Chemistry AP Exam

Name: ________________ School: _______________ Score:

1.	11.	21.	31.	41.	51.	61.	71.
2.	12.	22.	32.	42.	52.	62.	72.
3.	13.	23.	33.	43.	53.	63.	73.
4.	14.	24.	34.	44.	54.	64.	74.
5.	15.	25.	35.	45.	55.	65.	75.
6.	16.	26.	36.	46.	56.	66.	
7.	17.	27.	37.	47.	57.	67.	
8.	18.	28.	38.	48.	58.	68.	
9.	19.	29.	39.	49.	59.	69.	
10.	20.	30.	40.	50.	60.	70.	

1.

Chemistry AP Exam

Name: ________________ School: ________________ Score:

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Chemistry AP Exam

Name: ________________ School: ________________ Score:

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Name: ________________ School: ________________ Score:

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AP Chemistry Practice Exam —Multiple-Choice

Section 1
Time—1 hour and 30 minutes
NO CALCULATOR MAY BE USED WITH SECTION 1

Answer the following questions in the time allowed. You may use the periodic table in the back of the book.

1. Choose the strongest Lewis base from the following.

(A) Na^+
(B) Fe^{3+}
(C) NH_3
(D) Zn^{2+}
(E) BF_3

2. Which of the following CANNOT behave as both a Brønsted base and a Brønsted acid?

(A) HPO_4^{2-}
(B) $C_2O_4^{2-}$
(C) HSO_4^-
(D) $HC_2O_4^-$
(E) HCO_3^-

3. A species, molecule, or ion, is called a Lewis base if it does which of the following?

(A) It is an electron-pair donor.
(B) It donates an H^+.
(C) It accepts an H^+.
(D) It is an electron-pair acceptor.
(E) It increases the $H^+(aq)$ in water.

4. Which of following are proper laboratory procedures for a titration?

I. Make sure the color change of the indicator persists for at least 30 s.
II. Allow all materials to cool to room temperature before they are weighed.
III. Rinse the buret with deionized water before it is filled with titrant for the first titration.

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

5. In most of its compounds, this element exists as a monatomic cation.

(A) F
(B) S
(C) N
(D) Ca
(E) Cl

6. In which of the following groups are the species listed correctly in order of increasing radius?

(A) Sr, Ca, Mg
(B) Se^{2-}, S^{2-}, O^{2-}
(C) Mn^{3+}, Mn^{2+}, Mn
(D) I^-, Br^-, Cl^-
(E) K, Ca, Sc

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7. Which of the following elements has the lowest electronegativity?

(A) F
(B) I
(C) C
(D) K
(E) Al

8. Which of the following represents the correct formula for hexamminechromium(III) chloride?

(A) $[Cr(NH_3)_6](ClO_3)_3$
(B) $(NH_3)_6Cr_3Cl$
(C) Am_6CrCl_3
(D) $[Cr(NH_3)_6]Cl_3$
(E) $[Cr_3(NH_3)_6]Cl_3$

9. ____$Fe(OH)_3(s)$ + ____$H_2SeO_4(aq)$ →
____$Fe_2(SeO_4)_3(s)$ + ____$H_2O(l)$

After the above chemical equation is balanced, the lowest whole-number coefficient for water is

(A) 1
(B) 6
(C) 9
(D) 12
(E) 3

10. Which of the following best represents the net ionic equation for the reaction of barium hydroxide with an aqueous potassium sulfate solution?

(A) $Ba(OH)_2 + KSO_4 \rightarrow BaSO_4 + KOH$
(B) $Ba^{2+} + K_2SO_4 \rightarrow BaSO_4 + 2\,K^+$
(C) $Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$
(D) $Ba(OH)_2 + SO_4^{2-} \rightarrow BaSO_4 + 2\,OH^-$
(E) $Ba(OH)_2 + K_2SO_4 \rightarrow BaSO_4 + 2\,KOH$

11. A sample of magnesium metal is heated in the presence of nitrogen gas. After the sample was heated, some water was added to it. Which of the following statements is **false**?

(A) The magnesium reacted with the nitrogen to produce magnesium nitride.
(B) No reaction occurred because nitrogen gas is so unreactive.
(C) The solid did not dissolve in the water.
(D) After the addition of the water, the distinctive odor of ammonia gas was present.
(E) The water converted some of the magnesium nitride to magnesium hydroxide.

12. A student mixes 50.0 mL of 0.10 M $Ni(NO_3)_2$ solution with 50.0 mL of 0.10 M NaOH. A green precipitate forms, and the concentration of the hydroxide ion becomes very small. Which of the following correctly places the concentrations of the remaining ions in order of decreasing concentration?

(A) $[Na^+] > [Ni^{2+}] > [NO_3^-]$
(B) $[Ni^{2+}] > [NO_3^-] > [Na^+]$
(C) $[Na^+] > [NO_3^-] > [Ni^{2+}]$
(D) $[NO_3^-] > [Na^+] > [Ni^{2+}]$
(E) $[Ni^{2+}] > [Na^+] > [NO_3^-]$

13. The addition of concentrated $Ba(OH)_2(aq)$ to a 1.0 M $(NH_4)_2SO_4$ solution will result in which of the following observations?

(A) The odor of ammonia is detected, and a white precipitate forms.
(B) The formation of a white precipitate takes place.
(C) The solution becomes acidic.
(D) The odor of ammonia is detected.
(E) An odorless gas forms and bubbles out of the mixture.

14. Manganese, Mn, forms a number of oxides. A particular oxide is 69.6% Mn. What is the simplest formula for this oxide?

(A) MnO
(B) Mn_2O_3
(C) Mn_3O_4
(D) MnO_2
(E) Mn_2O_7

15. Sodium sulfate forms a number of hydrates. A sample of a hydrate is heated until all the water is removed. What is the formula of the original hydrate if it loses 56% of its mass when heated?

(A) $Na_2SO_4.H_2O$
(B) $Na_2SO_4.2\,H_2O$
(C) $Na_2SO_4.6\,H_2O$
(D) $Na_2SO_4.8\,H_2O$
(E) $Na_2SO_4.10\,H_2O$

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16. $3\ Cu(s) + 8\ HNO_3(aq) \rightarrow 3\ Cu(NO_3)_2(aq) + 2\ NO(g) + 4\ H_2O(l)$

Copper metal reacts with nitric acid according to the above equation. A 0.30-mol sample of copper metal and 100.0 mL of 3.0 M nitric acid are mixed in a flask. How many moles of NO gas will form?

(A) 0.20 mol
(B) 0.038 mol
(C) 0.10 mol
(D) 0.075 mol
(E) 0.30 mol

17. Gold(III) oxide, Au_2O_3, can be decomposed to gold metal, Au, plus oxygen gas, O_2. How many moles of oxygen gas will form when 2.21 g of solid gold(III) oxide is decomposed? The formula mass of gold(III) oxide is 442.

(A) 0.00750 mol
(B) 0.0150 mol
(C) 0.00500 mol
(D) 0.00250 mol
(E) 0.0100 mol

18. ____$C_4H_{11}N(l)$ + ____$O_2(g)$ → ____$CO_2(g)$ + ____$H_2O(l)$ + ____$N_2(g)$

When the above equation is balanced, the lowest whole number coefficient for CO_2 is:

(A) 4
(B) 16
(C) 27
(D) 22
(E) 2

19. $2\ KMnO_4 + 5\ H_2C_2O_4 + 3\ H_2SO_4 \rightarrow K_2SO_4 + 2\ MnSO_4 + 10\ CO_2 + 8\ H_2O$

How many moles of $MnSO_4$ are produced when 2.0 mol of $KMnO_4$, 5.0 mol of $H_2C_2O_4$, and 1.5 mol of H_2SO_4 are mixed?

(A) 2.0 mol
(B) 1.5 mol
(C) 1.0 mol
(D) 3.0 mol
(E) 2.5 mol

20. ____$KClO_3$ → ____KCl + ____O_2

After the above equation is balanced, how many moles of O_2 can be produced from 1.0 mol of $KClO_3$?

(A) 1.5 mol
(B) 3.0 mol
(C) 1.0 mol
(D) 3.0 mol
(E) 6.0 mol

21. $Sr + 2\ H_2O \rightarrow Sr(OH)_2 + H_2$

Strontium reacts with water according to the above reaction. What volume of hydrogen gas, at standard temperature and pressure, is produced from 0.100 mol of strontium?

(A) 3.36 L
(B) 5.60 L
(C) 2.24 L
(D) 4.48 L
(E) 1.12 L

22. A sample of nitrogen gas is placed in a container with constant volume. The temperature is changed until the pressure doubles. Which of the following also changes?

(A) density
(B) moles
(C) average velocity
(D) number of molecules
(E) potential energy

23. An experiment to determine the molecular mass of a gas begins by heating a solid to produce a gaseous product. The gas passes through a tube and displaces water in an inverted, water-filled bottle. The mass of the solid is measured, as is the volume and the temperature of the displaced water. Once the barometric pressure has been recorded, what other information is needed to finish the experiment?

(A) the heat of formation of the gas
(B) the density of the water
(C) the mass of the displaced water
(D) the vapor pressure of the water
(E) the temperature to which the solid was heated

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24. Determine the final temperature of a sample of hydrogen gas. The sample initially occupied a volume of 6.00 L at 127°C and 875 mm Hg. The sample was heated, at constant pressure, until it occupied a volume of 15.00 L.

(A) 318°C
(B) 727°C
(C) 45°C
(D) 160°C
(E) 1000°C

25. From the following, choose the gas that probably shows the least deviation from ideal gas behavior.

(A) Kr
(B) CH_4
(C) O_2
(D) H_2
(E) NH_3

Choose from the following types of energy for questions 26–28.

(A) free energy
(B) lattice energy
(C) kinetic energy
(D) activation energy
(E) ionization energy

26. The maximum energy available for useful work from a spontaneous reaction

27. The energy needed to separate the ions in an ionic solid

28. The energy difference between the transition state and the reactants

1. $2\ ClF(g) + O_2(g) \rightarrow Cl_2O(g) + OF_2(g)$ $\quad \Delta H° = 167.5$ kJ
2. $2\ F_2(g) + O_2(g) \rightarrow 2\ OF_2(g)$ $\quad \Delta H° = -43.5$ kJ
3. $2\ ClF_3(l) + 2\ O_2(g) \rightarrow Cl_2O(g) + 3\ OF_2(g)$ $\quad \Delta H° = 394.1$ kJ

29. Using the information given above, calculate the enthalpy change for the following reaction:

$$ClF(g) + F_2(g) \rightarrow ClF_3(l)$$

(A) −135.1 kJ
(B) +135.1 kJ
(C) 270.2 kJ
(D) −270.2 kJ
(E) 0.0 kJ

30. When lithium sulfate, Li_2SO_4, is dissolved in water, the temperature increases. Which of the following conclusions may be related to this?

(A) Lithium sulfate is less soluble in hot water.
(B) The hydration energies of lithium ions and sulfate ions are very low.
(C) The heat of solution for lithium sulfate is endothermic.
(D) The solution is not an ideal solution.
(E) The lattice energy of lithium sulfate is very low.

31. What is the energy required to form a gaseous cation from a gaseous atom?

(A) ionization energy
(B) kinetic energy
(C) activation energy
(D) lattice energy
(E) free energy

32. $C_2H_4(g) + H_2O(g) \rightarrow C_2H_5OH(g)$ $\quad \Delta H = -46$ kJ

Determine ΔH for the above reaction if $C_2H_5OH(l)$ was formed in the above reaction instead of $C_2H_5OH(g)$. The ΔH of vaporization for C_2H_5OH is 43 kJ/mol.

(A) +3 kJ
(B) +89 kJ
(C) −3 kJ
(D) +43 kJ
(E) −89 kJ

33. The ground-state configuration of Ni^{2+} is which of the following?

(A) $1s^22s^22p^63s^23p^63d^84s^2$
(B) $1s^22s^22p^63s^23p^63d^{10}4s^2$
(C) $1s^22s^22p^63s^23p^63d^{10}$
(D) $1s^22s^22p^63s^23p^63d^8$
(E) $1s^22s^22p^63s^23p^63d^54s^2$

34. A ground-state electron in a calcium atom might have which of the following sets of quantum numbers?

(A) $n = 3$; $l = 2$; $m_l = 0$; $m_s = -1/2$
(B) $n = 5$; $l = 0$; $m_l = 0$; $m_s = -1/2$
(C) $n = 4$; $l = 1$; $m_l = 0$; $m_s = -1/2$
(D) $n = 4$; $l = 0$; $m_l = 0$; $m_s = -1/2$
(E) $n = 4$; $l = 0$; $m_l = +1$; $m_s = -1/2$

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The following answers are to be used for questions 35–38.

(A) Pauli exclusion principle
(B) electron shielding
(C) the wave properties of matter
(D) Heisenberg uncertainty principle
(E) Hund's rule

35. The diffraction of electrons

36. The maximum number of electrons in an atomic orbital is two.

37. An oxygen atom is paramagnetic in the ground state.

38. The position and momentum of an electron cannot be determined exactly.

39. Magnesium reacts with element X to form an ionic compound. If the ground-state electron configuration of X is $1s^2 2s^2 2p^5$, what is the simplest formula for this compound?

(A) Mg_2X_3
(B) MgX_2
(C) MgX_4
(D) Mg_2X_5
(E) MgX

40. VSEPR predicts that a BF_3 molecule will be which of the following shapes?

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

41. Which of the following is polar?

(A) BF_3
(B) IF_5
(C) CF_4
(D) XeF_4
(E) AsF_5

42. The only substance listed below that contains ionic, σ, and π bonds is:

(A) C_2H_4
(B) NaH
(C) NH_4Cl
(D) $NaC_2H_3O_2$
(E) H_2O

43. Which molecule or ion in the following list has the greatest number of unshared electron pairs around the central atom?

(A) IF_7
(B) NO_3^-
(C) BF_3
(D) NH_3
(E) CBr_4

44. Which of the following processes does not involve breaking an ionic or a covalent bond?

(A) $2\ NO(g) + O_2 \rightarrow 2\ NO_2(g)$
(B) $NaNO_3(s) \rightarrow Na^+(aq) + NO_3^-(aq)$
(C) $Zn(s) \rightarrow Zn(g)$
(D) $2\ H_2(g) + O_2(g) \rightarrow 2\ H_2O(g)$
(E) $2\ KClO_3(s) \rightarrow 2\ KCl(s) + 3\ O_2(g)$

Choose from the following solids for questions 45–48.

(A) composed of atoms held together by delocalized electrons
(B) composed of molecules held together by intermolecular dipole–dipole interactions
(C) composed of positive and negative ions held together by electrostatic attractions
(D) composed of macromolecules held together by strong bonds
(E) composed of molecules held together by intermolecular London forces

45. Graphite

46. Ca(s)

47. $CaCO_3(s)$

48. $SO_2(s)$

49. The critical point represents

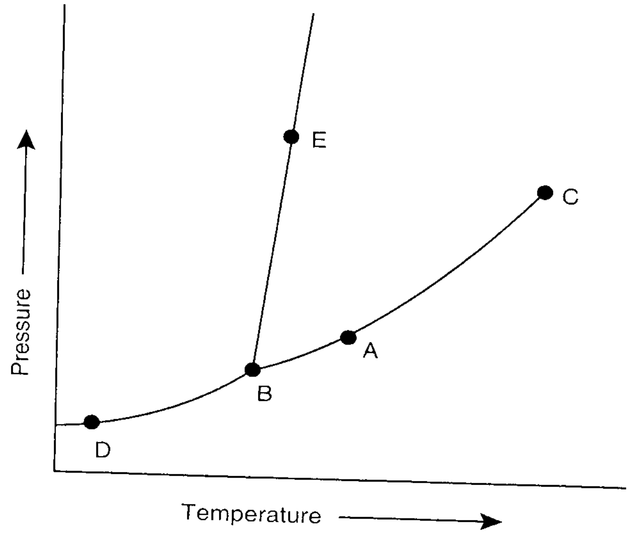
(A) the highest temperature and pressure where the substance may exist as discrete solid and gas phases.
(B) the highest temperature and pressure where the substance may exist as discrete liquid and gas phases.
(C) the temperature and pressure where the substance exists in equilibrium as solid, liquid, and gas phases.
(D) the highest temperature and pressure where the substance may exist as discrete liquid and solid phases.
(E) the highest temperature and pressure where a substance can sublime.

50. A sample of a pure liquid is placed in an open container and heated to the boiling point. Which of the following may increase the boiling point of the liquid?

I. The container is sealed.
II. The size of the container is increased.
III. More liquid is added.

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

51. Which point on the diagram below might represent the normal boiling point?



52. What is the total concentration of cations in a solution made by combining 700.0 mL, of 3.0 M $(NH_4)_3PO_4$ with 300.0 mL of 2.0 M Na_2SO_4?

(A) 2.7 M
(B) 13 M
(C) 7.5 M
(D) 5.0 M
(E) 2.5 M

53. A stock solution that is 0.30 M in Na_2SO_4 is available. How many moles of solid Na_3PO_4 must be added to 800 mL of this solution to increase the sodium ion concentration to 0.90 M?

(A) 0.060
(B) 0.12
(C) 0.080
(D) 0.16
(E) 0.24

54. If a solution of ethyl ether, $(C_2H_5)_2O$, in ethanol, C_2H_5OH, is treated as an ideal solution, what is the mole fraction of ethyl ether in the vapor over an equimolar solution of these two liquids? The vapor pressure of ethyl ether is 480 mm Hg at 20°C, and the vapor pressure of ethanol is 50 mm Hg at this temperature.

(A) 0.50
(B) 0.76
(C) 0.91
(D) 0.27
(E) 0.09

55. How many milliliters of concentrated ammonia (7.0-molar NH_3) are needed to prepare 0.250 L of 3.0-molar NH_3?

(A) 110 mL
(B) 0.11 mL
(C) 200 mL
(D) 150 mL
(E) 75 mL

56. The plot of ln[A] versus time gives a straight line. This implies the rate law is

(A) rate = $k[A]^2$
(B) rate = $k[A]^{-2}$
(C) rate = $k[A]^0$
(D) rate = $k[A]^{-1}$
(E) rate = $k[A]$

57. The specific rate constant, k, for radioactive lawrencium-256 is 86 h^{-1} What mass of a 0.0500 ng sample of lawrencium-256 remains after 58 s?

(A) 0.0500 ng
(B) 0.0250 ng
(C) 0.0125 ng
(D) 0.00625 ng
(E) 0.0375 ng

58. The purpose of using a lit match to start the fire in a gas grill is

(A) to supply the free energy for the reaction
(B) to catalyze the reaction
(C) to supply the heat of reaction
(D) to supply the kinetic energy for the reaction
(E) to supply the activation energy for the reaction

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59.

Acid	K_a, acid dissociation constant
H_3PO_4	7.2×10^{-3}
$H_2PO_4^-$	6.3×10^{-8}
HPO_4^{2-}	4.2×10^{-13}

Using the above information, choose the best answer for preparing a pH = 7.9 buffer.

(A) K_2HPO_4
(B) K_3PO_4
(C) $K_2HPO_4 + KH_2PO_4$
(D) $K_2HPO_4 + K_3PO_4$
(E) $H_3PO_4 + KH_2PO_4$

60. What is the ionization constant, K_a, for a weak monoprotic acid if a 0.6-molar solution has a pH of 2.0?

(A) 1.7×10^{-4}
(B) 1.7×10^{-2}
(C) 6×10^{-6}
(D) 2.7×10^{-3}
(E) 3.7×10^{-4}

Questions 61–64 refer to the following aqueous solutions. All concentrations are 1 M.

(A) CH_3NH_2 (methylamine) and LiOH (lithium hydroxide)
(B) $C_2H_5NH_2$ (ethylamine) and $C_2H_5NH_3NO_3$ (ethylammonium nitrate)
(C) CH_3NH_2 (methylamine) and $HC_3H_5O_2$ (propionic acid)
(D) $KClO_4$ (potassium perchlorate) and $HClO_4$ (perchloric acid)
(E) $H_2C_2O_4$ (oxalic acid) and KHC_2O_4 (potassium hydrogen oxalate)

61. The most basic solution (highest pH)

62. The solution with a pH nearest 7

63. A buffer with a pH > 7

64. A buffer with a pH < 7

65. At constant temperature, a change in volume will NOT affect the moles of the substances present in which of the following?

(A) $6\ CN^-(aq) + Fe^{3+}(aq) \rightarrow [Fe(CN)_6]^{3-}(aq)$

(B) $CO(g) + Cl_2(g) \rightarrow COCl_2(g)$

(C) $PCl_3(g) + Cl_2(g) \rightarrow PCl_5(g)$

(D) $CO(g) + H_2O(g) \rightarrow CO_2(g) + H_2(g)$

(E) $2\ NH_3(g) \rightarrow N_2(g) + 3\ H_2(g)$

66. $HCO_3^-(aq) + H_2O(e) \rightleftharpoons H_3O^+(aq) + CO_3^{2-}(aq)$

Which species, in the above equilibrium, behave as bases?

I. CO_3^{2-}
II. H_2O
III. HCO_3^-

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

67. $CO(g) + 2\ H_2(g) \rightarrow CH_3OH(g)$

A 1.00-L flask is filled with 0.70 mol of H_2 and 0.60 mol of CO, and allowed to come to equilibrium. At equilibrium, there are 0.40 mol of CO in the flask. What is the value of K_c, the equilibrium constant, for the reaction?

(A) 0.74
(B) 3.2
(C) 0.0050
(D) 5.6
(E) 1.2

68. $H_2O(l) + CrO_4^{2-}(aq) + HSnO_2^-(aq) \rightarrow$

$CrO_2^-(aq) + OH^-(aq) + HSnO_3^-(aq)$

What is the coefficient of OH^- when the above reaction is balanced?

(A) 10
(B) 2
(C) 5
(D) 4
(E) 1

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69. $2\,Bi^{3+} + 3\,SnO_2^{2-} + 6\,OH^- \rightarrow 3\,SnO_3^{2-} + 3\,H_2O + 2\,Bi$

For the above reaction, pick the true statement from the following:

(A) The oxidation number of tin changes from + 2 to + 4.
(B) The oxidation number of tin changes from + 4 to + 2.
(C) The Bi^{3+} is oxidized by the tin.
(D) The OH^- reduces the Bi^{3+}.
(E) The SnO_3^{2-} is formed by the reduction of SnO_2^{2-}.

70. An electrolysis cell was constructed with two platinum electrodes in a 1.00 M aqueous solution of KCl. An odorless gas evolved from one electrode and a gas with a distinctive odor evolved from the other electrode. Choose the correct statement from the following list.

(A) The odorless gas was oxygen.
(B) The odorless gas was evolved at the anode.
(C) The gas with the distinctive odor was evolved at the anode.
(D) The odorless gas was evolved at the positive electrode.
(E) The gas with the distinctive odor was evolved at the negative electrode.

71. When $^{226}_{88}Ra$ decays, it emits 2 α particles, then a β particle, followed by an α particle. The resulting nucleus is:

(A) $^{212}_{83}Bi$
(B) $^{222}_{86}Rn$
(C) $^{214}_{82}Pb$
(D) $^{214}_{83}Bi$
(E) $^{212}_{85}At$

72. Which of the following lists the types of radiation in the correct order of increasing penetrating power?

(A) α, γ, β
(B) β, α, γ
(C) α, β, γ
(D) β, γ, α
(E) γ, β, α

73. Which of the following statements are correct concerning β particles?

I. They have a mass number of zero and a charge of −1.
II. They are electrons.
III. They are less penetrating than α particles.

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

74. If 75% of a sample of pure ^3_1H decays in 24.6 yr, what is the half-life of ^3_1H?

(A) 24.6 yr
(B) 18.4 yr
(C) 12.3 yr
(D) 6.15 yr
(E) 3.07 yr

75. Alkenes are hydrocarbons with the general formula C_nH_{2n}. If a 0.420 g sample of any alkene is combusted in excess oxygen, how many moles of water will form?

(A) 0.0600
(B) 0.450
(C) 0.015
(D) 0.300
(E) 0.0300

STOP. End of AP Chemistry Practice Exam —Multiple-Choice

AP Chemistry Practice Exam —Free-Response

Time—1 hour and 35 minutes

Answer the following questions in the time allowed. You may use the tables at the back of the book. Write the answers on a separate sheet of paper.

Part A. Time — 55 minutes

You may use a calculator for part A.

Question 1.

Compound	K_{sp}
$Cr(OH)_2$	1.0×10^{-17}
$Cr(OH)_3$	6.3×10^{-31}
$Fe(OH)_2$	7.9×10^{-16}
$Pb(OH)_2$	1.1×10^{-20}
$Mg(OH)_2$	6.0×10^{-10}
$Mn(OH)_2$	1.9×10^{-13}
$Sn(OH)_2$	6.3×10^{-27}

Use the K_{sp} data given above to answer the following questions.

(a) Excess manganese(II) hydroxide, $Mn(OH)_2$, is added to 100.0 mL of deionized water. What is the pH of the solution?

(b) A solution that is 0.10 M in Mg^{2+} and 0.10 M in Fe^{2+} is slowly made basic. What is the concentration of Fe^{2+} when Mg^{2+} begins to precipitate?

(c) Two beakers are filled with water. Excess chromium(III) hydroxide is added to one and excess tin(II) hydroxide is added to the other. Which beaker has the higher concentration of metal ions? Calculate the concentration of metal ion in each beaker to support your prediction.

(d) Chromium(III) hydroxide, $Cr(OH)_3$, is less soluble than chromium(II) hydroxide, $Cr(OH)_2$. Explain.

(e) Calculate the grams of lead(II) hydroxide, $Pb(OH)_2$, that will dissolve in 1.00 L of water.

Question 2.

$$2\ PCl_3(g) + O_2(g) \rightarrow 2\ POCl_3(g)$$

Thermodynamic values related to the above reaction are given in the table below.

SUBSTANCE	ΔH_f° (kJ/mol)	S° (J/mol K)	BONDS	BOND ENERGIES (kJ/mol)
$PCl_3(g)$	–287	312	P–Cl	331
$O_2(g)$	0	205.0	O=O	498
$POCl_3(g)$	–542.2	325	O–O	204

(a) Determine the enthalpy change for the above reaction.

(b) Estimate the PO bond energy.

(c) Is the PO bond a single or a double bond? Justify your answer.

(d) Calculate the entropy change for the reaction.

(e) Is this reaction spontaneous or nonspontaneous at 25°C? Justify your prediction.

GO ON TO THE NEXT PAGE

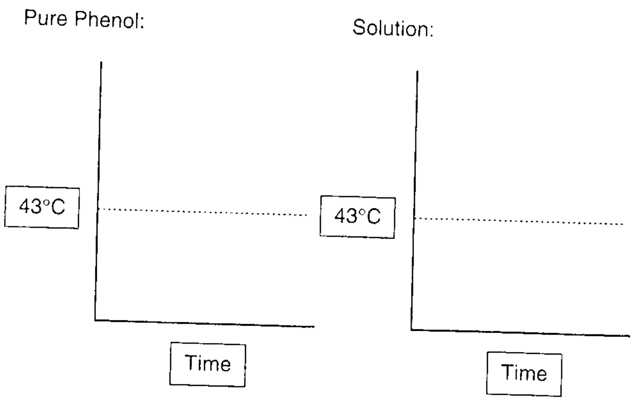
Question 3.

The following materials are made available for the determination of the molar mass of an unknown non-volatile solid.

analytical balance	thermometer	beaker	support stand and clamp
test tube	stopwatch	hot plate	

Phenol (melting point = 43°C and K_f = 7.40°C/m) is available as the solvent. The unknown behaves as a nonelectrolyte in phenol.

(a) Plot a cooling curve for phenol on the axes below, and plot the cooling curve for a solution of the unknown in phenol.



(b) What information must be obtained from the two graphs in order to calculate the molar mass?
(c) What additional information is needed to determine the molar mass of the unknown solid?
(d) Show how the above information may be used to calculate the molar mass of the unknown solid.

STOP

Part B. Time — 40 minutes

You may not use a calculator for part B.

Question 4.

Answer all three of the following questions. Each question will have two parts—writing the balanced chemical equation and answering a question about the reaction. Coefficients in the balanced chemical equation must be in the lowest whole-number ratio. Do not include formulas for substances that remain unchanged during the reaction. Unless otherwise noted, assume all the reactions occur in aqueous solution. If a substance is extensively ionized and therefore is present as ions in solution, write its formula as ions.

Example: Hydrochloric acid is added to a lead(II) nitrate solution.

$$Pb^{2+} + 2\ Cl^- \rightarrow PbCl_2$$

(a) Excess potassium cyanide is added to an iron(III) nitrate solution. Which species behaves as a Lewis base in the reaction? Explain.
(b) Chlorine gas is bubbled through a solution of calcium iodide. Identify the oxidizing and reducing agents in this reaction.
(c) An iron(III) nitrate solution is made basic with potassium hydroxide solution. Identify the spectator ions, if any, in this reaction.

Question 5

A sample of a solid, weak monoprotic acid, HA, is supplied along with standard sodium hydroxide solution. The sodium hydroxide solution was standardized with potassium hydrogen phthalate (KHP).

(a) List the apparatus required to titrate an HA solution.
(b) Sketch a pH versus volume of base added curve for the titration.
(c) Sketch the titration curve if the unknown acid was really a diprotic acid.
(d) Describe the steps required to determine the molar mass of HA.
(e) How would the molar mass of HA be changed if the KHP contained an inert impurity?

Question 6

Relate each of the following to atomic properties and the principles of bonding.

(a) The ionization energy of nitrogen atoms is higher than expected.
(b) Draw the Lewis electron-dot structures for CO_2 and CO. Explain the polarity of these compounds.
(c) The compound C_2H_3F is polar, but compounds with the general formula $C_2H_2F_2$ are sometimes polar and sometimes nonpolar. Show the structures and explain.
(d) There are two isomers with the formula C_2H_6O. One of the isomers is more soluble in water than the other. Use the structures of these two compounds to explain the difference in solubility.
(e) Why does SiF_4 react with fluoride ion, and CF_4 not react?

STOP. End of AP Chemistry Practice Exam

Chemistry AP Exam

Test 1

1. C	11. B	21. C	31. A	41. B	51. A	61. A	71. D
2. B	12. D	22. C	32. E	42. D	52. C	62. C	72. C
3. A	13. A	23. D	33. D	43. D	53. C	63. B	73. A
4. E	14. B	24. B	34. D	44. C	54. C	64. E	74. C
5. D	15. E	25. D	35. C	45. D	55. A	65. D	75. E
6. C	16. D	26. A	36. A	46. A	56. E	66. C	
7. D	17. A	27. B	37. E	47. C	57. C	67. D	
8. D	18. B	28. D	38. D	48. B	58. E	68. B	
9. B	19. C	29. A	39. B	49. B	59. C	69. A	
10. C	20. A	30. A	40. D	50. E	60. A	70. C	

› Answers and Explanations for Exam —Multiple-Choice

1. C—This is the only one that has a pair of electrons to donate.

2. B—All can behave as Brønsted bases. Only B cannot behave as an acid.

3. A—This is the definition of a Lewis base.

4. E—The buret should be rinsed with titrant, not water.

5. D—The others are normally monatomic anions.

6. C—Increasing sizes indicate decreasing charge, lower position in a column on the periodic table, or position to the left in a period on the periodic table.

7. D—The element furthest away from F.

8. D—Hexammine = $(NH_3)_6$; chromium(III) = Cr^{3+}; chloride = Cl^-

9. B—$2\ Fe(OH)_3(s) + 3\ H_2SeO_4(aq) \rightarrow Fe_2(SeO_4)_3(s) + 6\ H_2O(l)$

10. C—The soluble compounds should be separated and the spectator ions eliminated.

11. B—Magnesium nitride does form.

12. D—Some of the nickel remains, the sodium does not change, and two nitrates are formed per nickel(II) nitrate.

13. A—The reactions are: $NH_4^+ + OH^- \rightarrow NH_3 + H_2O$ and $Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$

14. B—Percentages: (A) 77.8; (B) 69.6; (C) 72.0; (D) 63.2; (E) 49.5

    Approximate the atomic weights to simplify the calculations.

15. E—Percentage of water: (A) 11; (B) 20; (C) 43; (D) 50; (E) 56

16. D—Nitric acid is the limiting reagent.

17. A—(2.21 g)(1 mol/442 g)(3 mol O_2/2 mol) = 7.50×10^{-3} mol. Simplify to $\left(\frac{2.2}{440}\right)(1.5)$.

18. B—$4\ C_4H_{11}N(l) + 27\ O_2(g) \rightarrow 16\ CO_2(g) + 22\ H_2O(l) + 2\ N_2(g)$

19. C—Sulfuric acid is the limiting reagent.

20. A—(1.0 mol $KClO_3$)(3 mol O_2/2 mol $KClO_3$) = 1.5 mol

21. C—(0.100 mol Sr)(1 mol H_2/1 mol Sr)(22.4 L/mol) = 2.24 L H_2

22. C—The average velocity is related to temperature.

23. D—Water, whenever present, will contribute its vapor pressure.

24. B—$T_2 = (V_2T_1)/V_1$ = [(15.00 L × 400 K)/(6.00 L)] − 273 = 727°C

25. D—Small and nonpolar

26. A—Definition

27. B—Definition

28. D—Definition

29. A—

$$
\begin{array}{lr}
\tfrac{1}{2}[2\ ClF(g) + O_2(g) \rightarrow Cl_2O(g) + OF_2(g)] & \tfrac{1}{2}(167.5\ kJ) \\
\tfrac{1}{2}[2\ F_2(g) + O_2(g) \rightarrow 2\ OF_2(g)] & \tfrac{1}{2}(-43.5\ kJ) \\
\tfrac{1}{2}[Cl_2O(g) + 3\ OF_2(g) \rightarrow 2\ ClF_3(l) + 2\ O_2(g)] & -\tfrac{1}{2}(394.1\ kJ) \\
\hline
ClF(g) + F_2(g) \rightarrow ClF_3(l) & -135.1\ kJ
\end{array}
$$

30. A—Exothermic processes shift toward the starting materials when heated.

31. A—Definition

32. E—Subtract the heat of vaporization from the original value.

33. D—Ni^{2+} has 26 electrons. The first electrons to leave are the 4s electrons.

34. D—This describes one of the 4s electrons.

35. C—Diffraction is a wave phenomenon.

36. A—Definition

37. E—Electrons fill the orbitals individually before pairing. Unpaired ↑ electrons = paramagnetic.

38. D—Definition

39. B—*X* is F and forms a − 1 ion. Magnesium forms a +2 ion.

40. D—BF_3 has three electron pairs around the B.

41. B—Using VSEPR, all the others are nonpolar.

42. D—Ionic bonding needs a metal and a nonmetal (usually). Only the acetate ion has resonating bonds (σ and π).

43. D—All the others have no unshared electron pairs.

44. C—Sublimation usually does not involve bond breaking. In any case, Zn is a metal, and it has no ionic or covalent bonds to break.

45. D—Both diamond and graphite are covalent network solids.

46. A—This is a description of metallic bonding.

47. C—This is a description of ionic bonding.

48. B—SO_2 consists of polar molecules.

49. B—Definition

50. E—This will increase the pressure and, therefore, the boiling point.

51. A—This is the only point on the liquid–gas transition line, other than the critical point.

52. C—[(0.7000 L)(3.0 mol/L)(3 cations/mol) + (0.3000 L)(2.0 mol) (2 cations/mol)]/1.000L

53. C—(0.800 L)(0.90 mol Na^+/L)-(0.800 L)(0.30 mol/L)(2 Na^+/mol) = 0.24 mol Na^+ needed (0.24 mol Na^+)(l mol Na_3PO_4/3 mol Na^+) = 0.080 mol Na_3PO_4

54. C—Equimolar gives a mole fraction of 0.5. 0.5 × 480 mm Hg + 0.5 × 50 mm Hg = 265 mm Hg (total vapor pressure) mole fraction ethyl ether = (0.5 × 480 mm Hg)/265 mm Hg

55. A—$V_{con} = M_{dil}\ V_{dil}/M_{con}$ = (3.0 M × 250 mL)/7.0 M

56. E—This plot gives a straight-line only for a first-order reaction.

57. C—$t_{1/2} = (0.693/86\ h^{-1})(3600\ s/h) = 29$ s. To save time on the exam you can approximate this equation as $t_{1/2} = (0.7/90)(3600)$. Dividing 3600 by 90 gives 40; 40 times 0.7=28. The time is equivalent to two half-lives, so one-fourth of the sample should remain.

58. E—Energy is required to initiate the reaction.

59. C—The pK_a for $H_2PO_4^-$ is nearest to the pH value needed. Thus, the simplest buffer would involve this ion. The phosphoric acid in E would lower the pH too much.

60. A—$K_a = [H^+][A^-]/[HA]$; $[H^+] = [A^-] = 1.0 \times 10^{-2}$ $[HA] = 0.6$

61. A—LiOH is a strong base.

62. C—A solution of a weak acid and a weak base would be nearly neutral.

63. B—Only B and E are buffers. B is basic, and E is acidic.

64. E—Only B and E are buffers. B is basic, and E is acidic.

65. D—If there are equal numbers of moles of gas on each side of the equilibrium arrow, then volume or pressure changes will not affect the equilibrium.

66. C—HCO_3^- and H_3O^+ behave as acids.

67. D—The loss of 0.20 mol of CO means that 0.40 mol of H_2 reacted (leaving 0.30 mol) and 0.20 mol of CH_3,OH formed. Dividing all the moles by the volume gives the molarity, and:

$$K_c = (0.20)/(0.40)(0.30)^2 = 5.6$$

68. B.—$H_2O(l) + 2\ CrO_4^{2-}(aq) + 3\ HSnO_2^-(aq)$

$\rightarrow 2\ CrO_2^-(aq) + 2\ OH^-(aq) + 3\ HSnO_3^-(aq)$

69. A—Assigning oxidation numbers and definitions is required.

70. C—Hydrogen (odorless) evolves at the cathode (negative), and chlorine (distinctive odor) evolves at the anode (positive).

71. D—The mass should be 226 – (4 + 4 + 0 + 4) = 214. The atomic number should be 88 – (2 + 2 – 1 + 2) = 83.

72. C—Alpha particles are the least penetrating, and gamma rays are the most penetrating.

73. A—In nuclear reactions, the mass of a β particle is treated as 0 and the charge is –1. Electrons and β particles are the same.

74. **C**—After one half-life, 50% would remain. After another half-life, this would be reduced by one-half to 25%. The total amount decayed is 75%. Thus, 24.6 years must be two half-lives of 12.3 years each.

75. **E**—One mole of alkene, C_nH_{2n}, will form *n* moles of water. It is possible to determine the value of *n* by dividing the mass of the alkene by the empirical formula mass.

Count the answers you got correct. This gives you your score on this set of questions.

› Answers and Explanations for Exam —Free-Response

Question 1.

(a) The volume of the solution is irrelevant. The equilibrium $Mn(OH)_2(s) \rightleftharpoons Mn^{2+}(aq) + 2\ OH^-(aq)$ is important. The mass-action expression for this equilibrium is: $K_{sp} = [Mn^{2+}][OH^-]^2 = 1.9 \times 10^{-13}$. Setting $[Mn^{2+}] = x$ and $[OH^-] = 2x$, and inserting into the mass-action expression gives: $(x)(2x)^2 = 4x^3 = 1.9 \times 10^{-13}$. Solving for x gives $x = 3.6 \times 10^{-5}$. and $[OH^-] = 2x = 7.2 \times 10^{-5}$.

You get 1 point for the correct $[OH^-]$.

There are two common ways to finish the problem. You do not need to show both.

(i) $pOH = -\log [OH^-] = -\log 7.5 \times 10^{-5} = 4.14$
$pH = 14.00 - pOH = 14.00 - 4.14 = 9.86$

(ii) $[H^+] = K_w/[OH^-] = 1.0 \times 10^{-14}/7.5 \times 10^{-5} = 1.4 \times 10^{-10}$
$pH = -\log [H^+] = -\log 1.4 \times 10^{-10} = 9.86$

You get 1 point for the correct pH. If you got the wrong $[OH^-]$ value, but used it correctly, you still get 1 point.

(b) The important equilibria are: $M(OH)_2(s) \rightleftharpoons M^{2+}(aq) + 2\ OH^-(aq)$, where M = Mg or Fe. It is necessary to determine the hydroxide ion concentration when the magnesium begins to precipitate.

$$K_{sp} = [Mg^{2+}][OH^-]^2 = 6.0 \times 10^{-10}$$

$$[OH^-]^2 = K_{sp}/[Mg^{2+}] = 6.0 \times 10^{-10}/0.10 = 6.0 \times 10^{-9}$$

$$[OH^-] = 7.7 \times 10^{-5}$$

Using this value with the iron equilibrium gives:

$$K_{sp} = [Fe^{2+}][OH^-]^2 = 7.9 \times 10^{-16}$$

$$[Fe^{2+}] = K_{sp}/[OH^-]^2 = (7.9 \times 10^{-16})/(7.7 \times 10^{-5})^2 = 1.3 \times 10^{-7}\ M$$

You get 1 point for the correct $[OH^-]$ and 1 point for the correct $[Fe^{2+}]$. Alternately, you get 1 point if you did only part of the procedure correctly. There is a maximum of 2 points for this part.

(c) Using the appropriate mass-action expressions:

$$K_{sp} = [Sn^{2+}][OH^-]^2 = 6.3 \times 10^{-27}$$

$$[Sn^{2+}] = x \text{ and } [OH^-]^2 = 2x$$

$$(x)(2x)^2 = 4x^3 = 6.3 \times 10^{-27}$$

$$x = 1.2 \times 10^{-9}\ M = [Sn^{2+}]$$

$$K_{sp} = [Cr^{3+}][OH^-]^3 = 6.3 \times 10^{-31}$$

$$[Cr^{3+}] = x \text{ and } [OH^-] = 3x$$

$$(x)(3x)^3 = 27x^4 = 6.3 \times 10^{-31}$$

$$x = 1.2 \times 10^{-8}\ M = [Cr^{3+}]$$

The tin(II) hydroxide beaker has the lower metal ion concentration.

You get 1 point for the correct beaker. You also get 1 point for each metal ion concentration you got correct. Your answers do not need to match exactly, but they should round to the same value.

(d) The higher the charge on the cation, the less soluble a substance is. You get 1 point for this answer.

(e) The mass-action expression is:

$$K_{sp} = [Pb^{2+}][OH^-]^2 = 1.1 \times 10^{-20}$$
$$[Pb^{2+}] = x \text{ and } [OH^-] = 2x$$
$$(x)(2x)^2 = 4x^3 = 1.1 \times 10^{-20}$$
$$x = 1.4 \times 10^{-7}\text{ M}$$
$$(1.4 \times 10^{-7}\text{mol/L})(1.00\text{L})(241.2\text{g/mol}) = 3.4 \times 10^{-5}\text{g}$$

You get 1 point for the correct answer (or an answer that rounds to this answer). You get 1 point for the setup.

Total your points for the different parts. There is a maximum of 10 points possible. Subtract one point if all answers did not have the correct number of significant figures.

Question 2.

(a) $\Delta H^\circ_{rxn} = [2(-542.2)] - [2(-287) + 1(0)] = -510.0$ kJ
The setup (products – reactants) is worth 1 point, and the answer is worth 1 point. You do not need to get the exact answer, but your answer should round to this one.

(b) The answer from part (a) equals the bonds broken minus the bonds formed. Both phosphorus molecules have three P–Cl bonds, and O_2 has an O=O bond.

$$[(2 \times 3 \times 331) + (498)] - [(2\text{ PO}) + (2 \times 3 \times 331)] = -510\text{ kJ}$$
$$\text{PO} = 504\text{ kJ}$$

The setup (broken – formed) is worth 1 point, and the answer is worth 1 point. You do not need to get the exact answer, but your answer should round to this one.

(c) It is a double bond. The value from part (b) is much higher than the single-bond values from the table.

You get 1 point for the correct prediction, and 1 point for the explanation. If you got the wrong answer for part (b), you can still get 1 or 2 points if you used the answer correctly on this part.

(d) $\Delta S^\circ_{rxn} = [2(325)] - [2(312) + 1(205.0)] = -179$ J/K

The setup (products – reactants) is worth 1 point, and the answer is worth 1 point. You do not need to get the exact answer, but your answer should round to this one.

(e) The free-energy change must be calculated.

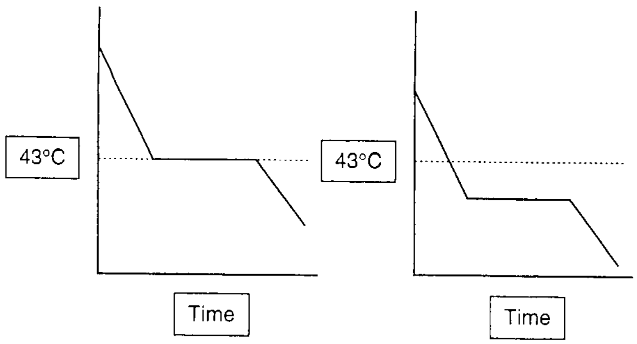
$\Delta G^\circ_{rxn} = \Delta H^\circ_{rxn} - T\Delta S^\circ_{rxn} = -510.\text{kJ} - (298\text{ K})(1\text{ kJ}/1000\text{ J})(-179\text{J/K}) = -457\text{ kJ}$

The negative value means the reaction is spontaneous.

You get 1 point for the prediction that the reaction is spontaneous. The setup (plugging into the equation) is worth 1 point if you remember to change the temperature to kelvin and convert joules to kilojoules. An additional 1 point comes from the answer. If you got the wrong value in either part (a) or (b), but used it correctly, you will still get the point for the answer. The free-energy equation is part of the material supplied in the exam booklet. Subtract one point if all your answers do not have the correct number of significant figures.

Question 3.

(a)



You get 1 point for the first plot. You get 1 point for the second plot only if the level region is definitely below 43°C.

(b) The difference in the temperatures of the two level regions (ΔT) is needed.

You get 1 point for this answer.

(c) The mass (in grams) of the unknown solid and the mass (in kilograms) of the phenol are required.

You get 1 point for each of these answers.

(d) The required equation is: $\Delta T = K_f m$

Calculate the molality of the solution by dividing the change in temperature (ΔT) by the freezing-point depression constant (K_f).

Calculate the moles of the unknown by multiplying the molality of the solution by the kilograms of phenol.

Calculate the molar mass by dividing the grams of the unknown by the moles of the unknown.

You get 1 point for each correct calculation you listed.

Total your points. There are 8 possible points.

Question 4.

(a)

$$6\ CN^-(aq) + Fe^{3+}(aq) \rightarrow [Fe(CN)_6]^{3-}(aq)$$

The cyanide ion is donating a pair of electrons to Fe^{3+}. Thus, the cyanide ion is a Lewis base.

You get 1 point for the correct formulas for the reactants and products, and 1 point for the correct coefficients in the balanced equation. Answering the associated question correctly is worth 1 point.

(b)

$$Cl_2 + 2\ I^- \rightarrow 2\ Cl^- + I_2$$

The reducing agent is the iodide ion and the oxidizing agent is chlorine gas.

You get 1 point for the correct formulas for the reactants and products, and 1 point for the correct coefficients in the balanced equation. Answering the associated question correctly is worth 1 point.

(c)

$$Fe^{3+} + 3\ OH^- \rightarrow Fe(OH)_3$$

The nitrate and potassium ions are spectator ions in this reaction.

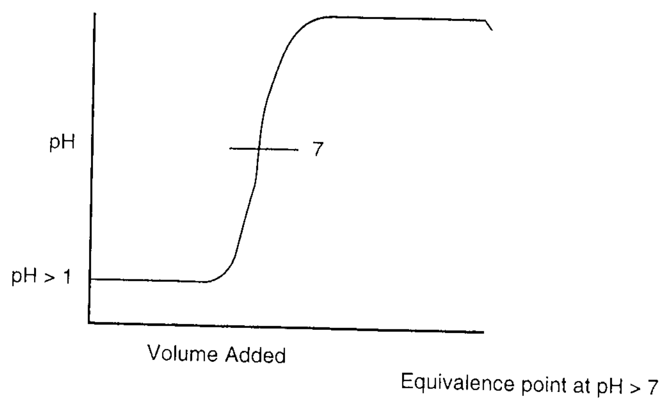
You get 1 point for the correct formulas for the reactants and products, and 1 point for the correct coefficients in the balanced equation. Answering the associated question correctly is worth 1 point.

Question 5.

(a) *analytical balance
desiccator
pH meter
wash bottle
*buret
drying oven
pipet
clamp
*Erlenmeyer flask
support stand

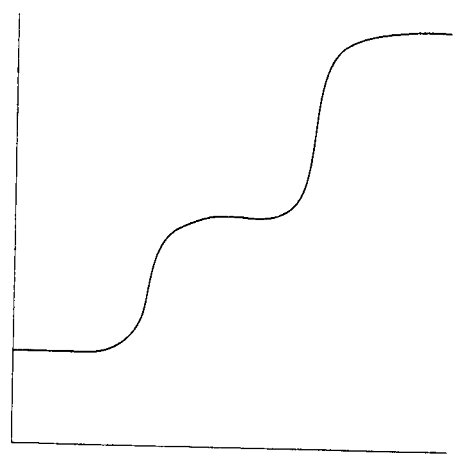
You get 1 point if you have ALL the starred items. You get 1 point for the other items. There is a maximum of 2 points. If you have only some of the starred items, your maximum is 1 point.

(b)



You get 1 point for this graph. You get 1 point for noting that the equivalence point is greater than 7.

(c)



You get 1 point for this graph. You must show two regions.

(d) 1. Weigh a sample of HA.
2. Titrate HA versus standard NaOH to find the volume of NaOH solution required to neutralize the acid.
3. Multiply the concentration of the NaOH solution times the volume used to get the moles of NaOH.
4. The moles of HA is the same as the moles of NaOH.
5. Divide the mass of HA by the moles of HA.

You get 2 points if you list all five steps. If you miss one or more steps you get only 1 point. You get 0 points if you get none of the steps correct. There are no bonus points for more steps or more details.

(e) If the KHP contained an inert impurity, the concentration of the NaOH solution would be too low. If the concentration of the NaOH solution were too low, then more solution would be needed for the titration of HA. This would yield a lower number of moles of HA, giving a higher molar mass.

You get 1 point for the NaOH concentration being low. You get 1 point for predicting a higher molar mass. If you incorrectly predicted the NaOH concentration to be too high, you can get 1 point if you predicted a lower molar mass.

Total your points. There is a maximum of 9 possible points.

Question 6

(a) Nitrogen atoms have a half-filled set of p-orbitals. Half-filled sets of orbitals have an increased stability.

You get 1 point for this answer.

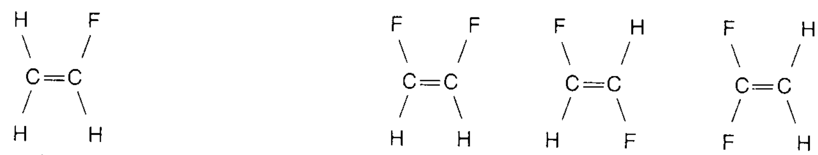
(b) :O::C::O: :C:::O:

CO_2 is linear and nonpolar. The different electronegativities of C and O make CO polar.

You get 1 point for each correct Lewis structure and 1 point if you explain both polarities correctly. There is a maximum of 3 points.

You may use a double line between the C and each of the O's in CO_2, and a triple line between the C and O in CO.

(c) There is one compound with the formula C_2H_3F, and there are three compounds with the formula $C_2H_2F_2$. The structures are:



polar polar nonpolar polar

The fluorines are the most electronegative atoms present, and the bonds to them are polar covalent. The only nonpolar compound is the result of the polar C–F bonds pulling equally in opposite directions.

You get 1 point for ALL the structures, and 1 point for a correct explanation. There is a maximum of 2 points.

(d) The structures are: CH_3–O–CH_3 and CH_3CH_2OH.

The first compound (dimethyl ether) is polar, but not as soluble in water as the second compound (ethanol) which is capable of hydrogen bonding to water.

You get 1 point if you show both structures, and you get 1 point for a correct explanation. The names shown in parentheses are not required.

(e) Silicon tetrafluoride is capable of reacting with the fluoride ion (to produce SiF_6^{2-}) because silicon can expand its octet. Carbon tetrafluoride does not react because carbon cannot expand its octet.

An alternate explanation would be that silicon has d orbitals available for reacting and carbon does not.

You get 1 point for either explanation.

Total your points for the problem. There is a maximum of 9 possible points.

TOTAL SCORE:

Question 1 _______

Question 2 _______

Question 3 _______

Question 4 _______

Question 5 _______

Question 6 _______