Advanced Placement Chemistry
Practice Exam III

Three hours are allotted for this examination. One hour and 30 minutes are allotted for Section I, which consists of multiple-choice questions. For Section II, Part A, 40 minutes are allotted; for Section II, Part B, 50 minutes are allotted.

NO CALCULATORS MAY BE USED IN THIS SECTION OF THE EXAMINATION.

SECTION I

Time—1 hour and 30 minutes

Number of questions—75

Percent of total grade—45

Note: For all questions, assume that the temperature is 298 K, the pressure is 1.00 atmosphere and solutions are aqueous unless otherwise noted.

Throughout the test the following symbols have the definitions specified unless otherwise noted.

T	= temperature	*M*	= molar
P	= pressure	*m*	= molal
V	= volume	L, mL	= liter(s), milliliter(s)
S	= entropy	g	= gram(s)
H	= enthalpy	nm	= nanometer(s)
G	= free energy	atm	= atmosphere(s)
R	= molar gas constant	J, kJ	= joule(s), kilojoule(s)
n	= number of moles	V	= volt(s)
		mol	= mole(s)

Part A

Directions: Each set of lettered choices below refers to the numbered statements immediately following it. Select the one lettered choice that best answers each question or best fits each statement and then fill in the corresponding oval on the answer sheet. A choice may be used once, more than once, or not at all in each set.

Questions 1 – 4:

(A) SO_4^{2-}
(B) Zn^{2+}
(C) CO_3^{2-}
(D) Ag^{+}
(E) MnO_4^{-}

A student is given an "unknown" consisting of an aqueous solution of a salt that contains one of the ions listed above. Which ion can the student eliminate on the basis of each of the following observations of the "unknown"?

1. The solution is colorless.
2. The solution gives no precipitate upon adding dilute hydrochloric acid.
3. No gas is formed upon adding dilute hydrochloric acid.
4. No precipitate is formed when a dilute solution of $Mg(NO_3)_2$ is added to a sample of the solution.

Questions 5 – 8: The set of lettered choices is a list of chemical compounds that are soluble in water and take part in acid base reactions.

(A) C_2H_5OH
(B) BaO
(C) NH_3
(D) $NaHSO_4$
(E) NH_4Cl

5. Is amphiprotic in water solution.
6. Forms a strong base in water solution.
7. Is a Lewis base but not an Arrhenius base.
8. A salt that forms a buffer when combined with one of the other compounds listed.

Questions 9 – 12:

(A) alpha
(B) beta
(C) gamma
(D) X-ray
(E) ultraviolet

9. Radiation having the highest energy.
10. Radiation used in determining the crystal structure of a solid.
11. Radiation that catalyzes the breakdown of the ozone layer.
12. Radiation that exists as a stream of particles that are equivalent to helium nuclei.

Questions 13 – 16:

(A) metallic solid
(B) ionic solid
(C) network covalent solid
(D) molecular solid with dispersion forces
(E) molecular solid with nonpolar molecules at each lattice point

13. iodine crystals
14. diamond
15. iron filings
16. copper(II) chloride

Questions 17 - 21: The set of lettered choices is a list of aqueous solutions of nitrate compounds in various amounts.

(A) 250 mL of 0.50 M KNO_3 (molar mass = 101)
(B) 400 mL of 0.10 M $Al(NO_3)_3$ (molar mass = 213)
(C) 500 mL of 0.20 M NH_4NO_3 (molar mass = 80)
(D) 300 mL of 0.30 M $Pb(NO_3)_2$ (molar mass = 170)
(E) 200 mL of 0.10 M $Ni(NO_3)_2$ (molar mass = 183)

17. Is an appropriate reagent for a Beer's Law experiment.
18. Forms a precipitate when 0.50 moles of solid NaCl is added.
19. Has the highest boiling point.
20. Has the highest $[NO_3^-]$.
21. Has the highest van't Hoff factor.

Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case and then fill in the corresponding oval on the answer sheet.

22. When dilute acid was added to a solution of one of the following chemicals, a gas was evolved. This gas is more dense than air and can be poured over a flaming candle to extinguish the flame. The chemical was

(A) household ammonia, NH_3
(B) baking soda, $NaHCO_3$
(C) table salt, NaCl
(D) isopropyl alcohol, C_2H_5OH
(E) vinegar, 5% $HC_2H_3O_2$

23. The structural isomers CH_3CH_2COOH and CH_3COCH_2OH would be expected to have the same values for which of the following? (Assume ideal behavior.)

(A) Freezing points
(B) Boiling points
(C) Specific heat
(D) Molar mass
(E) Heats of combustion

24. Pi bonding occurs in each of the following species EXCEPT

(A) SO_2
(B) CH_3COOH
(C) SCN^-
(D) NO_3^-
(E) PF_3

25. The net ionic equation for the reaction that occurs during the titration of chlorous acid with potassium hydroxide is

(A) $H^+ + OH^- \rightarrow H_2O$
(B) $HClO_2 + K^+ + OH^- \rightarrow KClO_2 + H_2O$
(C) $HClO_2 + OH^- \rightarrow ClO_2^- + H_2O$
(D) $HClO_2 + H_2O \rightarrow ClO_2^- + H_3O^+$
(E) $HClO_2 + KOH \rightarrow K^+ + ClO_2^- + H_2O$

26. Which of the following substances would be least soluble in water?

(A) $Zn(NO_3)_2$
(B) $Na_2[Zn(OH)_4]$
(C) $ZnCl_2 \bullet x\ H_2O$
(D) $Zn(OH)_2$
(E) $ZnCl_2$

27. $FeCl_3(aq) + NaOH(aq) \rightarrow Fe(OH)_3(s) + NaCl\ (aq)$

Which of the following corresponds to the maximum number of moles of products formed when 1.2 moles of $FeCl_3$ is mixed with 1.2 moles NaOH in aqueous solution?

	mol $Fe(OH)_3$	mol NaCl
(A)	0.40	0.40
(B)	0.40	1.20
(C)	1.20	0.40
(D)	1.20	1.20
(E)	1.20	3.60

28. K, Mn, Fe, Zn, Kr

Gaseous atoms of which of the elements above are diamagnetic?

(A) K and Kr only
(B) K and Mn only
(C) Kr and Zn only
(D) Mn, Fe, and Zn only
(E) K, Mn, Fe and Zn only

29. All of the following can be inferred from the dot diagram below EXCEPT

(A) Element A is a halogen.
(B) Element A forms an anion with a negative one charge.
(C) Element A has a valence electron with a possible set of quantum numbers equaling 3,1,1,$^{-}$½
(D) Element A is highly electronegative when compared to other elements in its period.
(E) Element A forms a strong acid.

30. A solution is known to contain an inorganic salt of one of the following elements. A 1.0 M solution of the salt is colorless. The solution contains a salt of

(A) Co
(B) I
(C) Fe
(D) Ni
(E) Zn

31. Of the following reactions, which involves the largest decrease in entropy?

(A) $MgCO_3(s) \rightarrow MgO(s) + CO_2(g)$
(B) $2\ NO(g) + O_2(g) \rightarrow 2\ NO_2(g)$
(C) $Pb(NO_3)_3(aq) + 2\ NaCl(aq) \rightarrow PbCl_2(s) + 2\ NaNO_3(aq)$
(D) $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2\ H_2O(l)$
(E) $4\ Al(s) + 3\ O_2(g) \rightarrow 2\ Al_2O_3(s)$

32. What is the hybridization of the xenon atom in XeF_2?

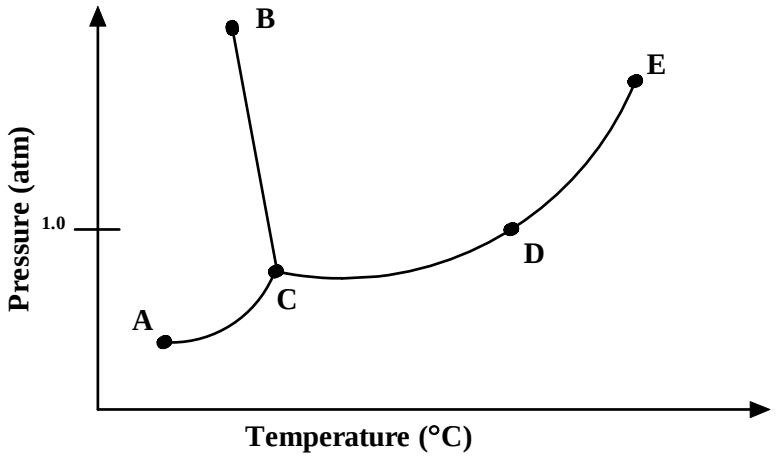
(A) sp
(B) sp^2
(C) sp^3
(D) sp^3d
(E) sp^3d^2

33. $MgO(s) + H_2(g) \rightleftarrows Mg(s) + H_2O(g)$; $\Delta H = -12.0$ kilojoules

When the substances in the equation above are at equilibrium at pressure P and temperature T, the equilibrium can be shifted to favor the products by

(A) increasing the pressure by decreasing the volume at constant T
(B) increasing the pressure by adding an inert gas such as neon
(C) decreasing the temperature
(D) allowing some gases to escape at constant P and T
(E) adding a catalyst

Questions 34 – 35: The phase diagram of an unknown substance is shown below.



34. The lowest temperature above which this substance cannot be liquefied at any applied pressure is located at point

(A) A
(B) B
(C) C
(D) D
(E) E

35. Which point represents the normal boiling point for this substance?

(A) A
(B) B
(C) C
(D) D
(E) E

36. Which of the following systems would NOT experience a change in the concentration of the substances present at equilibrium when the volume of the system is changed at constant temperature?

(A) $SO(g) + NO(g) \rightleftarrows SO_2(g) + 1/2\ N_2(g)$

(B) $O_2(g) + 2\ H_2(g) \rightleftarrows 2\ H_2O(g)$

(C) $N_2(g) + 2\ O_2(g) \rightleftarrows 2\ NO_2(g)$

(D) $N_2O_4(g) \rightleftarrows 2\ NO_2(g)$

(E) $CH_4(g) + 2\ O_2(g) \rightleftarrows CO_2(g) + 2\ H_2O(g)$

37. $NH_4^+(aq) + OH^-(aq) \rightarrow NH_3\ (g)\ + H_2O(l)$

For the reaction represented above, the experimental rate law is given as follows.

$$\text{Rate} = k\ [NH_4^+]$$

If some solid potassium hydroxide is added to a solution that is 0.050-molar in NH_4^+ and 0.50-molar in KOH, which of the following is true? (Assume the temperature and volumes remain constant.)

Both the reaction rate and k increase.
(B) Both the reaction rate and k decrease.
(C) Both the reaction rate and k remain the same.
(D) The reaction rate increases but k remains the same.
(E) The reaction rate decreases but k remains the same.

$$CoS(s) + 2\ H^+ \rightleftarrows Co^{2+} + H_2S\ (g)$$

38. At 25 °C the solubility product constant, K_{sp}, for CoS is 5×10^{-22} and the acid dissociation constants K_1 and K_2 for H_2S are 1×10^{-7} and 1×10^{-13}, respectively. What is the equilibrium constant for the reaction represented by the equation above at 25 °C?

(A) $1 \times 10^{-13} / 5 \times 10^{-22}$
(B) $5 \times 10^{-22} / 1 \times 10^{-7}$
(C) $1 \times 10^{-7} / 5 \times 10^{-20}$
(D) $5 \times 10^{-22} / 1 \times 10^{-20}$
(E) $1 \times 10^{-20} / 5 \times 10^{-22}$

39. Carbohydrates have the empirical formula CH_2O. Which of the following represents the molecular formula of a carbohydrate having a molecular mass of 210 g/mole?

(A) $C_4H_8O_4$
(B) $C_5H_{10}O_5$
(C) $C_6H_{12}O_6$
(D) $C_7H_{14}O_7$
(E) $C_9H_{18}O_9$

Questions 40 – 41:

A study was made of the effect of the hydroxide concentration on the rate of the reaction

$$I^-(aq) + OCl^-(aq) \rightarrow IO^-(aq) + Cl^-(aq)$$

The experimental rate law of the reaction is determined to be:

$$\text{Rate} = k\,[I^-]\,[OCl^-]\,[OH^-]$$

40. What is the order of the reaction with respect to I^-?

(A) 1
(B) 2
(C) 3
(D) 5
(E) 6

41. According to the rate law for the reaction, an increase in the concentration of hydroxide ion has what effect on this reaction?

(A) The rate of reaction increases.
(B) The rate of reaction decreases.
(C) The value of the equilibrium constant increases.
(D) The value of the equilibrium constant decreases.
(E) Neither the rate nor the value of the equilibrium constant is changed.

42. When solid sodium hydroxide, NaOH(s) is added to water at 25 °C, it dissolves and the temperature of the solution increases. Which of the following is true for the values of ΔH and ΔS for the dissolving process?

	ΔH	ΔS
A)	>0	>0
B)	>0	<0
C)	>0	0
D)	<0	>0
E)	<0	<0

43. Which of the following statements is not a component of the kinetic molecular theory?

(A) The volume occupied by gas particles is only significant at very low pressures.
(B) The particles of a gas experience no intermolecular attractive forces.
(C) The particles of a gas move in random straight line paths until a collision occurs.
(D) The collisions that occur between gas particles are considered to be “elastic” collisions.
(E) At a given temperature, all gas molecules within a sample possess the same average kinetic energy.

44. $\_\ H^{+}_{(aq)} + \_\ Cr_2O_7^{2-}{}_{(aq)} + \_\ C_2H_5OH_{(l)} \rightarrow \_\ Cr^{3+}{}_{(aq)} + \_\ CO_{2\ (g)} + \_ H_2O_{(l)}$

When the equation for the redox reaction represented above is balanced and all coefficients are reduced to lowest whole⁻number terms, the coefficient for water is

A. 1

B. 7

C. 11

D. 14

E. 15

45. $CH_3OH(g) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$

What is the value of ΔH_{rxn} for the complete combustion of methanol given the following information?

Compound		$\Delta H_f°$ (kJ/mol)
$CH_3OH(g)$	=	⁻200
$CO_2(g)$	=	⁻400
$H_2O(g)$	=	⁻240

A) ⁻440 kJ
B) ⁻840 kJ
C) ⁻880 kJ
D) ⁻1,120kJ
E) ⁻1,360 kJ

46. A sample of an ideal gas is cooled from 50.0 °C to 25.0 °C in a sealed container of constant volume. Which of the following values for the gas will decrease?

I. The average molecular mass of the gas
II. The average distance between the molecules
III. The average speed of the molecules

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

47. A molecule in which the central atom exhibits sp^2 hybrid orbitals has which of the following molecular shapes

(A) linear
(B) trigonal planar
(C) trigonal bipyramidal
(D) square planar
(E) tetrahedral

48. $\text{rate} = k[A]^2$

For the reaction whose rate law is given above, a plot of which of the following is a straight line?

(A) [A] versus time
(B) log [A] versus time
(C) 1/[A] versus time
(D) [A] versus 1/time
(E) log [A] versus 1/time

49. At 25 °C, a sample of NH_3 (molar mass 17 grams) effuses at the rate of 0.050 mole per minute. Under the same conditions, which of the following gases effuses at approximately one-half that rate?

(A) O_2 (molar mass 32 grams)
(B) He (molar mass 4.0 grams)
(C) CO_2 (molar mass 44 grams)
(D) Cl_2 (molar mass 71 grams)
(E) CH_4 (molar mass 16 grams)

50. The addition of an oxidizing agent such as bromine water to a clear solution of an unknown compound results in a color change. When this solution is shaken with an equal volume of mineral oil, the mineral oil layer turns purple. The unknown compound probably contains

(A) Cl^-
(B) Br^-
(C) MnO_4^-
(D) I^-
(E) Co^{2+}

51. Which of the following have most nearly the same atomic radius?

(A) Al, Si, P, S
(B) F, Cl, Br, I
(C) Ar, Cl, S, K
(D) Fe, Co, Ni, Cu
(E) K, Ca, Sc, Ti

52. Which of the following contribute most to the increased viscosity of a liquid?

I. Large intermolecular forces between molecules.
II. Increased molecular complexity.
III. A high capacity for hydrogen bonding between molecules.

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

53. A gaseous mixture containing 7.0 moles of nitrogen, 2.5 moles of oxygen, and 0.50 mole of helium exerts a total pressure of 0.90 atmospheres. What is the partial pressure of the nitrogen?

(A) 0.13 atm
(B) 0.27 atm
(C) 0.63 atm
(D) 0.90 atm
(E) 6.3 atm

Questions 54 – 55: The equation below refers to an electrochemical cell:

$$Cu^{2+} + Cd\,(s) \rightarrow Cu\,(s) + Cd^{2+} \qquad E°_{cell} = +0.74 \text{ volts}$$

54. Which expression gives the value for $\Delta G°$ in kJ/mol for this reaction?

(A) $-2 \times 8.31 \times 0.74$

(B) $2 \times 8.31 \times 0.74$

(C) $-2 \times 96,500 \times 0.74$

(D) $\dfrac{2 \times 96,500 \times 0.74}{1,000}$

(E) $\dfrac{-2 \times 96,500}{8.31 \times 0.74}$

55. Which expression gives the voltage for such a cell at non⁻standard conditions where $[Cu^{2+}]$ is 0.010 M and $[Cd^{2+}]$ is 1.00 M?

(A) $0.74 + 0.0592$
(B) $0.74 + (0.0592 \times 2)$
(C) $0.74 - 0.0592$
(D) $0.74 - (0.0592 \times 2)$
(E) $0.74 + 0.0592^2$

56. A 2.0 liter flask contains 8.00 grams of oxygen at a temperature of 127.0°C. What is the approximate pressure inside the flask?

(A) 1.3 atm
(B) 2.6 atm
(C) 4.1 atm
(D) 8.2 atm
(E) 16.4 atm

57. A 0.10-molar solution of a weak base, BOH, has a pH of 12.00. The ionization constant of this acid is

(A) 1.0×10^{-24}
(B) 1.0×10^{-23}
(C) 1.0×10^{-11}
(D) 1.0×10^{-3}
(E) 1.0×10^{-1}

58. A sample of an unknown hydrocarbon was burned in excess oxygen to form 22.0 grams of carbon dioxide and 18.0 grams of water. What is a possible empirical formula of the hydrocarbon?

(A) CH
(B) C_2H
(C) CH_2
(D) CH_3
(E) CH_4

59. If 0.080 faraday is passed through an electrolytic cell containing a solution of Ni^{2+} ions, the maximum number of moles of Ni that could be deposited at the cathode is

(A) 0.010 mole
(B) 0.020 mole
(C) 0.040 mole
(D) 0.080 mole
(E) 0.16 mole

60. Which of the following pairs of liquids forms the solution that is most ideal?

A) $Br_2(l)$ and $H_2O(l)$
B) $C_2H_5OH(l)$ and $H_2O(l)$
C) $C_2H_5OH(l)$ and $C_3H_7OH(l)$
D) $H_3PO_4(l)$ and $H_2O(l)$
E) $C_9H_{20}(l)$ and $C_{12}H_{26}(l)$

61. Which expression gives percent by mass of sulfur in $CuSO_4 \cdot 5H_2O$?

(A) $\frac{23}{112} \times 100$

(B) $\frac{32}{112} \times 100$

(C) $\frac{23}{130} \times 100$

(D) $\frac{23}{250} \times 100$

(E) $\frac{32}{250} \times 100$

62. $2\ Na + 2\ H_2O \rightarrow 2\ Na^+ + 2\ OH^- + H_2$

When 0.500 mole of sodium reacts with excess water at standard temperature and pressure as shown in the equation above, the volume of hydrogen gas produced is

(A) 11.2 liters
(B) 5.60 liters
(C) 2.80 liters
(D) 0.56 liters
(E) 0.28 liters

63. Which of the following has the highest first ionization energy?

(A) Li
(B) Be
(C) B
(D) C
(E) N

64. $3\ H_2(g) + N_2(g) \rightleftarrows 2\ NH_3(g) + \text{energy}$

Some H_2 and N_2 are mixed in a container at 300 °C and the system reaches equilibrium according to the equation above. Which of the following causes an increase in the number of moles of ammonia present at equilibrium?

I. Decreasing the volume of the container
II. Raising the temperature
III. Adding a mole of He gas at constant volume

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

65. $ClO_3^- + 5\ Cl^- + 6\ H^+ \rightleftarrows 3\ Cl_2 + 3\ H_2O$

If 25.0 milliliters of 0.400-molar ClO_3^- is mixed with 75.0 milliliters of 0.100-molar Cl^- solution that contains a large excess of H^+, the amount of water formed, according to the equation above, is

(A) 1.00×10^{-3} mole
(B) 1.50×10^{-3} mole
(C) 4.50×10^{-3} mole
(D) 7.50×10^{-3} mole
(E) 3.00×10^{-2} mole

66. Which applies to any reaction that proceeds spontaneously to form products from initial standard state conditions?

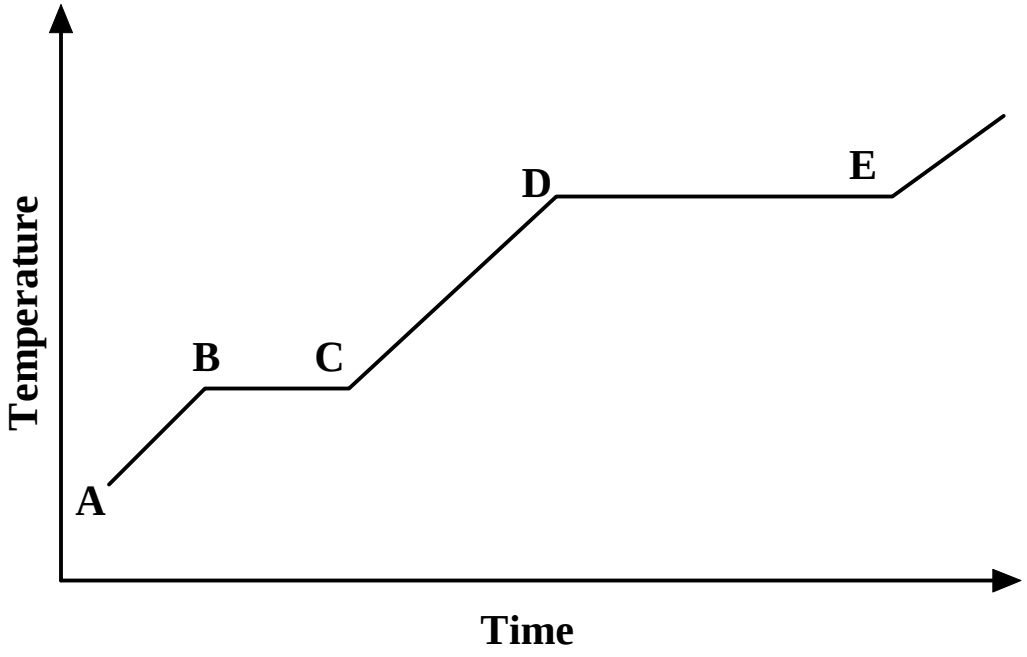
I. $K > 1$

II. $\Delta G < 0$

III. $E^\circ > 0$

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

Questions 67 – 69: Energy is added to a system at a constant rate as shown in the warming curve below.



67. Which of the following best represents the energy calculation involving region C—D of the graph?

(A) mass × ΔH_{fus}
(B) mass × c_{vapor} × ΔT
(C) mass × ΔH_{vap}
(D) mass × c_{liquid} × ΔT
(E) mass × ΔH_{vap} × ΔT

68. Which of the following best represents the energy calculation involving region D—E of the graph?

(A) mass × ΔH_{fus}
(B) mass × c_{vapor} × ΔT
(C) mass × ΔH_{vap}
(D) mass × c_{liquid} × ΔT
(E) mass × ΔH_{vap} × ΔT

69. Which points on the curve would be eliminated if the substance sublimes at standard conditions?

(A) B only
(B) C only
(C) B and C only
(D) B, C and D
(E) D and E only

70. The solubility of AgBr is 5×10^{-13} molar. What is the solubility product constant, K_{sp}, for AgBr?

(A) 10×10^{-26}
(B) 2.5×10^{-25}
(C) 5×10^{-13}
(D) 2.5×10^{-7}
(E) 2.3×10^{-7}

71. What number of moles of O_2 is needed to produce 25.5 grams of Al_2O_3 from solid Al? (Molecular weight Al_2O_3 =102)

(A) 0.125 mole
(B) 0.250 mole
(C) 0.375 mole
(D) 0.500 mole
(E) 1.00 mole

72. A sample of an ideal gas is allowed to expand. Which combination below best describes the change in the following attributes of the system once it has reestablished equilibrium?

	heat, q	**Entropy**	**Temperature**	**Pressure**
(A)	+	+	+	+
(B)	+	+	–	–
(C)	–	–	+	+
(D)	+	–	–	–
(E)	–	+	–	–

Experiment	Initial [NO] (mol L^{-1})	Initial [O_2] (mol L^{-1})	Initial Rate of Formation of NO_2 (mol L^{-1} s^{-1})
1	0.05	0.10	5.75×10^{-2}
2	0.10	0.10	2.30×10^{-1}
3	0.10	0.05	1.15×10^{-1}

73. The initial rate data in the table above were obtained for the reaction represented below.

$$NO_{(g)} + 2\ O_{2\,(g)} \rightarrow 2\ NO_{2\,(g)}$$

What is the experimental rate law for the reaction?

(A) rate = k[NO] [O_2]
(B) rate = k[NO] [O_2]^2
(C) rate = k[NO]^2 [O_2]
(D) rate = k[NO]^2 [O_2]^2
(E) rate = k[NO] / [O_2]

74. $2\ CO_2(g) \rightleftarrows O_2(g) + 2\ CO(g)$

When 0.20 mole of CO_2 and 0.30 mole of O_2 are placed in an evacuated 1.00 liter flask, the reaction represented above occurs. After the reactants and the product reach equilibrium and the initial temperature is restored, the flask is found to contain 0.10 mole of CO. Based on these results, the expression for the equilibrium constant, K_c, of the reaction is

(A) $[(0.30)(0.10)^2]/(0.35)$

(B) $[(0.20)^2 (0.30)]/[(0.10)^2]$

(C) $[(2 \times 0.10)(.35)] / [(0.10)^2]$

(D) $(0.10) / [(0.35)(0.10)]$

(E) $[(0.35)(0.10)^2] /(0.10)^2$

75. How many grams of calcium carbonate, $CaCO_3$, contains 40. grams of oxygen atoms?

(A) 300 grams
(B) 100 grams
(C) 83.3 grams
(D) 166 grams
(E) 13.3 grams