# 1999 U. S. NATIONAL CHEMISTRY OLYMPIAD

## NATIONAL EXAM—PART I

**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 26, 1999, 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.

| | | | |
|---|---|---|---|
| **Part I** | **60 questions** | **single-answer multiple-choice** | **1 hour, 30 minutes** |
| **Part II** | **8 questions** | **problem-solving, explanations** | **1 hour, 45 minutes** |
| **Part III** | **2 questions** | **laboratory practical** | **1 hour, 15 minutes** |

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 you name on the answer sheet; an ID number is already entered for you. **Make a record of this ID number as 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 which 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 having 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 National Exam after April 26, 1999.**

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

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

# PERIODIC TABLE OF THE ELEMENTS

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 **H** 1.008 | | | | | | | | | | | | | | | | | 2 **He** 4.003 |
| 3 **Li** 6.941 | 4 **Be** 9.012 | | | | | | | | | | | 5 **B** 10.81 | 6 **C** 12.01 | 7 **N** 14.01 | 8 **O** 16.00 | 9 **F** 19.00 | 10 **Ne** 20.18 |
| 11 **Na** 22.99 | 12 **Mg** 24.31 | | | | | | | | | | | 13 **Al** 26.98 | 14 **Si** 28.09 | 15 **P** 30.97 | 16 **S** 32.07 | 17 **Cl** 35.45 | 18 **Ar** 39.95 |
| 19 **K** 39.10 | 20 **Ca** 40.08 | 21 **Sc** 44.96 | 22 **Ti** 47.88 | 23 **V** 50.94 | 24 **Cr** 52.00 | 25 **Mn** 54.94 | 26 **Fe** 55.85 | 27 **Co** 58.93 | 28 **Ni** 58.69 | 29 **Cu** 63.55 | 30 **Zn** 65.39 | 31 **Ga** 69.72 | 32 **Ge** 72.61 | 33 **As** 74.92 | 34 **Se** 78.96 | 35 **Br** 79.90 | 36 **Kr** 83.80 |
| 37 **Rb** 85.47 | 38 **Sr** 87.62 | 39 **Y** 88.91 | 40 **Zr** 91.22 | 41 **Nb** 92.91 | 42 **Mo** 95.94 | 43 **Tc** (98) | 44 **Ru** 101.1 | 45 **Rh** 102.9 | 46 **Pd** 106.4 | 47 **Ag** 107.9 | 48 **Cd** 112.4 | 49 **In** 114.8 | 50 **Sn** 118.7 | 51 **Sb** 121.8 | 52 **Te** 127.6 | 53 **I** 126.9 | 54 **Xe** 131.3 |
| 55 **Cs** 132.9 | 56 **Ba** 137.3 | 57 **La** 138.9 | 72 **Hf** 178.5 | 73 **Ta** 181.0 | 74 **W** 183.8 | 75 **Re** 186.2 | 76 **Os** 190.2 | 77 **Ir** 192.2 | 78 **Pt** 195.1 | 79 **Au** 197.0 | 80 **Hg** 200.6 | 81 **Tl** 204.4 | 82 **Pb** 207.2 | 83 **Bi** 209.0 | 84 **Po** (209) | 85 **At** (210) | 86 **Rn** (222) |
| 87 **Fr** (223) | 88 **Ra** 226.0 | 89 **Ac** 227.0 | 104 **Rf** (261) | 105 **Db** (262) | 106 **Sg** (263) | 107 **Bh** (262) | 108 **Hs** (265) | 109 **Mt** (266) | 110 (269) | 111 (272) | 112 (277) | | 114 (289) | | | | |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 58 **Ce** 140.1 | 59 **Pr** 140.9 | 60 **Nd** 144.2 | 61 **Pm** (145) | 62 **Sm** 150.4 | 63 **Eu** 152.0 | 64 **Gd** 157.3 | 65 **Tb** 158.9 | 66 **Dy** 162.5 | 67 **Ho** 164.9 | 68 **Er** 167.3 | 69 **Tm** 168.9 | 70 **Yb** 173.0 | 71 **Lu** 175.0 |
| 90 **Th** 232.0 | 91 **Pa** 231.0 | 92 **U** 238.0 | 93 **Np** 237.0 | 94 **Pu** (244) | 95 **Am** (243) | 96 **Cm** (247) | 97 **Bk** (247) | 98 **Cf** (251) | 99 **Es** (252) | 100 **Fm** (257) | 101 **Md** (258) | 102 **No** (259) | 103 **Lr** (260) |

**DIRECTIONS**

- When you have selected your answer to each question, blacken the corresponding space on the answer sheet using pencil. Make a heavy, full mark, but no stray marks. If you decide to change an answer, erase the unwanted mark ver
- Make no marks on the test booklet. Do all calculations on scratch paper provided by your instructor.
- There is only one correct answer to each question. Any questions for which more than one response has been blackened **wi 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 substance is most likely to be soluble in a nonpolar solvent?

**(A)** glucose **(B)** graphite

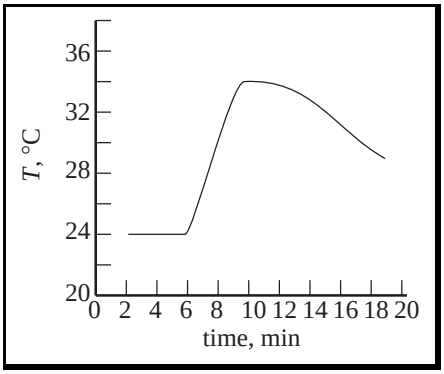
**(C)** lithium fluoride **(D)** sulfur

**2.** A solution of which substance can best be used as both a titrant and its own indicator in an oxidation–reduction titration?

**(A)** $I_2$ **(B)** NaOCl

**(C)** $K_2Cr_2O_7$ **(D)** $KMnO_4$

**3.** What value of $\Delta T$ should be used for the calorimetry experiment that gives these graphed results?




**(A)** 10 ˚C **(B)** 12 ˚C **(C)** 15 ˚C **(D)** 19 ˚C

**4.** $Fe^{3+}(aq) + SCN^{-}(aq) \rightleftharpoons FeSCN^{2+}(aq)$

The equilibrium constant for this reaction can best be determined by means of

**(A)** chromatography. **(B)** conductance.

**(C)** ion exchange. **(D)** spectrophotometry.

**5.** Which solid reacts with dilute hydrochloric acid at 25 ˚C to produce a gas that is more dense than air?

**(A)** Zn **(B)** $Pb(NO_3)_2$

**(C)** NaBr **(D)** $NaHCO_3$

**6.** A 20.00 mL sample of a $Ba(OH)_2$ solution is titrated with 0.245 M HCl. If 27.15 mL of HCl is required, what is the molarity of the $Ba(OH)_2$ solution?

**(A)** 0.166 M **(B)** 0.180 M

**(C)** 0.333 M **(D)** 0.666 M

**7.** When ionic hydrides react with water, the products are

**(A)** acidic solutions and hydrogen gas.

**(B)** acidic solutions and oxygen gas.

**(C)** basic solutions and hydrogen gas.

**(D)** basic solutions and oxygen gas.

**8.** 0.250 g of an element, **M**, reacts with excess fluorine to produce 0.547 g of the hexafluoride, $\mathbf{M}F_6$. What is the element?

**(A)** Cr **(B)** Mo **(C)** S **(D)** Te

**9.** How many moles of $Na^+$ ions are in 20 mL of 0.40 M $Na_3PO_4$?

**(A)** 0.0080 **(B)** 0.024

**(C)** 0.050 **(D)** 0.20

**10.** What is the mass percent of oxygen in $Al_2(SO_4)_3 \cdot 18H_2O$?

| Molar Mass, M |
|---|
| $Al_2(SO_4)_3 \cdot 18H_2O$ 666.43 g·mol |

**(A)** 9.60 **(B)** 28.8 **(C)** 43.2 **(D)** 72.0

**11.** What is the coefficient for $H^+(aq)$ when the equation is balanced with whole number coefficients?

$$\_\_Mn^{2+}(aq) + \_\_BiO_3^-(aq) + \_\_H^+(aq) \rightarrow \_\_Bi^{3+}(aq) + \_\_MnO_4^-(aq) + \_\_H_2O(l)$$

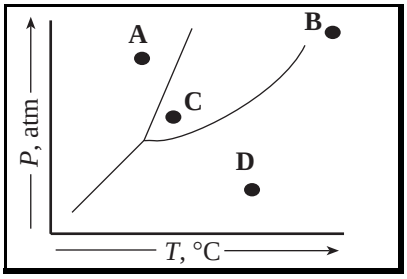
**(A)** 3 **(B)** 4 **(C)** 7 **(D)** 14

**12.** What is the number of $O_2$ molecules in the 2.5 g of $O_2$ inhaled by the average person in one minute?

**(A)** $1.9 \times 10^{22}$ **(B)** $3.8 \times 10^{22}$

**(C)** $4.7 \times 10^{22}$ **(D)** $9.4 \times 10^{22}$

**13.** Which point in the phase diagram best represents supercritical conditions?




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

**14.** The vapor pressure of a liquid in a closed container depends on

1. temperature of the liquid
2. quantity of liquid
3. surface area of the liquid

**(A)** **1** only **(B)** **2** only

**(C)** **1** and **3** only **(D)** **1**, **2** and **3**

**15.** What is the maximum number of phases that can be in equilibrium in a one component system?

**(A)** 1 **(B)** 2 **(C)** 3 **(D)** 4

**16.** The molar mass of a gas with a density of 5.8 $g \cdot L^{-1}$ at 25 ˚C and 740 mm Hg is closest to

**(A)** 10 $g \cdot mol^{-1}$ **(B)** 20 $g \cdot mol^{-1}$

**(C)** 150 $g \cdot mol^{-1}$ **(D)** 190 $g \cdot mol^{-1}$

**17.** Which substance would be expected to exhibit the greatest surface tension at 25 ˚C?

**(A)** $CH_3OCH_3$ **(B)** $C_2H_5OH$

**(C)** $CH_3CH(OH)CH_3$ **(D)** $CH_2(OH)CH_2OH$

**18.** $3N_2O(g) + 2NH_3(g) \rightarrow 4N_2(g) + 3H_2O(g)$ $\Delta H = -879.6$ kJ

What is $\Delta H_f^\circ$ for $N_2O$ in $kJ \cdot mol^{-1}$?

| Heats of Formation | |
|---|---|
| $NH_3$ | $-45.9$ $kJ \cdot mol^{-1}$ |
| $H_2O$ | $-241.8$ $kJ \cdot mol^{-1}$ |

**(A)** +246 **(B)** +82 **(C)** –82 **(D)** –246

**19.** What is the change in internal energy, $\Delta E$, for a reaction that gives off 65 joules of heat and does 38 joules of work?

**(A)** –103 J **(B)** –27 J **(C)** +27 J **(D)** +103 J

**20.** What are the signs of $\Delta H$ and $\Delta S$ for this reaction?

$2C(s) + O_2(g) \rightarrow 2CO(g)$

| | $\Delta H$ | $\Delta S$ |
|---|---|---|
| **(A)** | – | – |
| **(B)** | – | + |
| **(C)** | + | + |
| **(D)** | + | – |

**21.** The rate of formation of $O_3(g)$ is $2.0 \times 10^{-7}$ $mol \cdot L^{-1} \cdot s^{-1}$ for the reaction

$$3O_2(g) \rightarrow 2O_3(g)$$

What is the rate of disappearance of $O_2(g)$ in $mol \cdot L^{-1} \cdot s^{-1}$?

**(A)** $1.3 \times 10^{-7}$ **(B)** $2.0 \times 10^{-7}$

**(C)** $3.0 \times 10^{-7}$ **(D)** $4.5 \times 10^{-7}$

**22.** Which statements are true?

1. $S^\circ$ values for all elements in their standard states are positive.
2. $S^\circ$ values for all aqueous ions are positive.
3. $\Delta S^\circ$ values for all spontaneous reactions are positive.

**(A)** **1** only **(B)** **1** and **2** only

**(C)** **2** and **3** only **(D)** **1**, **2** and **3**

**23.** $$Ag^+(aq) + 2\ NH_3(aq) \rightleftharpoons Ag(NH_3)_2^+(aq)$$

For this reaction, $K = 1.7 \times 10^7$ at 25 ˚C. What is the value of $\Delta G^\circ$ in kJ?

**(A)** –41.2 **(B)** –17.9 **(C)** +17.9 **(D)** +41.2

**24.** The value of $\Delta H$ for a reaction can be found by appropriate combination of bond enthalpies (the energy required to break a particular bond, represented *BE*). Which expression will give $\Delta H$ for this reaction?

$$C_2H_4(g) + H_2(g) \rightarrow C_2H_6(g)$$

**(A)** $BE_{C=C} + BE_{H-H} - [BE_{C-C} + 2BE_{C-H}]$

**(B)** $BE_{C-C} + 2BE_{C-H} - [BE_{C=C} + BE_{H-H}]$

**(C)** $1/2BE_{C=C} + BE_{H-H} - 2BE_{C-H}$

**(D)** $2BE_{C-H} - 1/2BE_{C=C} + BE_{H-H}$

**25.** What is the sign of $\Delta G^\circ$ and the value of $K$ for an electrochemical cell for which $E^\circ_{cell} = 0.80$ V?

| | $\Delta G^\circ$ | $K$ |
|---|---|---|
| **(A)** | – | > 1 |
| **(B)** | + | > 1 |
| **(C)** | + | < 1 |
| **(D)** | – | < 1 |

**26.** The reaction between $NO(g)$ and $O_2(g)$ to give $NO_2(g)$ is second order in $NO(g)$ and first order in $O_2(g)$. By what factor will the reaction rate change if the concentrations of both reactants are doubled?

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

**27.** The decomposition of ethane into two methyl radicals has a first order rate constant of $5.5 \times 10^{-4}$ sec$^{-1}$ at 700 ˚C. What is the half-life for this decomposition in minutes?

**(A)** 9.1 **(B)** 15 **(C)** 21 **(D)** 30

**28.** The dependence of the rate constant of a reaction on temperature is given by the equation $k = e^{-E_a/kT}$. Under what conditions is $k$ the smallest?

**(A)** high $T$ and large $E_a$ **(B)** high $T$ and small $E_a$

**(C)** low $T$ and large $E_a$ **(D)** low $T$ and small $E_a$

**29.** The reaction

$$CHCl_3(g) + Cl_2(g) \rightarrow CCl_4(g) + HCl(g)$$

is believed to proceed by this mechanism:

| | |
|---|---|
| $Cl_2(g) \rightarrow 2Cl(g)$ | fast |
| $Cl(g) + CHCl_3(g) \rightarrow HCl(g) + CCl_3(g)$ | slow |
| $CCl_3(g) + Cl(g) \rightarrow CCl_4(g)$ | fast |

What rate equation is consistent with this mechanism?

**(A)** Rate = $k[Cl_2]$

**(B)** Rate = $k[Cl][CHCl_3]$

**(C)** Rate = $k[Cl_2][CHCl_3]$

**(D)** Rate = $k[Cl_2]^{1/2}[CHCl_3]$

**30.** The activation energy of a certain reaction is 87 kJ·mol$^{-1}$. What is the ratio of the rate constants for this reaction when the temperature is decreased from 37 ˚C to 15 ˚C?

**(A)** 5/1 **(B)** 8.3/1 **(C)** 13/1 **(D)** 24/1

**31.** $P_4(s) + 6Cl_2(g) \rightleftharpoons 4PCl_3(g)$

Phosphorus reacts with chlorine as shown. W... equilibrium constant expression, $K_p$, for this rea...

**(A)** $\dfrac{4P_{PCl_3}}{6P_{PCl_3} \cdot P_{Cl_2}}$ **(B)** $\dfrac{4P_{PCl_3}}{6P_{Cl_2}}$

**(C)** $\dfrac{P_{PCl_3}}{P_{P_4} \cdot P^6_{Cl_2}}$ **(D)** $\dfrac{P^4_{PCl_3}}{P^6_{Cl_2}}$

**32.** The equilibrium constant for the reaction

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

is $6.10 \times 10^{-3}$ at 25˚C. Calculate the value of K for this reaction:

$$NO_2(g) \rightleftharpoons 1/2N_2O_4(g)$$

**(A)** 327 **(B)** 164

**(C)** 12.8 **(D)** $3.05 \times 10^{-3}$

**33.** The ion-product constant for water at 45 ˚C is $4.0 \times 10^{-14}$. What is the pH of pure water at this temperature?

**(A)** 6.7 **(B)** 7.0 **(C)** 7.3 **(D)** 13.4

**34.** The position of equilibrium lies to the right in each of these reactions.

$$N_2H_5^+ + NH_3 \rightleftharpoons NH_4^+ + N_2H_4$$

$$NH_3 + HBr \rightleftharpoons NH_4^+ + Br^-$$

$$N_2H_4 + HBr \rightleftharpoons N_2H_5^+ + Br^-$$

Based on this information, what is the order of acid strength?

**(A)** $HBr > N_2H_5^+ > NH_4^+$ **(B)** $N_2H_5^+ > N_2H_4 > NH_4^+$

**(C)** $NH_3 > N_2H_4 > Br^-$ **(D)** $N_2H_5^+ > HBr > NH_4^+$

**35.** HCN is a weak acid ($K_a = 6.2 \times 10^{-10}$). $NH_3$ is a weak base ($K_b = 1.8 \times 10^{-5}$). A 1.0 M solution of $NH_4CN$ would be

**(A)** strongly acidic **(B)** weakly acidic

**(C)** neutral **(D)** weakly basic

**36.** What is the percent ionization of a 0.010 M HCN solution? ($K_a = 6.2 \times 10^{-10}$)

**(A)** 0.0025% **(B)** 0.025%

**(C)** 0.25% **(D)** 2.5%

**37.** How many moles of HCOONa must be added to 1.0 L of 0.10 M HCOOH to prepare a buffer solution with a pH of 3.4? (HCOOH $K_a = 2 \times 10^{-4}$)

**(A)** 0.01 **(B)** 0.05 **(C)** 0.1 **(D)** 0.2

**38.** The acid–base indicator methyl red has a $K_a$ of $1 \times 10^{-5}$. Its acidic form is red while its alkaline form is yellow. If methyl red is added to a colorless solution with a pH = 7, the color will be

**(A)** pink **(B)** red **(C)** orange **(D)** yellow

**39.** Silver ions are added to a solution with $[Br^-] = [Cl^-] = [CO_3^{2-}] = [AsO_4^{3-}] = 0.1$ M. Which compound will precipitate at the lowest $[Ag^+]$?

**(A)** AgBr ($K_{sp} = 5.0 \times 10^{-13}$)

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

**(C)** $Ag_2CO_3$ ($K_{sp} = 8.1 \times 10^{-12}$)

**(D)** $Ag_3AsO_4$ ($K_{sp} = 1.0 \times 10^{-22}$)

**40.** Consider a voltaic cell based on these half–cells.

$Ag^+(aq) + e^- \rightarrow Ag(s)$ $\quad E^\circ = +0.80$ V

$Cd^{2+}(aq) + 2e^- \rightarrow Cd(s)$ $\quad E^\circ = -0.40$ V

Identify the anode and give the voltage of this cell under standard conditions.

**(A)** Ag; $E_{cell} = 0.40$ V **(B)** Ag; $E_{cell} = 2.00$ V

**(C)** Cd; $E_{cell} = 1.20$ V **(D)** Cd; $E_{cell} = 2.00$ V

**41.** Which two species react spontaneously?

**(A)** $Cu(s) + Ag^+(aq)$ **(B)** $Br_2(l) + Cl^-(aq)$

**(C)** $H_2O(l) + Ca^{2+}(aq)$ **(D)** $Au(s) + Mg^{2+}(aq)$

**42.** When aluminum oxide is electrolyzed in the industrial process for the production of aluminum metal, aluminum is produced at one electrode and oxygen gas is produced at the other. For a given quantity of electricity, what is the ratio of moles of aluminum to moles of oxygen gas?

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

Questions **43.** and **44.** should be answered w… the reaction.

$2Cr(s) + 3Cu^{2+}(aq) \rightarrow 2Cr^{3+}(aq) + 3Cu(s)$ $\quad E$…

**43.** Which expression gives the value for $\Delta G^\circ$ in kJ·mo… this reaction at 25 °C?

**(A)** $-6 \times 8.31 \times 0.43 \times 1000$

**(B)** $\dfrac{-6 \times 96500 \times 0.43 \times 1000}{8.31}$

**(C)** $\dfrac{-6 \times 96500 \times 0.43}{1000}$

**(D)** $\dfrac{-6 \times 8.31 \times 0.43}{1000}$

**44.** What is the voltage for this cell when $[Cu^{2+}] = 1.0$ M and $[Cr^{3+}] = 0.010$ M?

**(A)** 1.2 **(B)** 0.87 **(C)** 0.47 **(D)** 0.39

**45.** All of these sets of quantum numbers are permissible ***except***

| | $n$ | $l$ | $m_l$ | $m_s$ |
|---|---|---|---|---|
| **(A)** | 1 | 0 | 0 | +1/2 |
| **(B)** | 2 | 2 | 0 | –1/2 |
| **(C)** | 3 | 1 | 1 | –1/2 |
| **(D)** | 3 | 2 | –1 | +1/2 |

**46.** Which element can exhibit more than one oxidation state in compounds?

**1.** Cr **2.** Pb **3.** Sr

**(A)** **1** only **(B)** **1** and **2** only

**(C)** **2** and **3** only **(D)** **1**, **2** and **3**

**47.** When the isoelectronic species, $K^+$, $Ca^{2+}$, and $Cl^-$, are arranged in order of increasing radius, what is the correct order?

**(A)** $K^+$, $Ca^{2+}$, $Cl^-$ **(B)** $K^+$, $Cl^-$, $Ca^{2+}$

**(C)** $Cl^-$, $Ca^{2+}$,$K^+$ **(D)** $Ca^{2+}$, $K^+$, $Cl^-$

**48.** Which Group 2 element has chemical properties least like the other members of the group?

**(A)** Be **(B)** Ca **(C)** Sr **(D)** Ba

**49.** In the vapor state which atom has the largest ionization energy?

**(A)** Na **(B)** K **(C)** Mg **(D)** Ca

**50.** All of these species have the same number of valence electrons as $NO_3^-$ ***except***

**(A)** $CO_3^{2-}$ **(B)** $HCO_3^-$ **(C)** $NF_3$ **(D)** $SO_3$

**51.** Which set contains no ionic species?

**(A)** $NH_4Cl$, $OF_2$, $H_2S$ **(B)** $CO_2$, $Cl_2$, $CCl_4$

**(C)** $BF_3$, $AlF_3$, $TlF_3$ **(D)** $I_2$, $CaO$, $CH_3Cl$

**52.** When these species are arranged in order of ***increasing*** bond energy, what is the correct sequence?

**(A)** $N_2$, $O_2$, $F_2$ **(B)** $F_2$, $O_2$, $N_2$

**(C)** $O_2$, $F_2$, $N_2$ **(D)** $O_2$, $N_2$, $F_2$

**53.** The geometry of the atoms in the species $PCl_4^+$ is best described as

**(A)** tetrahedral **(B)** see–saw

**(C)** square **(D)** trigonal bipyramidal

**54.** Which are nonpolar molecules?

**1.** $NCl_3$ **2.** $SO_3$ **3.** $PCl_5$

**(A)** **1** only **(B)** **2** only

**(C)** **1** and **3** only **(D)** **2** and **3** only

**55.** What are the hybridizations of carbon **1** and carbon **2** in the hydrocarbon?

$$\underset{\mathbf{1}}{CH_3}\underset{\mathbf{2}}{C}HCH_2$$

**(A)** $sp^3$, $sp$ **(B)** $sp^3$, $sp^2$

**(C)** $sp^2$, $sp^2$ **(D)** $sp$, $sp^2$

**56.** How many carbon–carbon bonds are [illegible] of 2-methyl-2-butanol?

**(A)** 2 **(B)** 3 **(C)** 4

**57.** Which molecule can exist as stereoisomers?

**(A)** CHF=CHF **(B)** $F_2C=CCl_2$

**(C)** $CH_2F–CHF_2$ **(D)** $CF_3–CH_3$

**58.** What are the most likely products in the reaction between $CH_3CH_2CH_2OH$ and HI?

**(A)** $CH_3CH_2CH_2I$ and $H_2O$

**(B)** $CH_3CH_2CH_3$ and HOI

**(C)** $CH_3OH$ and $CH_3CH_2I$

**(D)** $ICH_2CH_2CH_2OH$ and $H_2$

**59.** Addition polymers include

**1.** polyamide **2.** polyethylene **3.** polyester

**(A)** **1** only **(B)** **2** only

**(C)** **2** and **3** only **(D)** **1**, **2** and **3**

**60.** All of these are aromatic compounds ***except***

**(A)** hexene, $C_6H_{12}$

**(B)** toluene, $C_6H_5CH_3$

**(C)** *p*-dichlorobenzene, $C_6H_4Cl_2$

**(D)** naphthalene, $C_{10}H_8$

## END OF TEST

# US National Chemistry Olympiad – 1999
# National Examination—Part I
# SCORING KEY

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