DIRECTIONS

- When you have selected your answer, blacken the corresponding space on the answer sheet with a soft, black #2 pencil. Make a heavy, full mark, but no stray marks. If you decide to change an answer, erase the unwanted mark very carefully.
- Make no marks in the test booklet. Do all calculations on scratch paper provided by your examiner.
- 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.
- The best strategy is to arrive at your own answer to a question before looking at the choices. Otherwise, you may be misled by plausible, but incorrect, responses.

1. Which metal reacts most vigorously with water?

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

2. Which substance produces an acidic solution when it is bubbled into water?

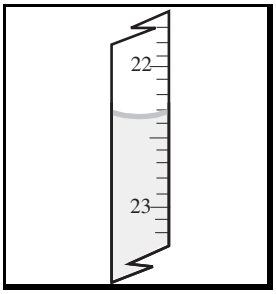
(A) CO_2 **(B)** Ar **(C)** NH_3 **(D)** CH_4

3. Which substance is the least soluble in H_2O?

(A) K_2CO_3 **(B)** $KHCO_3$

(C) $Ca(HCO_3)_2$ **(D)** $CaCO_3$

4. What value should be reported for the buret reading shown?



(A) 22.3 mL **(B)** 22.30 mL

(C) 22.36 mL **(D)** 22.40 mL

5. Which technique is recommended for determining the odor of an unknown liquid in the laboratory?

(A) Hold a test tube of the liquid under the nose and inhale the vapor.

(B) Transfer a few drops of the liquid to the desk top and inhale the vapor from there.

(C) Use a medicine dropper to collect a small quantity of the vapor and squirt this under the nose while inhaling.

(D) Use a hand to fan some of the vapor from the test tube to the nose and inhale.

6. A colorless solution is known to contain one of these ions. Which ion is present if adding dilute HCl produces a white precipitate that dissolves when the solution is warmed?

(A) Ag^+ **(B)** Cu^{2+} **(C)** Hg_2^{2+} **(D)** Pb^{2+}

7. A student is asked to measure 12 mL of a liquid as precisely as possible. Which piece of equipment should she select for this task?

(A) 25 mL beaker

(B) 25 mL graduated cylinder

(C) 25 mL conical flask

(D) 25 mL volumetric flask

8. Which separation technique is based on differences in the volatility of the substances to be separated?

(A) filtration **(B)** distillation

(C) solvent extraction **(D)** paper chromatography

9. If 1.50 g of $H_2C_2O_4 \cdot 2H_2O$ were heated to drive off the water of hydration, how much anhydrous $H_2C_2O_4$ would remain?

(A) 0.34 g **(B)** 0.92 g

(C) 1.07 g **(D)** 1.50 g

10. How many H atoms are in 3.4 g of $C_{12}H_{22}O_{11}$?

(A) 6.0×10^{23} **(B)** 1.3×10^{23}

(C) 3.8×10^{22} **(D)** 6.0×10^{21}

11. How many mL of 8.00 M HCl are needed to prepare 150. mL of a 1.60 M HCl solution?

(A) 30.0 mL **(B)** 24.0 mL

(C) 18.8 mL **(D)** 12.0 mL

12. Analysis of a compound known to contain only Mg, P, and O gives this analysis.

21.8% Mg 27.7% P 50.3% O

What is its empirical formula?

(A) $MgPO_2$ **(B)** $MgPO_3$

(C) $Mg_2P_2O_7$ **(D)** $Mg_3P_2O_8$

13. The reaction of ethanol, C_2H_5OH, with oxygen is a popular classroom demonstration. Balance the equation to find the number of moles of gaseous products formed per mole of ethanol.

$$\_\_\_C_2H_5OH_{(g)} + \_\_\_O_{2(g)} \rightarrow \_\_\_CO_{2(g)} + \_\_\_H_2O_{(g)}$$

(A) 2 **(B)** 3 **(C)** 4 **(D)** 5

14. Ammonia is produced in accordance with this equation.

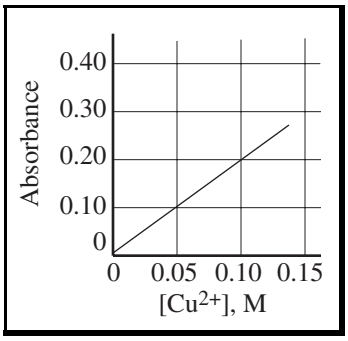
$$N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$$

In a particular experiment, 0.25 mol of NH_3 is formed when 0.5 mol of N_2 is reacted with 0.5 mol of H_2. What is the percent yield?

(A) 75% **(B)** 50%

(C) 33% **(D)** 25%

15. A 20.0 mL sample of a Cu^{2+} solution was diluted to 250.0 mL. A portion of this solution was found to have an absorbance of 0.15 under the same conditions that were used to generate the given absorbance vs. $[Cu^{2+}]$ graph. What was the concentration of Cu^{2+} ions in the original sample?



(A) 0.0060 M **(B)** 0.075 M

(C) 0.30 M **(D)** 0.94 M

16. Under which conditions will a gas behave most ideally?

(A) low *P* and high *T* **(B)** low *P* and low *T*

(C) high *P* and low *T* **(D)** high *P* and high *T*

17. The mass of 560 cm^3 of a gas at 0 °C and 1 atm is 1.60 g. Which gas could it be?

(A) O_2 **(B)** CO_2 **(C)** SO_2 **(D)** Cl_2

18. Oxygen, which is 16 times as dense as hydrogen, diffuses

(A) 1/16 times as fast. **(B)** 1/4 times as fast.

(C) 4 times as fast. **(D)** 16 times as fast.

19. How is the vapor pressure of a liquid in a closed container affected when the quantity of liquid is doubled at constant temperature?

(A) The vapor pressure increases.

(B) The vapor pressure decreases.

(C) The vapor pressure stays the same.

(D) The vapor pressure may increase or decrease, depending on the liquid.

20. A low molar heat of fusion is expected for a solid that is

(A) ionic. **(B)** metallic.

(C) molecular. **(D)** network covalent.

21. Which gas is least suitable for collection over water?

(A) Ar **(B)** O_2 **(C)** CO_2 **(D)** NH_3

22. Which characteristic is most useful for determining that a substance is a metal?

(A) conductivity **(B)** hardness

(C) melting point **(D)** X-ray pattern

23. For which of these is ΔH_f^o not equal to zero?

(A) $Br_{2(l)}$ **(B)** $Fe_{(s)}$ **(C)** $I_{2(s)}$ **(D)** $O_{3(g)}$

24. The enthalpy change for which reaction represents the standard enthalpy of formation for hydrogen cyanide, HCN?

(A) $H_{(g)} + C_{(graphite)} + N_{(g)} \rightarrow HCN_{(g)}$

(B) $\frac{1}{2}H_{2(g)} + C_{(graphite)} + \frac{1}{2}N_{2(g)} \rightarrow HCN_{(g)}$

(C) $HCN_{(g)} \rightarrow \frac{1}{2}H_{2(g)} + C_{(graphite)} + \frac{1}{2}N_{2(g)}$

(D) $H_{2(g)} + 2C_{(graphite)} + N_{2(g)} \rightarrow 2HCN_{(g)}$

25. What is the standard enthalpy of formation of $MgO_{(s)}$ if 300.9 kJ is evolved when 20.15 g of $MgO_{(s)}$ is formed by the combustion of magnesium under standard conditions?

(A) $-601.8\ kJ \cdot mol^{-1}$ **(B)** $-300.9\ kJ \cdot mol^{-1}$

(C) $+300.9\ kJ \cdot mol^{-1}$ **(D)** $+601.8\ kJ \cdot mol^{-1}$

26. Which combination of solutions of HCl and NaOH would produce the largest ΔT?

(A) 50 mL of 1 M HCl with 50 mL of 1 M NaOH

(B) 50 mL of 2 M HCl with 50 mL of 2 M NaOH

(C) 100 mL of 1 M HCl with 50 mL of 2 M NaOH

(D) 100 mL of 1 M HCl with 100 mL of 1 M NaOH

27. Which change occurs with the largest increase in entropy at 25 °C?

(A) $Br_{2(l)} \rightarrow Br_{2(g)}$

(B) $C_{(graphite)} \rightarrow C_{(diamond)}$

(C) $H_2O_{(s)} \rightarrow H_2O_{(l)}$

(D) $HCl_{(g)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$

28. What are the signs of ΔH° and ΔS° for a reaction that is spontaneous at all temperatures?

	ΔH°	ΔS°
(A)	+	+
(B)	+	−
(C)	−	+
(D)	−	−

29. Iodide ion is oxidized by acidified dichromate ions as shown in this equation.

$$Cr_2O_7^{2-}(aq) + 9I^-(aq) + 14H^+(aq) \rightarrow 2Cr^{3+}(aq) + 3I_3^-(aq) + 7H_2O(l)$$

These data were obtained when the reaction was studied at a constant pH.

Experiment	$[Cr_2O_7^{2-}]$, M	$[I^-]$, M	Rate, M·s^{-1}
1	0.0040	0.010	0.00050
2	0.0080	0.010	0.0010
3	0.0120	0.020	0.0060

What is the order of the reaction with respect to $Cr_2O_7^{2-}(aq)$ and $I^-(aq)$?

(A) first order with respect to both $Cr_2O_7^{2-}$ and I^-

(B) second order with respect to both $Cr_2O_7^{2-}$ and I^-

(C) second order with respect to $Cr_2O_7^{2-}$ and first order with respect to I^-

(D) first order with respect to $Cr_2O_7^{2-}$ and second order with respect to I^-

30. The reaction **A** → **B** is first order in **A**. Which plot will be linear?

(A) [**A**] vs. time (B) ln [**A**] vs. time

(C) 1/[**A**]^2 vs. time (D) 1/[A] vs. time

31. One of the steps in the manufacture of nitric acid is the oxidation of ammonia shown in this equation.

$$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$$

If gaseous water appears at a rate of 0.025 mol·min^{-1}, at what rate does ammonia disappear?

(A) 0.0040 mol·min^{-1} **(B)** 0.017 mol·min^{-1}

(C) 0.038 mol·min^{-1} **(D)** 0.150 mol·min^{-1}

32. This reaction is first order with respect to N_2O_5.

$$2N_2O_5(g) \rightarrow 4NO_2(g) + O_2(g)$$

If the half-life for this reaction is 19.0 minutes, what is the rate constant, k?

(A) 0.0158 min^{-1} **(B)** 0.0263 min^{-1}

(C) 0.0365 min^{-1} **(D)** 0.0526 min^{-1}

33. For a system in equilibrium, the rate constant for the forward reaction is represented by k_f and the rate constant for the reverse reaction is represented by k_r. Which equation represents the equilibrium constant for this reaction in the forward direction?

(A) $K_{eq} = k_f \cdot k_r$ **(B)** $K_{eq} = k_f / k_r$

(C) $K_{eq} = k_r / k_f$ **(D)** $K_{eq} = 1 / k_f \cdot k_r$

Questions **34** and **35** should both be answered with reference to this reaction, for which ΔH^o is negative.

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$$

34. Which would increase the partial pressure of $NO_2(g)$ at equilibrium?

(A) decreasing the volume of the system

(B) adding a noble gas to increase the pressure of the system

(C) removing some $NO(g)$ from the system

(D) adding an appropriate catalyst

35. At a certain temperature the equilibrium concentrations for this system are:

$$[NO] = 0.52M;\ [O_2] = 0.24M;\ [NO_2] = 0.18M.$$

What is the value of K_C at this temperature?

(A) 0.063 **(B)** 0.50 **(C)** 1.4 **(D)** 2.0

36. What is the pH of a 0.025 M solution of KOH?

(A) 1.60 **(B)** 3.69 **(C)** 10.31 **(D)** 12.40

37. What is the $[H^+]$ of a 0.075 M solution of the acid HA?

Equilibrium Constant, K_a	
HA	4.8×10^{-8}

(A) 6.1×10^{-4} M **(B)** 2.2×10^{-4} M

(C) 6.0×10^{-5} M **(D)** 4.8×10^{-8} M

38. Which salt produces the most alkaline solution at a concentration of 0.1 M?

(A) KNO_3 **(B)** $MgCl_2$

(C) NH_4Cl **(D)** $NaNO_2$

39. A 0.052 M solution of benzoic acid, C_6H_5COOH, is titrated with a strong base. What is the $[H^+]$ of the solution one-half way to the equivalence point?

Equilibrium Constant, K_a	
C_6H_5COOH	6.3×10^{-5}

(A) 6.3×10^{-5} M **(B)** 1.8×10^{-3} M

(C) 7.9×10^{-3} M **(D)** 2.6×10^{-2} M

40. A buffer solution made with NH_3 and NH_4Cl has a pH of 10.0. Which procedure(s) could be used to lower the pH?

1. adding HCl
2. adding NH_3
3. adding NH_4Cl

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

41. How many moles of calcium fluoride, CaF_2, must be dissolved in 2.0 L of water at 25 °C to form a saturated solution?

K_{sp} at 25 °C	
CaF_2	1.6×10^{-10}

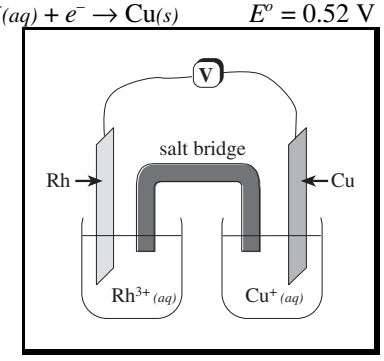
(A) 2.6×10^{-2} mol **(B)** 1.3×10^{-3} mol
(C) 6.8×10^{-4} mol **(D)** 3.4×10^{-4} mol

42. Which equation represents an oxidation-reduction reaction?

(A) $H_2SO_4 + 2NH_3 \rightarrow (NH_4)_2SO_4$
(B) $H_2SO_4 + Na_2CO_3 \rightarrow Na_2SO_4 + H_2O + CO_2$
(C) $2K_2CrO_4 + H_2SO_4 \rightarrow K_2Cr_2O_7 + K_2SO_4 + H_2O$
(D) $2H_2SO_4 + Cu \rightarrow CuSO_4 + 2H_2O + SO_2$

Questions **43** and **44** should be answered with reference to the voltaic cell shown and these half-reactions.

$Rh^{3+}(aq) + 3e^- \rightarrow Rh(s)$ $E^o = 0.80$ V
$Cu^+(aq) + e^- \rightarrow Cu(s)$ $E^o = 0.52$ V



43. What is the direction of electron flow in the external circuit if the concentrations of Cu^+ and Rh^{3+} are each 1 M?

(A) from the Rh anode to the Cu cathode
(B) from the Rh cathode to the Cu anode
(C) from the Cu anode to the Rh cathode
(D) from the Cu cathode to the Rh anode

44. What is the voltage of this cell if the concentrations of Cu^+ and Rh^{3+} are each 1 M?

(A) 0.28 V **(B)** 0.76 V **(C)** 1.32 V **(D)** 2.36 V

45. What is the correct order when the substances O_2, H_2O, OF_2, and H_2O_2 are arranged in order of increasing oxidation number for oxygen?

(A) O_2, H_2O, OF_2, H_2O_2 **(B)** H_2O, H_2O_2, O_2, OF_2
(C) H_2O_2, O_2, H_2O, OF_2 **(D)** OF_2, O_2, H_2O_2, H_2O

46. Which element has an outer electron configuration of s^2p^4?

(A) Ca **(B)** Cr **(C)** Ge **(D)** Se

47. How many unpaired electrons does a gaseous atom of phosphorus, P, have in its ground state?

(A) 1 **(B)** 3 **(C)** 5 **(D)** 7

48. Which element has the lowest first ionization energy?

(A) B **(B)** C **(C)** Al **(D)** Si

49. Which of these elements has the greatest electronegativity?

(A) Br **(B)** N **(C)** O **(D)** S

50. Which oxide produces the most acidic solution when 0.1 mol is added to 1 L of H_2O?

(A) BaO **(B)** BaO_2 **(C)** SO_2 **(D)** SO_3

51. Which set contains only covalently bonded molecules?

(A) BCl_3, $SiCl_4$, PCl_3 **(B)** NH_4Br, N_2H_4, HBr
(C) I_2, H_2S, NaI **(D)** Al, O_3, As_4

52. What is the total number of valence electrons in the chlorate ion, ClO_3^-?

(A) 24 **(B)** 26 **(C)** 28 **(D)** 32

53. The concept of resonance is used to describe molecular structures which

(A) oscillate between two structures.
(B) have mirror images.
(C) can be isolated in several isomeric forms.
(D) have more than one possible Lewis structure.

54. What is the arrangement in space of the hybrid orbitals of an atom with sp^2 hybridization?

(A) linear **(B)** bent
(C) pyramidal **(D)** trigonal planar

55. Which species is isoelectronic with NO_2^+?

(A) N_2O **(B)** NO_2^-
(C) NH_2^- **(D)** SO_2

56. Which species can form intermolecular hydrogen bonds with other molecules or ions of the same type?

1. HF **2.** CH_3F **3.** NH_4^+

(A) **1** only **(B)** **3** only

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

57. How many isomers have the molecular formula C_5H_{12}?

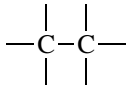
(A) 1 **(B)** 2 **(C)** 3 **(D)** 5

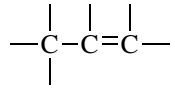
58. Carbon is found in the highest oxidation state in which of these classes of organic compounds?

(A) carboxylic acids **(B)** alcohols

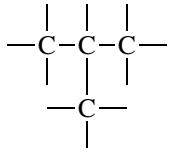
(C) aldehydes **(D)** alkynes

59. Which structural formula represents a mono-unsaturated aliphatic hydrocarbon?

(A) 

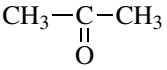
(B) 

(C) 

(D) 

60. Which compound has the highest boiling point?

(A) $CH_3CH_2CH_3$ **(B)** $CH_3OCH_2CH_3$

(C)  **(D)** $CH_3CH_2CH_2OH$

END OF TEST

U.S. NATIONAL CHEMISTRY OLYMPIAD
2000 LOCAL SECTION EXAM — KEY

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