (A) red    (B) blue    (C) green    (D) yellow

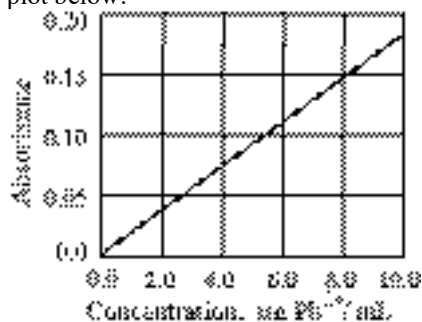
7. What is the mass percent

Formula Weight, g
$\text{UO}_2(\text{C}_2\text{H}_3\text{O}_2)_2 \cdot \text{NH}_4\text{C}_2\text{H}_3\text{O}_2 \cdot 6\text{H}_2\text{O}$ 573

of oxygen in the compound  $\text{UO}_2(\text{C}_2\text{H}_3\text{O}_2)_2 \cdot \text{NH}_4\text{C}_2\text{H}_3\text{O}_2 \cdot 6\text{H}_2\text{O}$ ?

- (A) 5.58%    (B) 16.8%    (C) 22.3%    (D) 39.1%

8. A 25.0 mL sample of waste water is obtained to analyze for  $\text{Pb}^{2+}$  ions. This sample is evaporated to dryness and redissolved in 2.0 mL of  $\text{H}_2\text{O}$ , mixed with 2.0 mL of a buffer solution and 2.0 mL of a solution of dithizone then diluted to 10.0 mL. The absorbance of the colored  $\text{Pb}^{2+}$ -dithizone complex is compared with the Beer-Lambert plot below.



The absorbance of a portion of the final solution is 0.13. What is the concentration of  $\text{Pb}^{2+}$  ions in the waste water in ppm?

- (A) 2.9    (B) 7.2    (C) 18    (D) 36

9. Reductic acid contains 52.63% carbon, 5.30% hydrogen, and 42.07% oxygen. Its empirical formula is the same as its molecular formula. What is the number of carbon atoms in a molecule of this acid?

- (A) 4    (B) 5    (C) 6    (D) 8

10. Sulfur trioxide,  $\text{SO}_3$ , is made by oxidizing sulfur dioxide,  $\text{SO}_2$ , according to the equation,  $2\text{SO}_2 + \text{O}_2 \rightarrow 2\text{SO}_3$ . If a 16.0 g sample of  $\text{SO}_2$  yields 18.0 g of  $\text{SO}_3$ , what is the percent yield?

- (A) 70.0%    (B) 80.0%    (C) 90.0%    (D) 100.0%

11. A 1.0 g sample of which substance contains the largest number of molecules?  
 (A)  $\text{HN}_3$  (B)  $\text{N}_2\text{H}_4$  (C)  $\text{H}_2\text{O}_2$  (D)  $\text{HCl}$
12. What is the maximum mass of  $\text{PbI}_2$  that can be precipitated by mixing 25.0 mL of 0.100 M  $\text{Pb}(\text{NO}_3)_2$  with 35.0 mL of 0.100 M  $\text{NaI}$ ?  

Molar Mass, $\text{g}\cdot\text{mol}^{-1}$	
$\text{PbI}_2$	461

  
 (A) 0.807 g (B) 1.15 g (C) 1.61 g (D) 2.30 g
13. Which statement is not a principle (postulate) of kinetic molecular theory?  
 (A) The molecules of a gas are in rapid random motion.  
 (B) The molecules of an ideal gas exhibit no attractive forces.  
 (C) The collisions of gaseous molecules with one another and the walls of their container are elastic.  
 (D) Equal volumes of gases at the same temperature and pressure contain equal numbers of molecules.
14. When a sample of an ideal gas is heated from  $25^\circ\text{C}$  to  $50^\circ\text{C}$  the average kinetic energy of the molecules increases. Which ratio gives the correct relationship between the average kinetic energies at the higher temperature to the lower temperature?  
 (A) 2 : 1 (B)  $\sqrt{2} : \sqrt{1}$   
 (C) 323 : 298 (D)  $\sqrt{323} : \sqrt{298}$
15. A partially filled tank of propane contains both a liquid and a gas phase. Which of these statements about the contents of the two phases are correct?  

I. The two phases have the same potential energy but different kinetic energies. II. The two phases have the same molar masses but different densities.	
--	--

  
 (A) I only (B) II only  
 (C) Both I and II (D) Neither I nor II
16. Which property or properties of metals can be accounted for by the electron sea model?  

I. electrical conductivity II. malleability	
--	--

  
 (A) I only (B) II only  
 (C) Both I and II (D) Neither I nor II
17. In a crystal of a typical metallic element, an atom has how many nearest neighbors?  
 (A) 4 (B) 6 (C) 12 (D) 16
18. Which aqueous solution has the highest osmotic pressure at  $25^\circ\text{C}$ ? (Assume all ionic compounds ionize completely in solution.)  
 (A) 0.1 M  $\text{Al}_2(\text{SO}_4)_3$  (B) 0.1 M  $\text{Na}_2\text{CO}_3$   
 (C) 0.2 M  $\text{KMnO}_4$  (D) 0.3 M  $\text{C}_6\text{H}_{12}\text{O}_6$
19. Which statement is correct at  $25^\circ\text{C}$  and 1 atm pressure?  
 (A)  $\Delta G^\circ_f$  for  $\text{Hg}(\text{l}) = 0 \text{ kJ}\cdot\text{mol}^{-1}$   
 (B)  $\Delta H^\circ_f$  for  $\text{I}_2(\text{g}) = 0 \text{ kJ}\cdot\text{mol}^{-1}$   
 (C)  $\Delta H^\circ_f$  for  $\text{H}_2\text{O}(\text{l}) = 0 \text{ kJ}\cdot\text{mol}^{-1}$   
 (D)  $S^\circ$  for  $\text{O}_2(\text{g}) = 0 \text{ J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$
20. What is the relationship among the magnitudes of the enthalpies of combustion ( $\Delta H_{\text{comb}}$ ), fusion ( $\Delta H_{\text{fus}}$ ) and vaporization ( $\Delta H_{\text{vap}}$ ) for a hydrocarbon such as hexane,  $\text{C}_6\text{H}_{14}$ ?  
 (A)  $\Delta H_{\text{fus}} < \Delta H_{\text{comb}} < \Delta H_{\text{vap}}$   
 (B)  $\Delta H_{\text{vap}} < \Delta H_{\text{fus}} < \Delta H_{\text{comb}}$   
 (C)  $\Delta H_{\text{comb}} < \Delta H_{\text{vap}} < \Delta H_{\text{fus}}$   
 (D)  $\Delta H_{\text{fus}} < \Delta H_{\text{vap}} < \Delta H_{\text{comb}}$
21. Which choice represents the signs for  $\Delta S$  and  $\Delta H$  for the sublimation of a compound that is occurring at constant temperature?  
 (A)  $\Delta S < 0, \Delta H < 0$  (B)  $\Delta S < 0, \Delta H > 0$   
 (C)  $\Delta S > 0, \Delta H > 0$  (D)  $\Delta S > 0, \Delta H < 0$
22. Determine  $\Delta H_{\text{rxn}}$  for this reaction in  $\text{kJ}\cdot\text{mol}^{-1}$   

$$2\text{NH}_3(\text{g}) + \frac{5}{2}\text{O}_2(\text{g}) \rightarrow 2\text{NO}(\text{g}) + 3\text{H}_2\text{O}(\text{g}).$$
  

$\Delta H^\circ_f, \text{kJ}\cdot\text{mol}^{-1}$	
$\text{H}_2\text{O}(\text{g})$	-241.8
$\text{NH}_3(\text{g})$	-46.1
$\text{NO}(\text{g})$	90.3

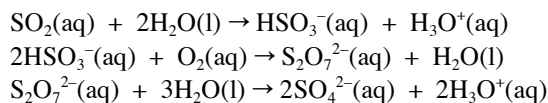
  
 (A) -105.4 (B) -226.3 (C) -452.6 (D) -637.0
23. The enthalpy of fusion for  $\text{NaF}(\text{s})$  at its melting point ( $992^\circ\text{C}$ ) is  $29.3 \text{ kJ}\cdot\text{mol}^{-1}$ . What is the value of  $\Delta S_{\text{fus}}^\circ$  in  $\text{J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$ ?  
 (A) 43.2 (B) 33.9 (C) 29.5 (D) 23.2
24. For the reaction at  $25^\circ\text{C}$ ,  

$$\text{C}_2\text{H}_4(\text{g}) + \text{H}_2(\text{g}) \rightleftharpoons \text{C}_2\text{H}_6(\text{g}) \quad K_p = 5.67 \times 10^7$$
  
 What is  $\Delta G^\circ$  for this reaction in  $\text{kJ}\cdot\text{mol}^{-1}$ ?  
 (A) -0.436 (B) -3.71 (C) -19.2 (D) -44.2

25. What is the rate law for a reaction,  $A + 2B \rightarrow C$ , based on the rate data?

$[A]_0, \text{mol}\cdot\text{L}^{-1}$	$[B]_0, \text{mol}\cdot\text{L}^{-1}$	Initial Rate, $\text{mol}\cdot\text{L}^{-1}\cdot\text{min}^{-1}$
0.20	0.10	300
0.40	0.30	3600
0.80	0.30	14400

- (A) Rate =  $k[A][B]$       (B) Rate =  $k[A][B]^2$   
 (C) Rate =  $k[A]^2[B]$       (D) Rate =  $k[A]^2[B]^3$
26. For the irreversible reaction;  $A \rightarrow B$ , which graph gives a straight line for a reaction that is second order in A?
- (A)  $[A]$  vs. time      (B)  $1/[A]$  vs. time  
 (C)  $[A]^2$  vs. time      (D)  $1/[A]^2$  vs. time
27. A sample of a radioactive element that contains  $1.0 \times 10^3$  nuclei decays to  $6.2 \times 10^1$  nuclei in 10. minutes. What is its specific decay constant?
- (A)  $6.2 \text{ min}^{-1}$       (B)  $1.2 \text{ min}^{-1}$   
 (C)  $0.28 \text{ min}^{-1}$       (D)  $0.062 \text{ min}^{-1}$
28. The oxidation of  $\text{SO}_2$  to  $\text{H}_2\text{SO}_4$  in acid rain is thought to occur by the following mechanism.



Which species in this mechanism can be given the following designations?

	reactant	catalyst	intermediate
(A)	$\text{SO}_2(\text{aq})$	$\text{H}_2\text{O}(\text{l})$	$\text{HSO}_3^-(\text{aq}), \text{H}_3\text{O}^+(\text{aq})$
(B)	$\text{SO}_2(\text{aq})$	$\text{HSO}_3^-(\text{aq})$	$\text{S}_2\text{O}_7^{2-}(\text{aq})$
(C)	$\text{SO}_2(\text{aq}), \text{H}_2\text{O}(\text{l})$	$\text{S}_2\text{O}_7^{2-}(\text{aq})$	$\text{HSO}_3^-(\text{aq})$
(D)	$\text{SO}_2(\text{aq}), \text{H}_2\text{O}(\text{l})$	none	$\text{HSO}_3^-(\text{aq}), \text{S}_2\text{O}_7^{2-}(\text{aq})$

29. For the reaction;  $\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightarrow 2\text{HI}(\text{g})$ , the rate law is Rate =  $k[\text{H}_2][\text{I}_2]$ . Which of the mechanisms given is consistent with this rate law?

I.	II.
$\text{I}_2 \rightleftharpoons \text{I} + \text{I}$ (fast)	$\text{I}_2 \rightleftharpoons \text{I} + \text{I}$ (slow)
$\text{H}_2 + \text{I} + \text{I} \rightarrow 2\text{HI}$ (slow)	$\text{H}_2 + \text{I} + \text{I} \rightarrow 2\text{HI}$ (fast)

- (A) I only      (B) II only  
 (C) Either I or II      (D) Neither I nor II

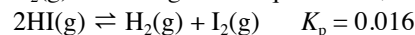
30. The rate of a reaction at  $100^\circ\text{C}$  is four times the rate at  $50^\circ\text{C}$ . What is its activation energy?

- (A)  $1152 \text{ kJ}\cdot\text{mol}^{-1}$       (B)  $80.1 \text{ kJ}\cdot\text{mol}^{-1}$   
 (C)  $54.0 \text{ kJ}\cdot\text{mol}^{-1}$       (D)  $27.8 \text{ kJ}\cdot\text{mol}^{-1}$

31. The equilibrium system,  $\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g})$ , has  $K_p = 11$ . For which equilibrium system is  $K_p = 0.091$ ?

- (A)  $2\text{NO}_2(\text{g}) \rightleftharpoons \text{N}_2\text{O}_4(\text{g})$       (B)  $\text{NO}_2(\text{g}) \rightleftharpoons 1/2\text{N}_2\text{O}_4(\text{g})$   
 (C)  $2\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 4\text{NO}_2(\text{g})$       (D)  $1/2\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons \text{NO}_2(\text{g})$

32. A 1.0 L evacuated tank is charged with  $\text{HI}(\text{g})$  to a pressure of 1.0 atm at  $793\text{K}$ . Some of the  $\text{HI}(\text{g})$  forms  $\text{H}_2(\text{g})$  and  $\text{I}_2(\text{g})$  according to the equilibrium;



What is the pressure (in atm) of  $\text{HI}$  at equilibrium?

- (A) 0.11      (B) 0.13      (C) 0.80      (D) 1.6

33. A solution of 0.10 M  $\text{NaZ}$  has a  $\text{pH} = 8.90$ . What is the  $K_a$  of  $\text{HZ}$ ?

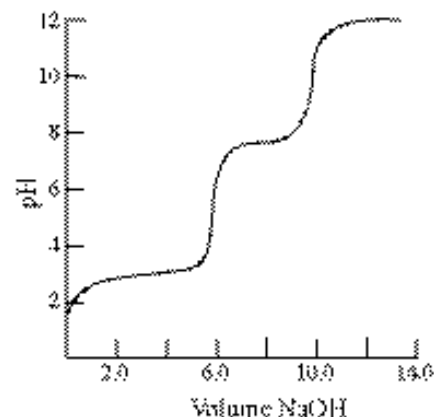
- (A)  $1.6 \times 10^{-4}$       (B)  $1.6 \times 10^{-5}$   
 (C)  $6.3 \times 10^{-10}$       (D)  $6.3 \times 10^{-11}$

34. What is the  $\text{pH}$  of a solution made by adding 0.41g of  $\text{NaC}_2\text{H}_3\text{O}_2$  to 100. mL of 0.10 M  $\text{HC}_2\text{H}_3\text{O}_2$ ?

Molar mass, $\text{g}\cdot\text{mol}^{-1}$	
$\text{NaC}_2\text{H}_3\text{O}_2$	82.0
$K_a$	
$\text{HC}_2\text{H}_3\text{O}_2$	$1.8 \times 10^{-5}$

- (A) 4.44      (B) 4.70      (C) 5.05      (D) 8.95

35. The curve represents the titration of



- (A) a diprotic acid.  
 (B) two monoprotic acids with the same  $K_a$ s but different concentrations.  
 (C) two monoprotic acids with different  $K_a$ s but the same concentrations.  
 (D) two monoprotic acids with different  $K_a$ s and different concentrations.

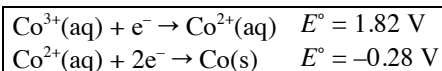
36. Which silver compound is the most soluble in water?

- (A)  $\text{AgCl}$   $K_{\text{sp}} = 1.8 \times 10^{-10}$   
 (B)  $\text{Ag}_2\text{CO}_3$   $K_{\text{sp}} = 8.5 \times 10^{-12}$   
 (C)  $\text{AgBr}$   $K_{\text{sp}} = 5.4 \times 10^{-13}$   
 (D)  $\text{Ag}_3\text{PO}_4$   $K_{\text{sp}} = 8.9 \times 10^{-17}$

37. When connected to a Standard Hydrogen Electrode (SHE) electrons flow from an unknown half cell to the SHE. Which statement is correct?

- (A) The unknown half cell is the anode.  
 (B) Oxidation occurs at the SHE.  
 (C)  $E^\circ_{\text{red}}$  for the unknown half cell is positive.  
 (D)  $E^\circ_{\text{cell}}$  is negative.

38. Given these standard



reduction potentials, what is the standard reduction potential for  $\text{Co}^{3+}(\text{aq}) + 3\text{e}^- \rightarrow \text{Co}(\text{s})$ ?

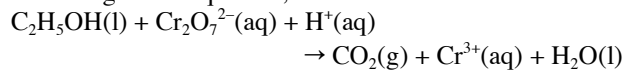
- (A) 2.10 V (B) 1.54 V  
 (C) 1.26 V (D) 0.42 V

39. The cell

$\text{Al}(\text{s}) | \text{Al}^{3+}(\text{aq}, 0.001 \text{ M}) || \text{Cu}^{2+}(\text{aq}, 0.10 \text{ M}) | \text{Cu}(\text{s})$   
 has a standard cell potential,  $E^\circ = 2.00 \text{ V}$ . What is the cell potential for this cell at the concentrations given?

- (A) 2.07 V (B) 2.03 V (C) 1.97 V (D) 1.94 V

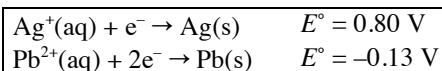
40. Ethanol reacts with dichromate ions in acid solution according to the equation;



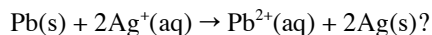
What is the coefficient for  $\text{H}^+(\text{aq})$  when this equation is balanced with the smallest whole number coefficients?

- (A) 10 (B) 12 (C) 14 (D) 16

41. Given these standard



reduction potentials, what is the free energy change (in  $\text{kJ}\cdot\text{mol}^{-1}$ ) for the reaction



- (A) -180 (B) -90 (C) 90 (D) 180

42. Chromium metal can be produced by the electrolysis of molten  $\text{CrO}_3$ . What current in amperes operating for 100 minutes is needed to produce 104 grams of this metal?

- (A) 193 (B) 96.5 (C) 64.3 (D) 32.2

43. What is the frequency of light with a wavelength of 480 nm?

- (A)  $1.60 \times 10^{-6} \text{ s}^{-1}$  (B)  $6.25 \times 10^5 \text{ s}^{-1}$   
 (C)  $6.25 \times 10^{14} \text{ s}^{-1}$  (D)  $1.44 \times 10^{20} \text{ s}^{-1}$

44. Which set of quantum numbers ( $n, l, m_l$ ) is forbidden?

- (A) 3, 2, 0 (B) 3, 1, -1  
 (C) 2, 0, 0 (D) 1, 1, 0

45. Which characteristic of an atomic orbital is most closely associated with the magnetic quantum number,  $m_l$ ?

- (A) size (B) shape  
 (C) occupancy (D) orientation

46. Which element exhibits the successive ionization energies given in the table?

**Ionization Energy,  $\text{kJ}\cdot\text{mol}^{-1}$**

1 <sup>st</sup>	738
2 <sup>nd</sup>	1451
3 <sup>rd</sup>	7733
4 <sup>th</sup>	10540
5 <sup>th</sup>	13628

- (A) Na (B) Mg (C) Al (D) Si

47. The energies of the 3s, 3p and 3d orbitals in a multi-electron atom increase in that order. To which factor(s) can this order be attributed?

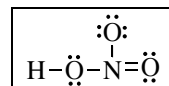
- |  |
|--|
| I. the relative penetrations of these orbitals near the nucleus    |
| II. the relative average distance of the electron from the nucleus |

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

48. Which element has the highest first ionization energy?

- (A) Al (B) Si (C) P (D) S

49. What is the formal charge on the nitrogen atom in  $\text{HNO}_3$ ?



- (A) 0 (B) +1 (C) +3 (D) +5

50. Which substance has the greatest lattice energy?

- (A) CaO (B) KCl (C)  $\text{MgI}_2$  (D) BaS

51. Given the bond energies, what is the  $\Delta H_f^\circ$   $\text{N}_2\text{H}_4(\text{g})$  in  $\text{kJ}\cdot\text{mol}^{-1}$ ?  
 $\text{N}_2(\text{g}) + 2\text{H}_2(\text{g}) \rightarrow \text{N}_2\text{H}_4(\text{g})$

**Bond Energies,  $\text{kJ}\cdot\text{mol}^{-1}$**

$\text{N}\equiv\text{N}$	946
$\text{N}=\text{N}$	418
$\text{N}-\text{N}$	163
$\text{N}-\text{H}$	389
$\text{H}-\text{H}$	436

- (A) 156 (B) 99 (C) -99 (D) -156

52. Which species has a trigonal planar geometry?

- (A)  $\text{ClF}_3$     (B)  $\text{NCl}_3$     (C)  $\text{CO}_3^{2-}$     (D)  $\text{I}_3^-$

53. Which of the molecules listed have an  $\text{sp}^3$  hybridized central atom?

- I.  $\text{PCl}_3$   
II.  $\text{COCl}_2$   
III.  $\text{SF}_4$

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

54. How many isomers exist for a square planar platinum compound which has four different groups attached to the platinum atom?

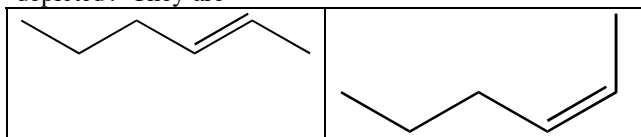
- (A) one    (B) two    (C) three    (D) four

55. Molecules of which type(s) do not contain a  $\text{C}=\text{O}$  bond?

- I. amide  
II. amine  
III. ether  
IV. ester

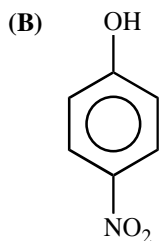
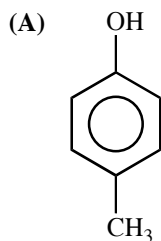
- (A) II only                      (B) I and IV only  
(C) II and III only          (D) III and IV only

56. What is the relationship between the two molecules depicted? They are



- (A) identical.                      (B) geometric isomers.  
(C) structural isomers.          (D) enantiomers.

57. For which compound is the  $-\text{OH}$  group the most acidic?

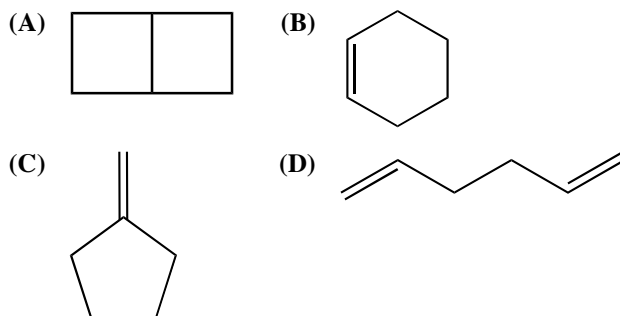


- (C)  $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$           (D)  $(\text{CH}_3)_3\text{COH}$

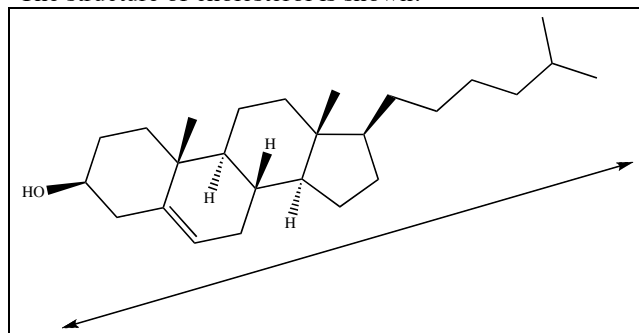
58. The most notable difference between a saturated and an unsaturated fat containing the same number of carbon atoms is that the saturated fat

- (A) melts at a higher temperature.  
(B) melts at a lower temperature.  
(C) releases much more energy when metabolized.  
(D) releases much less energy when metabolized.

59. Which  $\text{C}_6\text{H}_{10}$  isomer is the least stable?



60. The structure of cholesterol is shown.



What is the approximate length of this molecule (as indicated by the scale bar)? ( $1 \text{ \AA} = 1 \times 10^{-10} \text{ m}$ )

- (A)  $1.75 \text{ \AA}$                       (B)  $17.5 \text{ \AA}$   
(C)  $175 \text{ \AA}$                       (D)  $1750 \text{ \AA}$

**END OF TEST**

---

---

# Olympiad 2009 National Exam Part 1

## KEY

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