CHEMISTRY TEST

Note: For all questions involving solutions, assume that the solvent is water unless otherwise stated.

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

H	= enthalpy	atm	= atmosphere(s)
M	= molar	g	= gram(s)
n	= number of moles	J	= joule(s)
P	= pressure	kJ	= kilojoule(s)
R	= molar gas constant	L	= liter(s)
S	= entropy	mL	= milliliter(s)
T	= temperature	mm	= millimeter(s)
V	= volume	mol	= mole(s)
		V	= volt(s)

Part A

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

Questions 1-3 refer to the following pieces of laboratory equipment.

(A) Condenser
(B) Funnel
(C) Pipet
(D) Balance
(E) Barometer

1. Commonly used to transfer an exact volume of liquid from one container to another

2. Commonly used in a distillation setup

3. Commonly used in a filtration setup

Questions 4-6 refer to the following information.

Na_2CrO_4, a soluble yellow solid
$PbCrO_4$, an insoluble yellow solid
$NaNO_3$, a soluble white solid
$Pb(NO_3)_2$, a soluble white solid

(A) Yellow solid and colorless solution
(B) Yellow solid and yellow solution
(C) White solid and colorless solution
(D) No solid and yellow solution
(E) No solid and colorless solution

4. Observed when 1.0 mol of Na_2CrO_4 and 2.0 mol of $Pb(NO_3)_2$ are mixed with 1 L of water

5. Observed when 3.0 mol of Na_2CrO_4 and 1.0 mol of $Pb(NO_3)_2$ are mixed with 1 L of water

6. Observed when 1.0 mol of $NaNO_3$ and 1.0 mol of $Pb(NO_3)_2$ are mixed with 1 L of water

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Questions 7-9 refer to the following.

(A) Reduction potential
(B) Ionization energy (ionization potential)
(C) Electronegativity
(D) Heat of formation
(E) Activation energy

7. Is the energy change accompanying the synthesis of a compound from its elements in their standard states

8. Is the energy needed to remove an electron from a gaseous atom in its ground state

9. Is the minimum energy needed for molecules to react and form products

Questions 10-13 refer to the following pairs of substances.

(A) NH_3 and N_2H_4
(B) ^{16}O and ^{17}O
(C) NH_4Cl and NH_4NO_3
(D) CH_3OCH_3 and CH_3CH_2OH
(E) O_2 and O_3

10. Are isotopes

11. Have both ionic and covalent bonds

12. Are allotropes

13. Are strong electrolytes in aqueous solution

Questions 14-17 refer to the following subshells.

(A) 1*s*
(B) 2*s*
(C) 3*s*
(D) 3*p*
(E) 3*d*

14. Contains up to ten electrons

15. Contains one pair of electrons in the ground-state electron configuration of the lithium atom

16. Is exactly one-half filled in the ground-state electron configuration of the phosphorus atom

17. Contains the valence electrons in the ground-state electron configuration of the magnesium atom

Questions 18-20 refer to the following gases.

(A) O_3
(B) O_2
(C) CO
(D) Cl_2
(E) SO_2

18. Contributes to acid rain

19. In the stratosphere, screens out a large fraction of ultraviolet rays from the Sun

20. Is a product of the incomplete combustion of hydrocarbons

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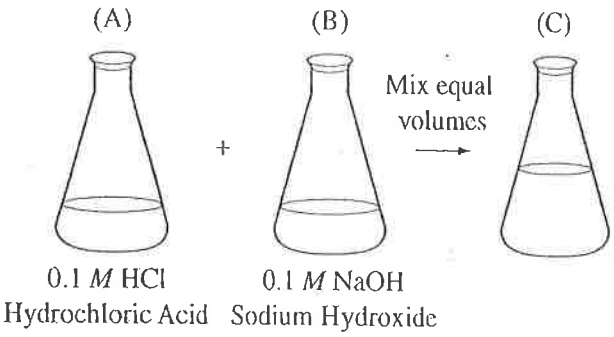
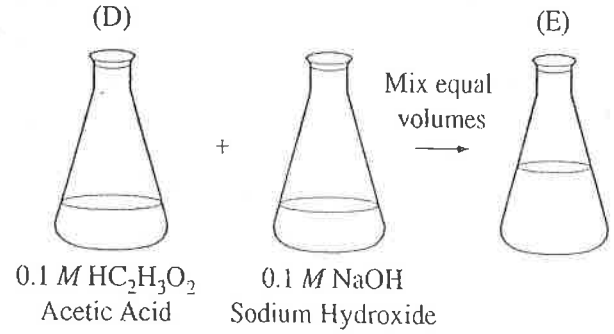
Questions 21-24 refer to the lettered solutions in the laboratory schemes represented below.





21. Has a hydroxide ion concentration of 10^{-7} *M* at 298 K

22. Has the highest pH at 298 K

23. Has a pH greater than 7, but less than 13 at 298 K

24. Has a pH greater than 2, but less than 7 at 298 K

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PLEASE GO TO THE SPECIAL SECTION LABELED CHEMISTRY AT THE LOWER LEFT-HAND CORNER OF THE PAGE OF THE ANSWER SHEET YOU ARE WORKING ON AND ANSWER QUESTIONS 101-115 ACCORDING TO THE FOLLOWING DIRECTIONS.

Part B

Directions: Each question below consists of two statements, I in the left-hand column and II in the right-hand column. For each question, determine whether statement I is true or false and whether statement II is true or false and fill in the corresponding T or F circles on your answer sheet. Fill in circle CE only if statement II is a correct explanation of the true statement I.

EXAMPLES:

	I		II
EX 1.	**H_2SO_4 is a strong acid**	**BECAUSE**	**H_2SO_4 contains sulfur.**
EX 2.	**An atom of oxygen is electrically neutral**	**BECAUSE**	**an oxygen atom contains an equal number of protons and electrons.**

SAMPLE ANSWERS

	I		II		CE*
EX1	●	Ⓕ	●	Ⓕ	○
EX2	●	Ⓕ	●	Ⓕ	●

	I		II
101.	C_2H_2 and C_6H_6 have the same chemical and physical properties	BECAUSE	C_2H_2 and C_6H_6 have the same percentages by mass of hydrogen.
102.	The melting of ice is an exothermic process	BECAUSE	water has a relatively high specific heat capacity.
103.	A 2 g sample of nitrogen and a 2 g sample of oxygen contain the same number of molecules	BECAUSE	equal masses of gaseous substances contain the same number of molecules.
104.	When an atom absorbs a photon of visible light, one of its electrons is promoted to a higher energy state	BECAUSE	an electron has a negative charge.
105.	The alkali metals are very good reducing agents	BECAUSE	the alkali metals are easily oxidized.
106.	A 1.0 g sample of calcium citrate, $Ca_3(C_6H_5O_7)_2$ (molar mass 498 g/mol), contains more Ca than a 1.0 g sample of calcium carbonate, $CaCO_3$ (molar mass 100 g/mol),	BECAUSE	there are more Ca atoms in 1.0 mol of calcium carbonate than in 1.0 mol of calcium citrate.
107.	The water molecule is polar	BECAUSE	the radius of an oxygen atom is greater than that of a hydrogen atom.

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	I		II
108.	All indicators are colorless in neutral solution	BECAUSE	indicators develop color only in the presence of a strong acid or a strong base.
109.	A 1 *M* sucrose solution and a 1 *M* NaCl solution have the same freezing point	BECAUSE	a 1 *M* sucrose solution and a 1 *M* NaCl solution contain the same number of solute particles per liter of solution.
110.	The average kinetic energy of gas molecules increases as the temperature increases	BECAUSE	the average speed of gas molecules decreases as the temperature increases.
111.	When a concentrated acid is diluted, the acid should be added slowly to the water	BECAUSE	if water is added to a concentrated acid, violent splattering might occur.
112.	Methane, CH_4, is very soluble in water	BECAUSE	water molecules form hydrogen bonds with methane molecules.
113.	A 1 mol sample of electrons is required to reduce 0.5 mol of chlorine gas to chloride ions	BECAUSE	chlorine molecules are diatomic and the charge on the chloride ion is −1.
114.	In 0.1 *M* acetic acid, $[H^+]$ is smaller than $[H^+]$ is in 0.1 *M* hydrochloric acid	BECAUSE	a molecule of acetic acid contains more atoms than does a molecule of hydrogen chloride.
115.	A fluoride ion, F^-, and an oxide ion, O^{2-}, have the same diameter	BECAUSE	the fluoride ion, F^-, and the oxide ion, O^{2-}, have the same number of electrons.

RETURN TO THE SECTION OF YOUR ANSWER SHEET YOU STARTED FOR CHEMISTRY AND ANSWER QUESTIONS 25-70.

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Part C

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 circle on the answer sheet.

$\ldots H_2S(g) + \ldots O_2(g) \rightarrow \ldots H_2O(g) + \ldots SO_2(g)$

25. When 2 mol of $H_2S(g)$ react with an excess of oxygen according to the equation above, how much $H_2O(g)$ is produced? (Equation is not balanced.)

(A) 1 mol
(B) 2 mol
(C) 3 mol
(D) 4 mol
(E) 6 mol

26. Increasing the temperature of a gas in a rigid closed container increases which of the following?

I. The pressure of the gas
II. The average speed of the gas molecules
III. The mass of the gas

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

27. The number of electrons in $^{118}_{50}Sn^{2+}$ is

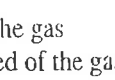
(A) 2
(B) 48
(C) 50
(D) 52
(E) 68

28. When two colorless liquid reagents are mixed, which of the following observations would suggest that a chemical reaction has occurred?

I. Formation of a precipitate
II. A color change
III. Appearance of gas bubbles

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

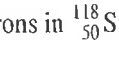
29. Which of the following is the correct and complete Lewis electron-dot diagram for PF_3 ?

(A) 

(B) 

(C)

(D)

(E) 

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30. Which of the following is a transition element?

(A) Iron
(B) Carbon
(C) Potassium
(D) Tin
(E) Radium

31. When 50. mL of 1.5 *M* NaCl(*aq*) is diluted with pure water to a final volume of 150. mL, what is the molarity of the resulting solution?

(A) 0.10 *M*
(B) 0.50 *M*
(C) 1.5 *M*
(D) 4.5 *M*
(E) 5.0 *M*

32. A 40.0 g sample of a hydrated salt was heated until all the water was driven off. The mass of the solid remaining was 32.0 g. What was the percent of water by mass in the original sample?

(A) 13.0%
(B) 20.0%
(C) 25.0%
(D) 75.0%
(E) 80.0%

33. A solution that has pH of 6.0 is

(A) strongly basic
(B) slightly basic
(C) neutral
(D) slightly acidic
(E) strongly acidic

34. Which of the following molecules is a saturated hydrocarbon?

(A) C_3H_8
(B) C_2H_4
(C) CH_3Cl
(D) CCl_4
(E) CO_2

$\ldots Fe_2O_3(s) + \ldots CO(g) \rightarrow \ldots Fe(s) + \ldots CO_2(g)$

35. When the equation above is balanced and all the coefficients are reduced to lowest whole-number terms, what is the coefficient for $Fe_2O_3(s)$?

(A) 1
(B) 2
(C) 3
(D) 4
(E) 5

36. In which of the following compounds does nitrogen have an oxidation number of +5 ?

(A) HNO_3
(B) N_2
(C) NO_2
(D) N_2O
(E) NH_2OH

37. If both NaOH and KOH were the same price per kilogram, it would be cheaper to use NaOH to neutralize a quantity of acid because NaOH

(A) weighs less per mole than KOH
(B) weighs more per mole than KOH
(C) neutralizes more acid per mole than KOH
(D) neutralizes less acid per mole than KOH
(E) is less dense than KOH

38. When a given amount of $Ca(OH)_2$ is completely neutralized with H_2SO_4, which of the following is the mole ratio of $Ca(OH)_2$ to H_2SO_4 in this reaction?

(A) 1 : 4
(B) 1 : 2
(C) 1 : 1
(D) 2 : 1
(E) 4 : 1

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39. Factors that influence whether or not two colliding molecules will react include which of the following?

I. The energy of the collision
II. The orientation of the molecules
III. The size difference between the reactant and product molecules

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

$$2\,SO_2(g) + O_2(g) \rightleftarrows 2\,SO_3(g)$$

40. What is the expression for the equilibrium constant, K_{eq}, for the reaction represented above?

(A) $K_{eq} = \dfrac{[SO_3]}{[SO_2][O_2]}$

(B) $K_{eq} = \dfrac{[SO_3]^2}{[SO_2]^2[O_2]}$

(C) $K_{eq} = \dfrac{[SO_2] + [O_2]}{[SO_3]}$

(D) $K_{eq} = \dfrac{[SO_2]^2 + [O_2]}{[SO_3]^2}$

(E) $K_{eq} = \dfrac{[SO_3]}{[SO_2] + [O_2]}$

41. A solution contains 1.00 mol of glucose, $C_6H_{12}O_6$, and 2.00 mol of urea, $(NH_2)_2CO$, in 7.00 mol of water. What is the mole fraction of glucose in the solution?

(A) 0.100
(B) 0.143
(C) 0.200
(D) 0.333
(E) 0.500

Temperature (°C)	Vapor Pressure of Ethyl Alcohol (mm Hg)
60	350
70	538
80	813
90	1,182
100	1,698

42. The barometric pressure on Pikes Peak (14,109 feet) in Colorado averages 455 mm Hg. From the table above, one can conclude that the boiling point of ethyl alcohol at this altitude would be

(A) 100°C
(B) between 90°C and 100°C
(C) between 80°C and 90°C
(D) between 70°C and 80°C
(E) between 60°C and 70°C

$$\ldots Zn(s) + \ldots H^+(aq) \rightarrow$$

43. When the equation for the reaction represented above is completed and balanced and all coefficients are reduced to lowest whole-number terms, the coefficient for $H^+(aq)$ is

(A) 2
(B) 3
(C) 4
(D) 5
(E) 6

44. Which of the following statements is true concerning a saturated solution of a salt at a constant temperature?

(A) The concentrations of salt and solvent are usually equal.
(B) The amount of dissolved salt is constant.
(C) Addition of solid salt shifts the equilibrium, which results in an increase in the amount of dissolved salt.
(D) The solution is unstable and sudden crystallization could occur.
(E) At the same temperature, a saturated solution of any other salt has the same concentration.

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$$2\,CO(g) + O_2(g) \rightarrow 2\,CO_2(g)$$

45. According to the reaction represented above, 1.00 mol of $CO(g)$ reacts at 0°C and 1 atm to consume how much $O_2(g)$?

(A) 32.0 g
(B) 11.2 L
(C) 22.4 L
(D) 1.00 mol
(E) 2.00 mol

46. Species that in water can either accept or donate protons include which of the following?

I. CH_4
II. HCO_3^-
III. HPO_4^{2-}

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

47. The ionization energies of Li and H are 520 kJ/mol and 1,312 kJ/mol, respectively. The ionization energy of He is

(A) 496 kJ/mol
(B) 656 kJ/mol
(C) 899 kJ/mol
(D) 1,086 kJ/mol
(E) 2,372 kJ/mol

48. An active ingredient in common household bleach solutions is most likely to be which of the following?

(A) NaCl
(B) NaClO
(C) $NaHCO_3$
(D) Na_2SO_4
(E) $HC_2H_3O_2$

$$^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{1}_{0}n + \_\_\_\_$$

49. The missing product in the nuclear reaction represented above is

(A) $^{1}_{1}H$
(B) $^{3}_{2}He$
(C) $^{4}_{2}He$
(D) $^{4}_{3}Li$
(E) $^{5}_{3}Li$

$$HCl(g) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$$

50. All of the following statements are correct for the reaction represented by the equation above EXCEPT:

(A) H_3O^+ is the conjugate acid of H_2O.
(B) Cl^- is the conjugate base of HCl.
(C) H_2O is behaving as a Brønsted-Lowry base.
(D) HCl is a weaker Brønsted-Lowry acid than H_2O.
(E) The reaction proceeds essentially to completion.

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P (atm)	2	1	0.5	0.4
V (L)	100	200	400	500
T (K)	200	200	200	200

51. The data given in the table above describe the behavior of a sample of gas. Which of the following empirical laws does the data illustrate? (k is a constant.)

(A) $P = kT$ at constant V

(B) $P_T = P_1 + P_2 + P_3 + \ldots$ at constant V and T

(C) $P = \frac{k}{V}$ at constant T

(D) $V = kT$ at constant P

(E) $P = kn$ (number of moles) at constant V and T

52. Of the following, which is an example of an oxidation-reduction reaction?

(A) $Fe(s) + Sn^{2+}(aq) \rightarrow Sn(s) + Fe^{2+}(aq)$

(B) $HCO_3^-(aq) + OH^-(aq) \rightarrow CO_3^{2-}(aq) + H_2O(l)$

(C) $Pb^{2+}(aq) + 2\,I^-(aq) \rightarrow PbI_2(s)$

(D) $HCl(g) + NH_3(g) \rightarrow NH_4Cl(s)$

(E) $Ba^{2+}(aq) + MnO_4^{2-}(aq) \rightarrow BaMnO_4(s)$

$$N_2(g) + 3\,H_2(g) \rightleftarrows 2\,NH_3(g) + \text{heat}$$

53. Which of the following statements about the reaction represented above is true?

(A) The forward reaction is endothermic.

(B) A 28 g sample of $N_2(g)$ reacts completely with a 3 g sample of $H_2(g)$.

(C) $NH_3(g)$ will dissociate into equal masses of $N_2(g)$ and $H_2(g)$.

(D) The reactants occupy a smaller volume than the products when measured at the same temperature and pressure.

(E) The equilibrium concentration of ammonia is affected by a change in temperature.

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54. The element carbon is the chief constituent of all of the following EXCEPT

(A) coal
(B) glass
(C) diamond
(D) charcoal
(E) graphite

55. At 0°C and 1.0 atm, the density of C_2H_4 gas is approximately

(A) 0.80 g/L
(B) 1.0 g/L
(C) 1.3 g/L
(D) 2.5 g/L
(E) 28 g/L

56. Which of the following contains a weak organic acid?

(A) Vinegar
(B) Hydrogen peroxide
(C) Baking soda
(D) Freon gas
(E) Ammonia

$$\ldots P_4O_{10}(s) + \ldots H_2O(l) \rightarrow \ldots H_3PO_4(aq)$$

57. When 1 mol of $P_4O_{10}(s)$ reacts completely with water to produce $H_3PO_4(aq)$ according to the reaction represented by the unbalanced equation above, the number of moles of $H_2O(l)$ consumed is

(A) 1 mol
(B) 3 mol
(C) 4 mol
(D) 6 mol
(E) 12 mol

58. Increased randomness results under which of the following conditions?

I. A 1 L sample of $He(g)$ and a 1 L sample of $Ne(g)$ are mixed in a 2 L flask.
II. Ice melts.
III. $CaO(s)$ reacts with $CO_2(g)$ to form $CaCO_3(s)$.

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

$$C_5H_{12}(l) + 8\,O_2(g) \rightarrow 5\,CO_2(g) + 6\,H_2O(l)$$

59. According to the balanced equation above, when 4 mol of $O_2(g)$ react completely with $C_5H_{12}(l)$, which of the following is true?

(A) 1 mol of $C_5H_{12}(l)$ must react.
(B) 2 mol of $C_5H_{12}(l)$ must react.
(C) 3 mol of $H_2O(l)$ must be formed.
(D) 12 mol of $H_2O(l)$ must be formed.
(E) 5 mol of $CO_2(g)$ must be formed.

60. True statements about transition metals include which of the following?

I. Most can exhibit more than one stable oxidation state.
II. Their compounds are often colored.
III. Their ions have partially filled *p*-orbitals.

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

61. The molarity of solution X is to be determined by a titration procedure. To carry out this procedure, all of the following must be known EXCEPT the

(A) equation for the chemical reaction that occurs during the titration
(B) volume of solution X that is used
(C) mass of solution X that is used
(D) volume of the solution that reacts with X
(E) molarity of the solution that reacts with X

62. The primary intermolecular attraction that makes it possible to liquefy hydrogen gas is called

(A) London dispersion forces
(B) dipole-dipole attraction
(C) covalent bonding
(D) ionic bonding
(E) hydrogen bonding

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Questions 63-65

$$Mg(s) + 2\,H^+ \rightarrow Mg^{2+} + H_2(g)$$

A student performed an experiment to determine the amount of hydrogen gas released in a reaction. The student produced the hydrogen gas by reacting hydrochloric acid and a strip of magnesium metal according to the equation above. All of the magnesium metal was consumed and the hydrogen gas was collected by displacement of water in an inverted bottle. The student's data contain the following information.

Mass of Mg	0.024 g
Volume of gas collected over water	25.2 mL
Water temperature	22.0°C
Room temperature	22.0°C
Atmospheric pressure	749.8 mm Hg
Vapor pressure of water at 22°C	19.8 mm Hg

63. What number of moles of magnesium was used?

(A) 5.8×10^{-1} mol
(B) 3.0×10^{-2} mol
(C) 2.4×10^{-2} mol
(D) 1.4×10^{-3} mol
(E) 1.0×10^{-3} mol

64. Why is it essential to know the water temperature in this experiment?

I. To find the vapor pressure of the water
II. To control the rate of reaction
III. To make sure that the reaction goes to completion

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

65. The volume of the dry hydrogen gas at 1 atm and room temperature would be

(A) $\frac{(25.2)(749.8 + 19.8)}{760}$ mL

(B) $\frac{(25.2)(760 - 19.8)}{749.8}$ mL

(C) $\frac{(25.2)(749.8 - 19.8)}{760}$ mL

(D) $\frac{(749.8 - 19.8)}{(760)(25.2)}$ mL

(E) $\frac{(760 - 19.8)}{(749.8)(25.2)}$ mL

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$$H_2(g) + F_2(g) \rightarrow 2\,HF(g) + 537.6\ kJ$$

66. If 0.10 mol of $HF(g)$ is formed according to the reaction represented above, approximately how much heat is evolved?

(A) 13 kJ
(B) 27 kJ
(C) 54 kJ
(D) 110 kJ
(E) 220 kJ

67. A chemical reaction is used to separate a mixture into separate substances in which of the following situations?

(A) Pure water is obtained from ocean water by evaporating the water and condensing it.
(B) Iron filings are separated from sand by the use of a magnet.
(C) Iron metal is produced from ore containing iron(III) oxide.
(D) Plant pigments in a solution are separated by the use of paper chromatography.
(E) Sand is obtained from a sand-sugar mixture by adding water to dissolve the sugar.

68. If a compound has an empirical formula of CH_2 and a molar mass of 70 g/mol, which of the following is most likely to be its molecular formula?

(A) C_3H_6
(B) C_4H_4
(C) C_4H_8
(D) C_5H_5
(E) C_5H_{10}

$$PCl_5(g) + \text{energy} \rightleftarrows PCl_3(g) + Cl_2(g)$$

69. The system above is at equilibrium in a closed container. Which of the following would increase the amount of PCl_3 in the system?

(A) Decreasing the pressure of the system at constant temperature
(B) Lowering the temperature at constant pressure
(C) Adding a catalyst
(D) Adding some $Cl_2(g)$ to the reaction vessel
(E) Removing some $PCl_5(g)$ from the reaction vessel

70. Which of the following terms gives a qualitative rather than a quantitative description of the concentration of a solution?

(A) Molality
(B) Mass percentage
(C) Dilute
(D) Mole fraction
(E) Molarity

STOP

IF YOU FINISH BEFORE TIME IS CALLED, YOU MAY CHECK YOUR WORK ON THIS TEST ONLY.
DO NOT TURN TO ANY OTHER TEST IN THIS BOOK.