



# 2006 U. S. NATIONAL CHEMISTRY OLYMPIAD

## NATIONAL EXAM PART 1



Prepared by the American Chemical Society Olympiad Examinations Task Force

### OLYMPIAD EXAMINATIONS TASK FORCE

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#### 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 25, 2006, 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.

ABBREVIATIONS AND SYMBOLS			
ampere	A	Faraday constant	$F$
atmosphere	atm	formula molar mass	$M$
atomic mass unit	u	free energy	$G$
atomic molar mass	$A$	frequency	$\nu$
Avogadro constant	$N_A$	gas constant	$R$
Celsius temperature	$^{\circ}\text{C}$	gram	g
centi- prefix	c	heat capacity	$C_p$
coulomb	C	hour	h
electromotive force	$E$	joule	J
energy of activation	$E_a$	kelvin	K
enthalpy	$H$	kilo- prefix	k
entropy	$S$	liter	L
equilibrium constant	$K$	milli- prefix	m
		molal	$m$
		molar	M
		molar mass	$M$
		mole	mol
		Planck's constant	$h$
		pressure	$P$
		rate constant	$k$
		retention factor	$R_f$
		second	s
		temperature, K	$T$
		time	$t$
		volt	V

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

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											3A	4A	5A	6A	7A	He
1.008	4.003											10.81	12.01	14.01	16.00	19.00	4.003
3	4	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Li	Be	B	C	N	O	F	Ne	Na	Mg	Al	Si	P	S	Cl	Ar		
6.941	9.012	10.81	12.01	14.01	16.00	19.00	20.18	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	(269)	(272)	(277)						
(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

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90	91	92	93	94	95	96	97	98	99	100	101	102	103
<b>Th</b>	<b>Pa</b>	<b>U</b>	<b>Np</b>	<b>Pu</b>	<b>Am</b>	<b>Cm</b>	<b>Bk</b>	<b>Cf</b>	<b>Es</b>	<b>Fm</b>	<b>Md</b>	<b>No</b>	<b>Lr</b>
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.
- This is a single use exam, so you may make marks in the test booklet.
- 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.**

- Which substance is NOT paired correctly with its name?  
(A) baking soda - potassium hydrogen tartrate  
(B) chalk - calcium carbonate  
(C) Epsom salt - magnesium sulfate heptahydrate  
(D) Plaster of Paris - calcium sulfate hemihydrate
  - Which acid should be stored in plastic containers rather than in glass ones?  
(A) hydrofluoric acid      (B) nitric acid  
(C) phosphoric acid      (D) sulfuric acid
  - Which element does NOT occur as distinct allotropes at temperatures between 0°C and 150°C?  
(A) phosphorus      (B) silicon  
(C) sulfur      (D) tin
  - Which gas is odorless?  
(A) CH<sub>4</sub>      (B) HCl      (C) NH<sub>3</sub>      (D) O<sub>3</sub>
  - Which technique is preferred for delivering a solid into a pre-weighed beaker for weighing?  
(A) Transfer more of the reagent than is needed to the beaker. Return the excess to the bottle with a spatula.  
(B) Transfer the desired amount of solid from the reagent bottle by holding the neck of the open bottle over the beaker and tapping the bottle. Then weigh the beaker and solid.  
(C) Weigh a spatula, scoop the desired amount of solid from the bottle, transfer it to the beaker and reweigh the spatula.  
(D) Weigh a piece of filter paper, tap the neck of the bottle to transfer solid to the filter paper, weigh the filter paper and transfer the solid to the beaker.
  - Bronze is an alloy of  
(A) copper and tin      (B) copper and zinc  
(C) nickel and tin      (D) nickel and zinc
  - What is the molarity of KI in a solution that is 5.00% KI by mass and has a density of 1.038 g·cm<sup>-3</sup>?  
(A) 0.0301 M      (B) 0.313 M  
(C) 0.500 M      (D) 0.625 M
  - What is the concentration of the solution that results from mixing 40.0 mL of 0.200 M HCl with 60.0 mL of 0.100 M NaOH? (You may assume the volumes are additive.)  
(A) 0.150 M NaCl  
(B) 0.0200 M NaCl and 0.0200 M HCl  
(C) 0.0200 M NaCl and 0.0600 M HCl  
(D) 0.0600 M NaCl and 0.0200 M HCl
  - Mole fractions are typically used to calculate which properties for solutions containing nonvolatile solutes?  
(A) I only      (B) III only  
(C) I and II only      (D) II and III only
- |     |                           |
|-----|---------------------------|
| I   | freezing point depression |
| II  | osmotic pressure          |
| III | vapor pressure            |
- An unknown anion in solution is to be identified by adding Ag<sup>+</sup> and Ba<sup>2+</sup> ions to separate portions of it. Which anion would produce the results listed for it? (+ indicates the presence of a precipitate)

	Ag <sup>+</sup>	Ba <sup>2+</sup>
(A) carbonate	+	-
(B) hydroxide	-	+
(C) iodide	+	-
(D) sulfide	-	-
  - A 1.0 L portion of a 0.30m solution of which of the following would be most effective at removing ice from a sidewalk?  
(A) C<sub>6</sub>H<sub>12</sub>O<sub>6</sub>      (B) NaBr  
(C) KNO<sub>3</sub>      (D) CaCl<sub>2</sub>

12.  $C_6H_6 + Br_2 \rightleftharpoons C_6H_5Br + HBr$   
 In an experiment to prepare bromobenzene according to the equation, a student reacted 20.0 g of  $C_6H_6$  with 0.310 mol of bromine. If 28.0 g of  $C_6H_5Br$  was obtained, what was the percentage yield?

(A) 31.5 (B) 40.3 (C) 57.6 (D) 69.7

13. When the substances are arranged in order of increasing boiling points, which order is correct?

<b>I</b>	$CH_3(CH_2)_3CH_3$
<b>II</b>	$CH_3CH_2CH(CH_3)_2$
<b>III</b>	$C(CH_3)_4$

(A) I < II < III (B) II < III < I  
 (C) III < II < I (D) III < I < II

14. A 225 mL sample of  $H_2$  is collected over water at 25 °C and 735 mmHg pressure. Which expression represents the set-up to find the volume of dry  $H_2$  at 0 °C and 1 atmosphere?

Vapor Pressure at 25 °C	
$H_2O$	24 mmHg

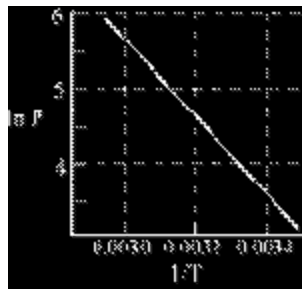
(A)  $V = \frac{225 \times (735 - 24) \times 273}{760 \times 298}$

(B)  $V = \frac{225 \times 760 \times 298}{(735 - 24) \times 273}$

(C)  $V = \frac{225 \times 273 \times 760}{(735 + 24) \times 298}$

(D)  $V = \frac{225 \times (735 + 24) \times 298}{760 \times 273}$

15. What is  $\Delta H_{vap}$  for the substance whose vapor pressure is represented by the diagram?



(A) 4.8 kJ·mol<sup>-1</sup> (B) 33 kJ·mol<sup>-1</sup>  
 (C) 44 kJ·mol<sup>-1</sup> (D) 50 kJ·mol<sup>-1</sup>

16. What occurs when liquid  $CH_2F_2$  evaporates?

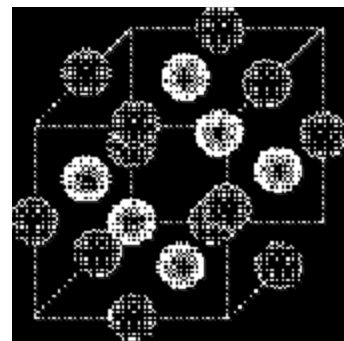
<b>I</b>	Dispersion forces are overcome.
<b>II</b>	Dipole-dipole forces are overcome.
<b>III</b>	Covalent bonds are broken.

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

17. In the van der Waals equation for real gases, corrections are introduced for both the pressure and the volume terms of the Ideal Gas Equation. Identify the origin of both correction factors and specify whether each is added to or subtracted from the corresponding term.

	Pressure	Volume
(A)	attractive forces / subtracted	molecular size / added
(B)	attractive forces / added	molecular size / subtracted
(C)	molecular size / subtracted	attractive forces / added
(D)	molecular size / added	attractive forces / subtracted

18. The structure of a unit cell of an oxide of niobium is depicted here. Niobiums are dark and oxygens are light. What is the empirical formula of this compound?

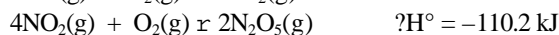
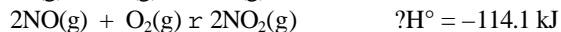


(A) NbO (B) NbO<sub>2</sub> (C) NbO<sub>3</sub> (D) Nb<sub>2</sub>O<sub>3</sub>

19. For a reaction that is exothermic and non-spontaneous at 25 °C, which quantity must be positive?

(A)  $\Delta E^\circ$  (B)  $\Delta G^\circ$  (C)  $\Delta H^\circ$  (D)  $\Delta S^\circ$

20. Use the thermochemical data given to calculate  $\Delta H_f^\circ$  for  $N_2O_5(g)$  in kJ·mol<sup>-1</sup>.



(A) -332.8 (B) -43.8 (C) 11.3 (D) 22.6

21. Bromine boils at 59°C with  $\Delta H_{vap}^\circ = 29.6$  kJ·mol<sup>-1</sup>. What is the value of  $\Delta S_{vap}^\circ$  in J·mol<sup>-1</sup>·K<sup>-1</sup>?

(A) 11.2 (B) 89.2 (C) 501 (D) 1750

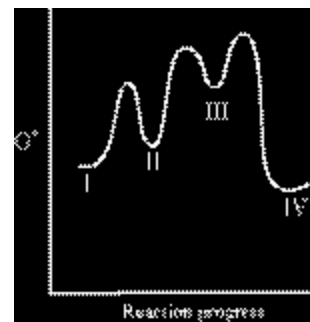
22. The  $K_{sp}$  of calcium fluoride is  $3.2 \times 10^{-11}$ . Calculate the  $\Delta G^\circ$  (in kJ·mol<sup>-1</sup>) for the dissolving of solid calcium fluoride at 25°C.

(A) 2.18 (B) 5.02 (C) 26.0 (D) 59.9

23. For which exothermic reaction is  $\Delta E$  more negative than  $\Delta H$ ?

- (A)  $\text{Br}_2(\text{l}) \rightleftharpoons \text{Br}_2(\text{g})$   
 (B)  $2\text{C}(\text{s}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{CO}(\text{g})$   
 (C)  $\text{H}_2(\text{g}) + \text{F}_2(\text{g}) \rightleftharpoons 2\text{HF}(\text{g})$   
 (D)  $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$
24. For a reaction at  $25^\circ\text{C}$ ,  $\Delta G = 12.7 \text{ kJ}$  when the reaction quotient,  $Q = 10.0$ . What is the value of  $\Delta G^\circ$  for this reaction?  
 (A)  $-12.1 \text{ kJ}$  (B)  $7.0 \text{ kJ}$   
 (C)  $18.4 \text{ kJ}$  (D)  $37.5 \text{ kJ}$
25. How can the rate of reaction at a specific time be determined from a graph of concentration against time?  
 (A) concentration at that time divided by the time  
 (B) logarithm of the concentration divided by the time  
 (C) absolute value of the slope of the graph at that time  
 (D) logarithm of the slope divided by the time
26. The rate constant for the radioactive decay of C-11 is  $0.0341 \text{ min}^{-1}$ . How long will it take for a sample of C-11 to decrease to  $1/4$  of its original activity?  
 (A) 20.3 min (B) 29.3 min  
 (C) 40.6 min (D) 58.6 min
27. If a reaction  $\text{A} \rightleftharpoons \text{B}$  has the rate law  $k[\text{A}]^2$ , which graph produces a straight line?  
 (A)  $1/[\text{A}]$  vs time (B)  $\ln[\text{A}]$  vs time  
 (C)  $[\text{A}]^2$  vs time (D)  $1/\ln[\text{A}]$  vs time
28. Two unimolecular reactions, I and II, have the same rate constant at  $25^\circ\text{C}$  but  $E_a$  for reaction I is larger than  $E_a$  for reaction II. Which statement about these two reactions is correct?  
 (A)  $k_{\text{reaction I}}$  is the same as  $k_{\text{reaction II}}$  at all temperatures.  
 (B)  $k_{\text{reaction I}}$  is larger than  $k_{\text{reaction II}}$  at lower temperatures but smaller at higher temperatures.  
 (C)  $k_{\text{reaction I}}$  is smaller than  $k_{\text{reaction II}}$  at lower temperatures but larger at higher temperatures.  
 (D)  $k_{\text{reaction I}}$  is larger than  $k_{\text{reaction II}}$  at temperatures both lower and higher than  $25^\circ\text{C}$ .

29. According to the reaction profile given, which reaction step is rate-determining in the forward direction?



- (A) I  $\rightleftharpoons$  II (B) II  $\rightleftharpoons$  III  
 (C) III  $\rightleftharpoons$  IV (D) III  $\rightleftharpoons$  IV
30. For the reaction;  
 $2\text{H}_2(\text{g}) + 2\text{NO}(\text{g}) \rightleftharpoons \text{N}_2(\text{g}) + 2\text{H}_2\text{O}(\text{g})$ ,  
 $\text{rate} = k[\text{H}_2][\text{NO}]^2$ .  
 This mechanism has been proposed:  
 step 1  $\text{H}_2 + \text{NO} \rightleftharpoons \text{H}_2\text{O} + \text{N}$   
 step 2  $\text{N} + \text{NO} \rightleftharpoons \text{N}_2 + \text{O}$   
 step 3  $\text{O} + \text{H}_2 \rightleftharpoons \text{H}_2\text{O}$   
 Which statement about this rate law and mechanism is correct?  
 (A) This mechanism is consistent with the rate law IF step 1 is the rate determining step.  
 (B) This mechanism is consistent with the rate law IF step 2 is the rate determining step.  
 (C) This mechanism is consistent with the rate law IF step 3 is the rate determining step.  
 (D) This mechanism can not be consistent with the rate law, regardless of which step is rate-determining.
31.  $\text{C}(\text{s}) + \text{CO}_2(\text{g}) \rightleftharpoons 2\text{CO}(\text{g})$   
 If this system is at equilibrium, which change(s) will alter the value of  $K_p$ ?  
 I raising the temperature  
 II adding solid C  
 III decreasing the pressure  
 (A) I only (B) II only  
 (C) I and III only (D) II and III only
32. A 0.10 M solution of a weak acid is 5.75% ionized. What is the  $K_a$  value for this acid?  
 (A)  $3.3 \times 10^{-3}$  (B)  $3.5 \times 10^{-4}$   
 (C)  $4.2 \times 10^{-5}$  (D)  $3.3 \times 10^{-5}$
33. Which base is most suitable to prepare a buffer solution with a  $\text{pH} = 11.00$ ?  
 (A) ammonia ( $K_b = 1.8 \times 10^{-5}$ )  
 (B) aniline ( $K_b = 4.0 \times 10^{-10}$ )  
 (C) methylamine ( $K_b = 4.4 \times 10^{-4}$ )  
 (D) pyridine ( $K_b = 1.7 \times 10^{-9}$ )

34. Calculate the pH of a 0.10 M solution of  $\text{H}_2\text{CO}_3$ .
- | $\text{H}_2\text{CO}_3$ Acid Ionization Constants |                       |
|---|-----------------------|
| $K_{1a}$  | $4.4 \times 10^{-7}$  |
| $K_{2a}$  | $4.7 \times 10^{-11}$ |
- (A) 3.68      (B) 5.76      (C) 7.36      (D) 9.34

35. Which saturated solution has the highest  $[\text{OH}^-]$ ?
- (A) aluminum hydroxide ( $K_{sp} = 1.8 \times 10^{-32}$ )  
 (B) calcium hydroxide ( $K_{sp} = 8.0 \times 10^{-6}$ )  
 (C) iron(II) hydroxide ( $K_{sp} = 1.6 \times 10^{-14}$ )  
 (D) magnesium hydroxide ( $K_{sp} = 1.2 \times 10^{-11}$ )

36. Consider these mixtures:

Mixture I. 100 mL of 0.006 M $\text{Pb}(\text{NO}_3)_2$ plus 50 mL of 0.003 M NaBr	
Mixture II. 100 mL of 0.008 M $\text{Pb}(\text{NO}_3)_2$ plus 100 mL of 0.006 M NaBr	
Which statement is correct?	<b><math>K_{sp}</math></b>
	$\text{PbBr}_2$ $6.6 \times 10^{-6}$

- (A) A precipitate will not form in either mixture.  
 (B) A precipitate will form only in mixture I.  
 (C) A precipitate will form only in mixture II.  
 (D) A precipitate will form in both mixtures.
37. The equation for one of the half-reactions in a lead storage battery is:  
 $\text{PbO}_2 + 4\text{H}^+ + \text{SO}_4^{2-} + 2\text{e}^- \rightleftharpoons \text{PbSO}_4 + 2\text{H}_2\text{O}$   
 What happens to the properties of the electrolyte as this cell discharges?
- |     | Density   | pH        |
|-----|-----------|-----------|
| (A) | increases | increases |
| (B) | increases | decreases |
| (C) | decreases | decreases |
| (D) | decreases | increases |
38. For the voltaic cell based on this reaction:  
 $2\text{Ag}^+(\text{aq}) + \text{Cu} \rightleftharpoons \text{Cu}^{2+}(\text{aq}) + 2\text{Ag}$   
 the concentrations of the aqueous ions and sizes of the electrodes can be changed independently. Which statement is correct?

- (A) Increasing the  $[\text{Cu}^{2+}]$  two-fold has the same effect on the cell voltage as increasing the  $[\text{Ag}^+]$  four-fold.  
 (B) Decreasing the  $[\text{Cu}^{2+}]$  ten-fold has the same effect on the cell voltage as decreasing the  $[\text{Ag}^+]$  by the same ratio.  
 (C) Decreasing the  $[\text{Cu}^{2+}]$  ten-fold has less effect on the cell voltage than decreasing the  $[\text{Ag}^+]$  by the same amount.  
 (D) Doubling the sizes of the cathode has exactly the same effect on the cell voltage as decreasing the  $[\text{Cu}^{2+}]$  by a factor of two.

39.  $3\text{Ni}^{2+} + 2\text{Al} \rightleftharpoons 2\text{Al}^{3+} + 3\text{Ni}$        $E^\circ = 1.41 \text{ V}$   
 For the reaction given, which expression gives the value of  $\Delta G^\circ$  in  $\text{kJ}\cdot\text{mol}^{-1}$ ?

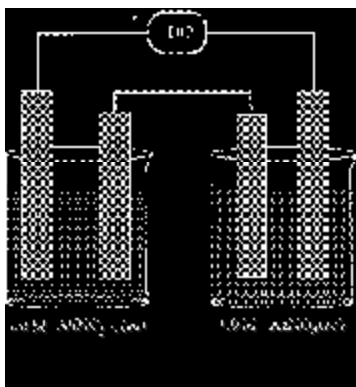
- (A)  $\frac{-3 \times 96.5}{1.41}$       (B)  $\frac{-6 \times 96.5}{1.41}$   
 (C)  $-3 \times 96.5 \times 1.41$       (D)  $-6 \times 96.5 \times 1.41$

40. In which species is the oxidation number for hydrogen different from those in the other three?

- (A)  $\text{AlH}_3$       (B)  $\text{H}_3\text{AsO}_4$   
 (C)  $\text{H}_3\text{PO}_3$       (D)  $\text{NH}_3$

41. A solution containing equimolar amounts of  $\text{NiCl}_2$  and  $\text{SnBr}_2$  is electrolyzed using a 9V battery and graphite electrodes. What are the first products formed?
- | <b>Standard Reduction Potential (V)</b>   |        |
|---|--------|
| $\text{Ni}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Ni}(\text{s})$  | -0.236 |
| $\text{Sn}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Sn}(\text{s})$  | -0.141 |
| $\text{Br}_2(\text{aq}) + 2\text{e}^- \rightleftharpoons 2\text{Br}^-(\text{aq})$ | 1.077  |
| $\text{Cl}_2(\text{aq}) + 2\text{e}^- \rightleftharpoons 2\text{Cl}^-(\text{aq})$ | 1.360  |
- (A) Ni(s) at cathode,  $\text{Cl}_2(\text{aq})$  at anode  
 (B) Ni(s) at cathode,  $\text{Br}_2(\text{aq})$  at anode  
 (C) Sn(s) at cathode,  $\text{Br}_2(\text{aq})$  at anode  
 (D) Sn(s) at cathode,  $\text{Cl}_2(\text{aq})$  at anode

42. True statements about the system shown after the passage of one Faraday of electricity include which of those given?



- I.** The number of moles of Al formed is greater than the number of moles of silver formed.  
**II.** The final  $[Al^{3+}]$  is greater than the final  $[Ag^+]$ .  
**III.** The number of electrons reacting with  $Al^{3+}$  ions is the same as the number reacting with  $Ag^+$  ions.

- (A) I only                      (B) I and III only  
 (C) II and III only            (D) I, II and III
43. When  $l = 3$ , what are the possible values for the quantum number  $m_l$ ?
- (A) 2, 1, 0                      (B) 3, 2, 1, 0  
 (C) 2, 1, 0, -1, -2            (D) 3, 2, 1, 0, -1, -2, -3
44. The first ionization energy of cesium is  $6.24 \times 10^{-19}$  J/atom. What is the minimum frequency of light that is required to ionize a cesium atom?
- (A)  $1.06 \times 10^{15} \text{ s}^{-1}$             (B)  $4.13 \times 10^{14} \text{ s}^{-1}$   
 (C)  $9.42 \times 10^{14} \text{ s}^{-1}$             (D)  $1.60 \times 10^{18} \text{ s}^{-1}$
45. When the isoelectronic ions,  $Cl^-$ ,  $S^{2-}$  and  $K^+$  are arranged in order of increasing size, which order is correct?
- (A)  $K^+$ ,  $Cl^-$ ,  $S^{2-}$                 (B)  $K^+$ ,  $S^{2-}$ ,  $Cl^-$   
 (C)  $S^{2-}$ ,  $Cl^-$ ,  $K^+$                 (D)  $Cl^-$ ,  $S^{2-}$ ,  $K^+$
46. Which is most similar for the elements in a group in the periodic table?
- (A) physical state  
 (B) melting point  
 (C) first ionization energy  
 (D) ground state electron configuration
47. How many unpaired electrons are present in a gaseous  $Co^{3+}$  ion in its ground state?
- (A) 1                      (B) 3                      (C) 4                      (D) 5
48. Which nucleus is not radioactive?

- (A) K-38            (B) K-39            (C) K-42            (D) K-43

49. When the species listed are arranged in order of increasing bond angle, which order is correct?
- (A)  $H_2Se$ ,  $H_2S$ ,  $H_2O$             (B)  $H_2S$ ,  $H_2Se$ ,  $H_2O$   
 (C)  $H_2S$ ,  $H_2O$ ,  $H_2Se$             (D)  $H_2O$ ,  $H_2S$ ,  $H_2Se$

50. Which terms are exothermic for the formation of  $NaF(s)$ ?

- I.**  $Na(g) \rightarrow Na^+(g) + e^-$   
**II.**  $F(g) + e^- \rightarrow F^-(g)$   
**III.**  $Na^+(g) + F^-(g) \rightarrow NaF(s)$

- (A) I only                      (B) II only  
 (C) I and III only            (D) II and III only
51. What is the shape of the  $TeF_5^-$  anion?
- (A) see-saw                      (B) square pyramidal  
 (C) trigonal pyramidal            (D) trigonal bipyramidal
52. How many sigma and pi bonds are in maleic acid,  $HO_2CCH=CHCO_2H$ ?
- (A) 7 sigma, 2 pi                (B) 8 sigma, 3 pi  
 (C) 9 sigma, 2 pi                (D) 11 sigma, 3 pi
53. How many isomers exist for the octahedral compound,  $Pt(NH_3)_2Cl_4$ ?
- (A) 1                      (B) 2                      (C) 3                      (D) 4
54. What is the formal charge on the sulfur atom in  $SO_2$ ? (Assume a Lewis dot structure in which all atoms obey the octet rule.)
- (A) +1                      (B) +2                      (C) -1                      (D) -2
55. How many structural isomers are possible for  $C_6H_{14}$ ?
- (A) 2                      (B) 3                      (C) 4                      (D) 5
56. Which is an ester?
- (A)  $CH_3COOCH_2CH_3$             (B)  $(CH_3)_3COOC(CH_3)_3$   
 (C)  $CH_3OCH_3$                       (D)  $(CH_3)_3CCOOH$
57. Which type of reaction is typical of aromatic compounds?
- (A) addition  
 (B) free-radical substitution  
 (C) substitution by positively-charged reagents  
 (D) substitution by negatively-charged reagents
58. What is the IUPAC name of  $(CH_3)_2CHCH=CHCH_3$ ?



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- (A) 1,2-methyl-isopropylethene  
(B) 1,1-dimethyl-2-butene  
(C) 1-isopropylpropene  
(D) 4-methyl-2-pentene
59. Which compound can exist in optically active forms?  
(A)  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$       (B)  $\text{CH}_3\text{CH}_2\text{CH}(\text{OH})\text{CH}_3$   
(C)  $(\text{CH}_3)_2\text{CHCH}_2\text{OH}$       (D)  $(\text{CH}_3)_3\text{COH}$
60. How many different tripeptides can be formed from the amino acids glycine, alanine and valine if each is used only once in each tripeptide?  
(A) 3      (B) 4      (C) 5      (D) 6

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**END OF PART I**

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**CHEMISTRY OLYMPIAD 2006**  
**National Test, PART I**  
**KEY**

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