Name: _____ _____

Version A

Period: _____

AP* Chemistry: 1989 Released Multiple Choice Exam

NO CALCULATORS MAY BE USED

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

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)		

Directions: Each set of lettered choices below refers to the numbered questions or 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. ***Before turning in your answer sheet, count the number of questions that you have skipped and place that number next to your name ON YOUR ANSWER SHEET and circle it.***

Questions 1-3 refer to the following elements.

A) O

B) La

C) Rb

D) Mg

E) N

1. What is the most electronegative element of the above?

2. Which element exhibits the greatest number of different oxidation states?

3. Which of the elements above has the smallest ionic radius for its most commonly found ion?

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Questions 4 - 7 refer to the following electron configurations.

A) $1s^2\ 2s^2 2p^5\ \ 3s^2 3p^5$

B) $1s^2\ 2s^2 2p^6\ \ 3s^2 3p^6$

C) $1s^2\ 2s^2 2p^6 2d^{10}\ 3s^2 3p^6$

D) $1s^2\ 2s^2 2p^6\ \ 3s^2 3p^6 3d^5$

E) $1s^2\ 2s^2 2p^6\ \ 3s^2 3p^6 3d^3\ 4s^2$

4. An impossible electronic configuration

5. The ground-state configuration for the atoms of a transition element

6. The ground-state configuration of a negative ion of a halogen

7. The ground-state configuration of a common ion of an alkaline earth element

Questions 8-10 refer to the following descriptions of chemical solutions.

A) a solution with a pH less than 7 that is not a buffer solution

B) a buffer solution with a pH between 4 and 7

C) a buffer solution with a pH between 7 and 10

D) a solution with a pH greater than 7 that is not a buffer solution

E) a solution with a pH of 7

Ionization Constants

$CH_3COOH = 1.8 \times 10^{-5}$

$NH_3 = 1.8 \times 10^{-5}$

H_2CO_3; $K_1 = 4 \times 10^{-7}$

H_2CO_3; $K_2 = 4 \times 10^{-11}$

8. A solution prepared to be initially 1 *M* in NaCl and 1 *M* in HCl.

9. A solution prepared to be initially 1 *M* in Na_2CO_3 and 1 *M* in CH_3COONa

10. A solution prepared to be initially 0.5 *M* in CH_3COOH and 1 *M* in CH_3COONa

Questions 11-14 refer to the following terms.

A) hydrogen bonding

B) hybridization

C) ionic bonding

D) resonance

E) van der Waals forces (London dispersion forces)

11. Is used to explain why iodine molecules are held together in the solid state

12. Is used to explain why the boiling point of HF is greater than the boiling point of HBr

13. Is used to explain the fact that the four bonds in methane are equivalent

14. Is used to explain the fact that the carbon-to-carbon bonds in benzene, C_6H_6, are identical

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.

15. The weight of H_2SO_4 (molecular weight 98.1) in 50.0 milliliters of a 6.00-molar solution is

    A) 3.10 grams

    B) 12.0 grams

    C) 29.4 grams

    D) 294 grams

    E) 300. grams

16. 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 atmosphere. 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

17. The Lewis dot structure of which of the following molecules shows only one unshared pair of valence electrons?

    A) Cl_2

    B) N_2

    C) NH_3

    D) CCl_4

    E) H_2O_2

18. For the types of radiation given, which of the following is the correct order of <u>increasing</u> ability to penetrate a piece of lead?

    A) Alpha particles < gamma rays < beta particles

    B) Alpha particles < beta particles < gamma rays

    C) Beta particles < alpha particles < gamma rays

    D) Beta particles < gamma rays < alpha particles

    E) Gamma rays < alpha particles < beta particles

19. In the titration of a weak acid of unknown concentration with a standard solution of a strong base, a pH meter was used to follow the progress of the titration. Which of the following is true for this experiment?

    A) The pH is 7 at the equivalence point.

    B) The pH at the equivalence point depends on the indicator used.

    C) The graph of pH *versus* volume of base added rises gradually at first and then much more rapidly.

    D) The graph of pH *versus* volume of base added shows no sharp rise.

    E) The $[H^+]$ at the equivalence point equals the ionization constant of the acid.

20.

$$6\ I^- + 2\ MnO_4^- + 4\ H_2O(l) \rightarrow 3\ I_2(s) + 2\ MnO_2(s) + OH^-$$

Which of the following statements regarding the reaction represented by the equation above is correct?

A) Iodide ion is oxidized by hydroxide ion.

B) MnO_4^- is oxidized by iodide ion.

C) The oxidation number of manganese changes from +7 to +2.

D) The oxidation number of manganese remains the same.

E) The oxidation number of iodine changes from –1 to 0.

21. Which of the following is true at the triple point of a pure substance?

A) The vapor pressure of the solid phase always equals the vapor pressure of the liquid phase.

B) The temperature is always 0.01 K lower that the normal melting point.

C) The liquid and gas phases of the substance always have the same density and are therefore indistinguishable.

D) The solid phase always melts if the pressure increases at constant temperature.

E) The liquid phase always vaporizes if the pressure increases at constant temperature.

22.

$$\ldots Cr_2O_7^{2-} + \ldots e^- + \ldots H^+ \rightarrow \ldots Cr^{3+} + \ldots H_2O(l)$$

When the equation for the half-reaction above is balanced with the lowest whole-number coefficients, the coefficient for H_2O is

A) 2

B) 4

C) 6

D) 7

E) 14

23. How many grams of calcium nitrate, $Ca(NO_3)_2$, contains 24 grams of oxygen atoms?

A) 164 grams

B) 96 grams

C) 62 grams

D) 50. grams

E) 41 grams

24. The mass of element Q found in 1.00 mole of each of four different compounds is 38.0 grams, 57.0 grams, 76.0 grams, and 114 grams, respectively. A possible atomic weight of Q is

A) 12.7

B) 19.0

C) 27.5

D) 38.0

E) 57.0

25. The simplest formula for an oxide of element X (*MM* = 76.0) that is 24.0 percent oxygen by weight is

A) X_2O

B) XO

C) XO_2

D) X_2O_3

E) X_2O_5

26. How many milliliters of 11.6-molar HCl must be diluted to obtain 1.0 liter of 3.0-molar HCl?

A) 3.9 mL

B) 35 mL

C) 260 mL

D) 1,000 mL

E) 3,900 mL

27. I. Difference in temperature between freezing point of solvent and freezing point of solvent and freezing point of solution

II. Molal freezing point depression constant, K_f, for solvent

In addition to the information above, which of the following gives the minimum data required to determine the molecular mass of a nonionic substance by the freezing point depression technique?

A) No further information is necessary.

B) Mass of solute

C) Mass of solute and mass of solvent

D) Mass of solute and volume of solvent

E) Mass of solute, mass of solvent, and vapor pressure of solvent

28. Which of the following is probably true for a solid solute with a highly endothermic heat of solution when dissolved in water?

A) The solid has a low lattice energy.

B) As the solute dissolves, the temperature of the solution increases.

C) The resulting solution is ideal.

D) The solid is more soluble at higher temperatures.

E) The solid has a high energy of hydration.

29. In which of the following systems would the number of moles of the substances present at equilibrium NOT be shifted by a change in the volume of the system at constant temperature?

A) $CO(g) + NO(g) \leftrightarrows CO_2(g) + \frac{1}{2} N_2(g)$

B) $N_2(g) + 3\ H_2(g) \leftrightarrows 2\ NH_3(g)$

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

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

E) $NO(g) + O_3(g) \leftrightarrows NO_2(g) + O_2(g)$

30. Hydrogen gas is collected over water at 24° C. The total pressure of the sample is 755 millimeters of mercury. At 24° C, the vapor pressure of water is 22 millimeters of mercury. What is the partial pressure of the hydrogen gas?

A) 22 mm Hg

B) 733 mm Hg

C) 755 mm Hg

D) 760 mm Hg

E) 777 mm Hg

31. The structural isomers C_2H_5OH and CH_3OCH_3 would be expected to have the same values for which of the following? (Assume ideal behavior.)

A) Gaseous densities at the same temperature and pressure

B) Vapor pressures at the same temperature

C) Boiling points

D) Melting points

E) Heats of vaporization

32. A 2.00-liter sample of nitrogen gas at 27° C and 600. millimeters of mercury is heated until it occupies a volume of 5.00 liters. If the pressure remains unchanged, the final temperature of the gas is

A) 68° C

B) 120° C

C) 477° C

D) 677° C

E) 950.° C

33. Which of the following conclusions can be drawn from J. J. Thomson's cathode ray experiments?

A) Atoms contain electrons.

B) Practically all the mass of an atom is contained in its nucleus.

C) Atoms contain protons, neutrons, and electrons.

D) Atoms have a positively charged nucleus surrounded by an electron cloud.

E) No two electrons in one atom can have the same four quantum numbers.

34. All of the following species can function as Brönsted-Lowery bases in solution EXCEPT

A) H_2O

B) NH_3

C) S^{2-}

D) NH_4^+

E) HCO_3^-

35. When phenolphthalein is used as the indicator in a titration of an HCl solution with a solution of NaOH, the indicator undergoes a color change from clear to red at the end point of the titration. This color change occurs abruptly because

A) phenolphthalein is a very strong acid that is capable of rapid dissociation

B) the solution being titrated undergoes a large pH change near the end point of the titration

C) phenolphthalein undergoes an irreversible reaction in basic solution

D) OH^- acts as a catalyst for the decomposition of phenolphthalein

E) phenolphthalein is involved in the rate-determining step of the reaction between H_3O^+ and OH^-

36. Appropriate laboratory procedures include which of the following?

I. Rinsing a buret with distilled water just before filling it with the titrant for the first titration

II. Lubricating glass tubing before inserting it into a stopper

III. For accurate results, waiting until warm or hot objects have reached room temperature before weighing them

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

37.

$$\ldots\ CH_3CH_2COOH(l)\ +\ \ldots\ O_2(g)\ \rightarrow\ \ldots\ CO_2(g)\ +\ \ldots\ H_2O(l)$$

How many moles of O_2 are required to oxidize 1 mole of CH_3CH_2COOH according to the reaction represented above?

A) 2 moles

B) $\frac{5}{2}$ moles

C) 3 moles

D) $\frac{7}{2}$ moles

E) $\frac{9}{2}$ moles

38.

$$^{251}_{98}\mathrm{Cf}\ \rightarrow\ 2n\ +\ ^{131}_{54}\mathrm{Xe}\ +\ \ldots$$

What is the missing product in the nuclear reaction represented above?

A) $^{118}_{42}\mathrm{Mo}$

B) $^{118}_{44}\mathrm{Ru}$

C) $^{120}_{42}\mathrm{Mo}$

D) $^{120}_{44}\mathrm{Ru}$

E) $^{122}_{46}\mathrm{Pd}$

39. When a hydrate of X_2CO_3 (MM = 106) is heated until all the water is removed, it loses 54 percent of its mass. The formula of the hydrate is

A) $X_2CO_3 \cdot 10\ H_2O$

B) $X_2CO_3 \cdot 7\ H_2O$

C) $X_2CO_3 \cdot 5\ H_2O$

D) $X_2CO_3 \cdot 3\ H_2O$

E) $X_2CO_3 \cdot H_2O$

40.

$$2\ K\ +\ 2\ H_2O\ \rightarrow\ 2\ K^+\ +\ 2\ OH^-\ +\ H_2$$

When 0.400 mole of potassium reacts with excess water at standard temperature and pressure as shown in the equation above, the volume of hydrogen gas produced is

A) 1.12 liters

B) 2.24 liters

C) 3.36 liters

D) 4.48 liters

E) 6.72 liters

41. Which of the following reactions has the largest positive value of ΔS per mole of Cl_2

A) $H_2(g) + Cl_2(g) \rightarrow 2\ HCl(g)$

B) $Cl_2(g) + \frac{1}{2}\ O_2(g) \rightarrow Cl_2O(g)$

C) $Mg(s) + Cl_2(g) \rightarrow MgCl_2(s)$

D) $2\ NH_4Cl(s) \rightarrow N_2(g) + 4\ H_2(g) + Cl_2(g)$

E) $Cl_2(g) \rightarrow 2\ Cl(g)$

42. The $SbCl_5$ molecule has trigonal bipyramid structure. Therefore, the hybridization of Sb orbitals should be

A) sp^2

B) sp^3

C) dsp^2

D) dsp^3

E) d^2sp^3

43. Which of the following does NOT behave as an electrolyte when it is dissolved in water?

A) CH_3OH

B) K_2CO_3

C) NH_4Br

D) HI

E) Sodium acetate, CH_3COONa

44. The metal calcium reacts with molecular hydrogen to form a compound. All of the following statements concerning this compound are true EXCEPT:

A) Its formula is CaH_2.

B) It is ionic.

C) It is solid at room temperature.

D) When added to water, it reacts to produce H_2 gas.

E) When added to water, it forms an acidic solution.

45. A measured mass of an unreactive metal was dropped into a small graduated cylinder half filled with water. The following measurements were made.

    Mass of metal = 19.611 grams

    Volume of water before addition of metal = 12.4 milliliters

    Volume of water after addition of metal = 14.9 milliliters

    The density of the metal should be reported as

    A) 7.8444 grams per mL

    B) 7.844 grams per mL

    C) 7.84 grams per mL

    D) 7.8 grams per mL

    E) 8 grams per mL

46. As the number of oxygen atoms increases in any series of oxygen acids, such as HXO, HXO_2, HXO_3, ..., which of the following is generally true?

    A) The acid strength varies unpredictably.

    B) The acid strength decreases only if X is a nonmetal.

    C) The acid strength decreases only if X is a metal.

    D) The acid strength decreases whether X is a nonmetal or a metal.

    E) The acid strength increases.

47. CCl_4, CO_2, PCl_3, PCl_5, SF_6

    Which of the following does not describe any of the molecules above?

    A) Linear

    B) Octahedral

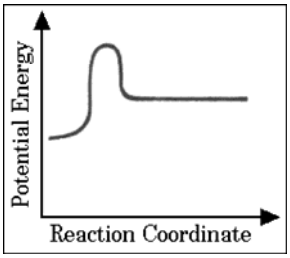
    C) Square planar

    D) Tetrahedral

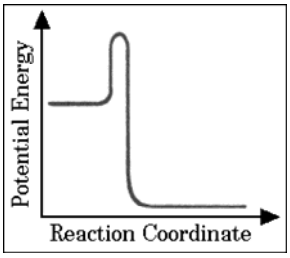
    E) Trigonal pyramidal

48. Which of the following is a graph that describes the pathway of reaction that is endothermic and has high activation energy?

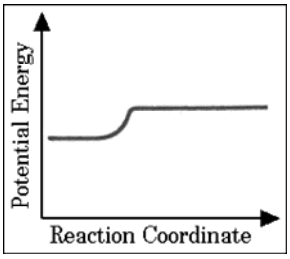
A)



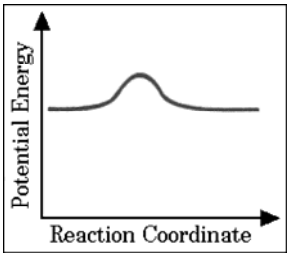
B)



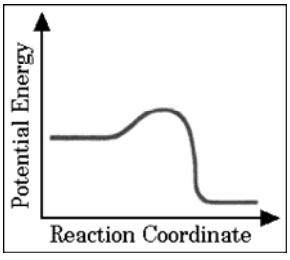
C)



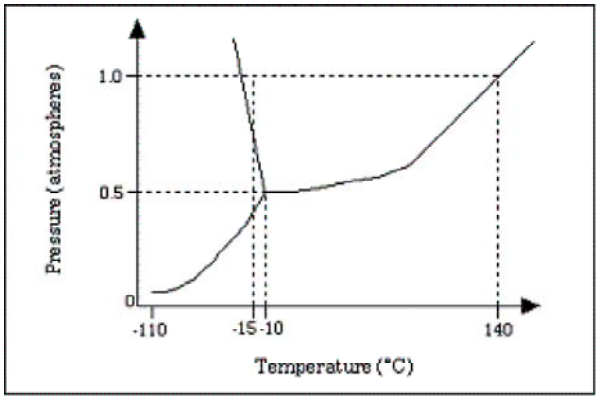
D)



E)



Questions 49-51 refer to the following diagram



49. The normal boiling point of the substance represented by the phase diagram above is

A) –15° C

B) –10° C

C) 140° C

D) greater than 140° C

E) not determinable from the diagram

50. The phase diagram above provides sufficient information for determining the

A) entropy change on vaporization

B) conditions necessary for sublimation

C) deviations from ideal gas behavior of the gas phase

D) latent heat of vaporization

E) latent heat of fusion

51. For the substance represented in the diagram, which of the phases is most dense and which is least dense at –15° C.

	Most Dense	Least Dense
A)	Solid	Gas
B)	Solid	Liquid
C)	Liquid	Solid
D)	Liquid	Gas

E) The diagram gives no information about densities.

52. The test for the presence of Ag^+ in an unknown solution involves the treatment of the silver-ammonia complex with dilute hydrochloric acid. The appearance of a white precipitate at this point indicates the presence of silver ion in the original sample. The net ionic equation that represents this test is

A) $Ag(NH_4)_4^+ + 4\ H^+ \leftrightarrows Ag(s) + 4\ NH_4^+$

B) $Ag(NH_4)_4^+ + Cl^- \leftrightarrows AgCl(s) + 4\ NH_4^+$

C) $Ag(NH_3)_4^+ + 4\ HCl \leftrightarrows AgCl(s) + 4\ NH_4^+ + 3\ Cl^-$

D) $Ag(NH_3)_4^+ + Cl^- \leftrightarrows Ag(NH_3)_2Cl(s)$

E) $Ag(NH_3)_4^+ + 2\ H^+ + Cl^- \leftrightarrows AgCl(s) + 2\ NH_4^+$

53. Which of the following must be true for a reaction that proceeds spontaneously from initial standard state conditions?

A) $\Delta G° > 0$ and $K_{eq} > 1$

B) $\Delta G° > 0$ and $K_{eq} < 1$

C) $\Delta G° < 0$ and $K_{eq} > 1$

D) $\Delta G° > 0$ and $K_{eq} > 1$

E) $\Delta G° = 0$ and $K_{eq} = 1$

54. Which of the following is the correct equilibrium expression for the hydrolysis of CO_3^{2-} ?

A) $K = \dfrac{[HCO_3^-]}{[CO_3^{2-}][H_3O^+]}$

B) $K = \dfrac{[HCO_3^-][OH^-]}{[CO_3^{2-}]}$

C) $K = \dfrac{[CO_3^{2-}][OH^-]}{[HCO_3^-]}$

D) $K = \dfrac{[CO_3^{2-}]}{[CO_2][OH^-]^2}$

E) $K = \dfrac{[CO_3^{2-}][H_3O^+]}{[HCO_3^-]}$

55.

$$H_2PO_4^- + HBO_3^{2-} \leftrightarrows HPO_4^{2-} + H_2BO_3^-$$

The equilibrium constant for the reaction represented by the equation above is greater than 1.0. Which of the following gives the correct relative strengths of the acids and bases in the reaction?

	Acids		Bases
A)	$H_2PO_4^- > H_2BO_3^-$	and	$HBO_3^{2-} > HPO_4^{2-}$
B)	$H_2BO_3^- > H_2PO_4^-$	and	$HBO_3^{2-} > HPO_4^{2-}$
C)	$H_2PO_4^- > H_2BO_3^-$	and	$HPO_4^{2-} > HBO_3^{2-}$
D)	$H_2BO_3^- > H_2PO_4^-$	and	$HPO_4^{2-} > HBO_3^{2-}$
E)	$H_2PO_4^- = H_2BO_3^-$	and	$HPO_4^{2-} = HBO_3^{2-}$

56. A 0.20-molar solution of a weak monoprotic acid, HA, has a pH of 3.00. The ionization constant of this acid is

A) 5.0×10^{-7}

B) 2.0×10^{-7}

C) 5.0×10^{-6}

D) 5.0×10^{-3}

E) 2.0×10^{-3}

57.

$$\text{rate} = k[\text{X}]$$

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

A) [X] *versus* time

B) log [X] *versus* time

C) 1/[X] *versus* time

D) [X] *versus* 1/time

E) log [X] *versus* 1/time

58.

$$(CH_3)_3CCl(aq) + OH^- \rightarrow (CH_3)_3COH(aq) + Cl^-$$

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

$$\text{Rate} = k\,[(CH_3)_3CCl]$$

If some solid sodium solid hydroxide is added to a solution that is 0.010-molar in $(CH_3)_3CCl$ and 0.10-molar in NaOH, which of the following is true? (Assume the temperature and volume remain constant.)

A) 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.

59. Which of the following compounds is ionic and contains both sigma and pi covalent bonds?

A) $Fe(OH)_3$

B) HClO

C) H_2S

D) NO_2

E) NaCN

60.

$Fe^{2+} + 2e^- \rightarrow Fe(s)$ $\quad E° = –0.44$ volt

$Ni^{2+} + 2e^- \rightarrow Ni(s)$ $\quad E° = –0.23$ volt

The standard reduction potentials for two half reactions are given above. The Nernst equation for a galvanic cell at 25°C in which Fe(*s*) reduces Ni^{2+} is the following.

$$E = E° - 0.03 \log \frac{[Fe^{2+}]}{[Ni^{2+}]}$$

What is the equilibrium constant for the reaction below?

$$Fe(s) + Ni^{2+} \rightarrow Fe^{2+} + Ni(s)$$

A) 1.9×10^{-23}

B) 7.6×10^{-8}

C) $3.6 \times 10^{+3}$

D) $1.3 \times 10^{+7}$

E) $5.2 \times 10^{+22}$

61. When acidified $K_2Cr_2O_7$ solution is added to Na_2S solution, green Cr^{3+} ions and free S are formed. When acidified $K_2Cr_2O_7$ solution is added to NaCl, no change occurs. Of the substances involved in these reactions, which is the best reducing agent?

A) $K_2Cr_2O_7$

B) Na_2S

C) Cr^{3+}

D) S

E) NaCl

62. As the temperature is raised from 20° C to 40° C, the average kinetic energy of neon atoms changes by a factor of

A) $\frac{1}{2}$

B) $\sqrt{\frac{313}{293}}$

C) $\frac{313}{293}$

D) 2

E) 4

63. Which of the following characteristics is common to elemental sulfur, chlorine, nitrogen, and carbon?

A) They are gaseous elements at room temperature.

B) They have oxides that are acid anhydrides.

C) They have perceptible color at room temperature.

D) They form ionic oxides.

E) They react readily with hydrogen at room temperature.

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

A) Cu

B) Mn

C) Fe

D) Ni

E) Zn

65. The solubility of CuI is 2×10^{-6} molar. What is the solubility product constant, K_{sp}, for CuI?

A) 1.4×10^{-3}

B) 2×10^{-6}

C) 4×10^{-12}

D) 2×10^{-12}

E) 8×10^{-18}

66.

$$MnS(s) + 2\,H^+ \leftrightarrows Mn^{2+} + H_2S(g)$$

At 25° C the solubility product constant, K_{sp}, for MnS is 5×10^{-15} 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) $\frac{1 \times 10^{-13}}{5 \times 10^{-15}}$

B) $\frac{5 \times 10^{-15}}{1 \times 10^{-7}}$

C) $\frac{1 \times 10^{-7}}{5 \times 10^{-20}}$

D) $\frac{5 \times 10^{-15}}{1 \times 10^{-20}}$

E) $\frac{1 \times 10^{-20}}{5 \times 10^{-15}}$

67.

$$BrO_3^- + 5\,Br^- + 6\,H^+ \leftrightarrows 3\,Br_2 + 3\,H_2O$$

If 25.0 milliliters of 0.200-molar BrO_3^- is mixed with 30.0 milliliters of 0.500-molar Br^- solution that contains a large excess of H^+, the amount of Br_2 formed, according to the equation above, is

A) 5.00×10^{-3} mole

B) 9.00×10^{-3} mole

C) 1.50×10^{-2} mole

D) 1.80×10^{-2} mole

E) 4.50×10^{-2} mole

68. The half-life for radioactive element X is 10.0 min. What weight of X was originally present in a sample if 40. grams is left after 60. minutes?

A) 320. grams

B) 640. grams

C) 1,280. grams

D) 2,400 grams

E) 2,560 grams

69. A white solid is observed to be insoluble in water, insoluble in excess ammonia solution, and soluble in dilute HCl. Which of the following compounds could the solid be?

A) $CaCO_3$

B) $BaSO_4$

C) $Pb(NO_3)_2$

D) $AgCl$

E) $Zn(OH)_2$

70.

$$H_2O(s) \rightarrow H_2O(l)$$

When ice melts at its normal melting point, 273.16 K and 1 atmosphere, which of the following is true for the process shown above?

A) $\Delta H < 0, \Delta S > 0, \Delta V > 0$

B) $\Delta H < 0, \Delta S < 0, \Delta V > 0$

C) $\Delta H > 0, \Delta S < 0, \Delta V < 0$

D) $\Delta H > 0, \Delta S > 0, \Delta V > 0$

E) $\Delta H > 0, \Delta S > 0, \Delta V < 0$

71. A solution of toluene (molecular weight 92.1) in an organic solvent (molecular weight 55.6) is prepared. The mole fraction of toluene in the solution is 0.100. What is the molality of the solution?

A) 1.00 *m*

B) 2.00 *m*

C) 7.03 *m*

D) 9.21 *m*

E) 9.95 *m*

72. How many moles of solid $Ba(NO_3)_2$ should be added to 300. milliliters of 0.20-molar $Fe(NO_3)_3$ to increase the concentration of the NO_3^- ion to 1.0-molar? (Assume that the volume of the solution remains constant.)

A) 0.060 mole

B) 0.12 mole

C) 0.24 mole

D) 0.30 mole

E) 0.40 mole

73. Adding water to some chemicals can be dangerous because large amounts of heat are liberated. Which of the following does NOT liberate heat when water is added to it?

A) KNO_3

B) $NaOH$

C) CaO

D) H_2SO_4

E) Na

74. Equal volumes of 0.10-molar H_3PO_4 and 0.20-molar KOH are mixed. After equilibrium is established, the type of ion in solution in largest concentration, other than the K^+ ion, is

A) $H_2PO_4^-$

B) HPO_4^{2-}

C) PO_4^{3-}

D) OH^-

E) H_3O^+

75. If a copper sample containing some zinc impurity is to be purified by electrolysis, the anode and the cathode must be which of the following?

	Anode	Cathode
A)	Pure copper	Pure zinc
B)	Pure zinc	Pure copper
C)	Pure copper sample	Impure copper
D)	Impure copper sample	Pure copper
E)	Impure copper sample	Pure zinc

Advanced Placement™ Chemistry

1989 Free Response Questions

Solve the following problem.

1. In an experiment to determine the molecular weight and the ionization constant for ascorbic acid (vitamin C), a student dissolved 1.3717 grams of the acid in water to make 50.00 milliliters of solution. The entire solution was titrated with a 0.2211-molar NaOH solution. The pH was monitored throughout the titration. The equivalence point was reached when 35.23 milliliters of the base had been added. Under the conditions of this experiment, ascorbic acid acts as a monoprotic acid that can be represented as HA.

   (a) From the information above, calculate the molecular weight of ascorbic acid.

   (b) When 20.00 milliliters of NaOH had been added during the titration, the pH of the solution was 4.23. Calculate the acid ionization constant for ascorbic acid.

   (c) Calculate the equilibrium constant for the reaction of the ascorbate ion, A^-, with water.

   (d) Calculate the pH of the solution at the equivalence point of the titration.

Solve ONE of the two problems in this part. (A second problem will not be scored).

2. The electrolysis of an aqueous solution of potassium iodide, KI, results in the formation of hydrogen gas at the cathode and iodine at the anode. A sample of 80.00 milliliters of a 0.150-molar solution of KI was electrolyzed for 3.00 minutes, using a constant current. At the end of this time, the I_2 produced was titrated against a 0.225-molar solution of sodium thiosulfate, which reacts with iodine according to the equation below. The end point of the titration was reached when 37.2 milliliters of the $Na_2S_2O_3$ solution had been added.

$$I_2 + 2\ S_2O_3^{2-} \rightarrow 2\ I^- + S_4O_6^{2-}$$

   (a) How many moles of I_2 was produced during the electrolysis?

   (b) The hydrogen gas produced at the cathode during the electrolysis was collected over water at 25 °C at a total pressure of 752 millimeters of mercury. Determine the volume of hydrogen collected. (The vapor pressure of water at 25 °C is 24 millimeters of mercury.)

   (c) Write the equations for the half reaction that occurs at the anode during the electrolysis.

   (d) Calculate the current used during the electrolysis.

3.

$$Br_2\ (\ell) \rightarrow Br_2\ (g)$$

At 25 °C the equilibrium constant, K_p, for the reaction above is 0.281 atmosphere.

   (a) What is $\Delta G°_{298}$ for this reaction?

   (b) It takes 193 joules to vaporize 1.00 gram of $Br_2(\ell)$ at 25 °C and 1.00 atmosphere pressure. What are the values of $\Delta H°_{298}$ and of $\Delta S°_{298}$ for this reaction?

   (c) Calculate the normal boiling point of bromine. Assume that $\Delta H°$ and $\Delta S°$ remain constant as the temperature is changed.

   (d) What is the equilibrium vapor pressure of bromine at 25 °C ?

4. Answer FIVE of the eight options in this part. (Answers to more than five will not be scored.)

Give the formulas to show the reactants and the products for FIVE of the following chemical reactions. Each of the reactions occurs in aqueous solution unless otherwise indicated. Represent substances in solutions as ions if the substance is extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction. In all cases a reaction occurs. You need not balance.

Example: A strip of magnesium is added to a solution of silver nitrate.

$$Mg^{+} + Ag^{+} \rightarrow Mg^{2+} + Ag$$

(a) Solutions of zinc sulfate and sodium phosphate are mixed.

(b) Solutions of silver nitrate and lithium bromide are mixed.

(c) A stream of chlorine gas is passed through a solution of cold, dilute sodium hydroxide.

(d) Excess hydrochloric acid solution is added to a solution of potassium sulfite.

(e) A solution of tin(II) chloride is added to an acidified solution of potassium permanganate.

(f) A solution of ammonium thiocyanate is added to a solution of iron(III) chloride.

(g) Samples of boron trichloride gas and ammonia gas are mixed.

(h) Carbon disulfide vapor is burned in excess oxygen.

Select THREE of the following five topics. (Additional topics will not be scored.)

5.

CF_4 XeF_4 ClF_3

(a) Draw a Lewis electron-dot structure for each of the molecules above and identify the shape of each.

(b) Use the valence shell electron-pair repulsion (VSEPR) model to explain the geometry of each of these molecules.

6. The melting points of the alkali metals decrease from Li to Cs. In contrast, the melting of the halogens increase from F_2 to I_2.

(a) Using bonding principles, account for the decrease in the melting point of the alkali metals.

(b) Using bonding principles, account for the increase in the melting points of the halogens.

(c) What is the expected trend in the melting points of the compounds LiF, NaCl, KBr, and CsI? Explain this trend using bonding principles.

7. Consider three unlabeled bottles, each containing small pieces of one of the following metals.

- Magnesium
- Sodium
- Silver

The following reagents are used for identifying the metals.

- Pure water
- A solution of 1.0-molar HCl
- A solution of concentrated HNO_3

(a) Which metal can be easily identified because it is much softer than the other two? Describe a chemical test that distinguishes this metal from the other two, using only one of the reagents above. Write a balanced chemical equation for the reaction that occurs.

(b) One of the other two metals reacts readily with the HCl solution. Identify the metal and write the balanced chemical equation for the reaction that occurs when this metal is added to the HCl solution. Use a table of standard reduction potentials to account for the fact that this metal reacts with HCl while the other does not.

(c) The one remaining metal reacts with the concentrated HNO_3 solution. Write a balanced chemical equation for the reaction that occurs.

(d) The solution obtained in (c) is diluted and a few drops of 1 *M* HCl is added. Describe what would be observed. Write a balanced chemical equation for the reaction that occurs.

8.

$$C_2H_4\,(g) + H_2\,(g) \rightarrow C_2H_6\,(g) \qquad \Delta H^\circ = -137 \text{ kJ}$$

Account for the following observations regarding the exothermic reaction represented by the equation above.

(a) An increase in the pressure of the reactants causes an increase rate.

(b) A small increase in temperature causes a large increase in the reaction rate.

(c) The presence of metallic nickel causes an increase in reaction rate.

(d) The presence of powdered nickel causes a larger increase in reaction rate than does the presence of a single piece of nickel of the same mass.

9. The carbon isotope of mass 12 is stable. The carbon isotopes of mass 11 and mass 14 are unstable. However, the type of radioactive decay is different for the these two isotopes. Carbon-12 is not produced in either case.

(a) Identify a type of decay expected for carbon-11 and write the balanced nuclear reaction for that decay process.

(b) Identify the type of decay expected for carbon-14 and write the balanced nuclear reaction for that decay process.

(c) Gamma rays are observed during the radioactive decay of carbon-11. Why is it unnecessary to include the gamma rays in the radioactive decay equation of (a)?

(d) Explain how the amount of carbon-14 in a piece of wood can be used to determine when the tree died.

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PERIODIC TABLE OF THE ELEMENTS

1 **H** 1.008																	2 **He** 4.00
3 **Li** 6.94	4 **Be** 9.01											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.30											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.06	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.90	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.39	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.1	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.75	52 **Te** 127.60	53 **I** 126.91	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	57 ***La** 138.91	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.85	75 **Re** 186.21	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** 226.02	89 **†Ac** 227.03	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (266)	107 **Bh** (264)	108 **Hs** (277)	109 **Mt** (268)	110 **Ds** (271)	111 **Rg** (272)							

*Lanthanide Series	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 151.97	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.04	71 **Lu** 174.97
†Actinide Series	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (262)

STANDARD REDUCTION POTENTIALS IN AQUEOUS SOLUTION AT 25°C

Half-reaction			$E°$(V)
$F_2(g) + 2e^-$	→	$2F^-$	2.87
$Co^{3+} + e^-$	→	Co^{2+}	1.82
$Au^{3+} + 3e^-$	→	$Au(s)$	1.50
$Cl_2(g) + 2e^-$	→	$2Cl^-$	1.36
$O_2(g) + 4H^+ + 4e^-$	→	$2H_2O(l)$	1.23
$Br_2(l) + 2e^-$	→	$2Br^-$	1.07
$2Hg^{2+} + 2e^-$	→	Hg_2^{2+}	0.92
$Hg^{2+} + 2e^-$	→	$Hg(l)$	0.85
$Ag^+ + e^-$	→	$Ag(s)$	0.80
$Hg_2^{2+} + 2e^-$	→	$2Hg(l)$	0.79
$Fe^{3+} + e^-$	→	Fe^{2+}	0.77
$I_2(s) + 2e^-$	→	$2I^-$	0.53
$Cu^+ + e^-$	→	$Cu(s)$	0.52
$Cu^{2+} + 2e^-$	→	$Cu(s)$	0.34
$Cu^{2+} + e^-$	→	Cu^+	0.15
$Sn^{4+} + 2e^-$	→	Sn^{2+}	0.15
$S(s) + 2H^+ + 2e^-$	→	$H_2S(g)$	0.14
$2H^+ + 2e^-$	→	$H_2(g)$	0.00
$Pb^{2+} + 2e^-$	→	$Pb(s)$	−0.13
$Sn^{2+} + 2e^-$	→	$Sn(s)$	−0.14
$Ni^{2+} + 2e^-$	→	$Ni(s)$	−0.25
$Co^{2+} + 2e^-$	→	$Co(s)$	−0.28
$Cd^{2+} + 2e^-$	→	$Cd(s)$	−0.40
$Cr^{3+} + e^-$	→	Cr^{2+}	−0.41
$Fe^{2+} + 2e^-$	→	$Fe(s)$	−0.44
$Cr^{3+} + 3e^-$	→	$Cr(s)$	−0.74
$Zn^{2+} + 2e^-$	→	$Zn(s)$	−0.76
$2H_2O(l) + 2e^-$	→	$H_2(g) + 2OH^-$	−0.83
$Mn^{2+} + 2e^-$	→	$Mn(s)$	−1.18
$Al^{3+} + 3e^-$	→	$Al(s)$	−1.66
$Be^{2+} + 2e^-$	→	$Be(s)$	−1.70
$Mg^{2+} + 2e^-$	→	$Mg(s)$	−2.37
$Na^+ + e^-$	→	$Na(s)$	−2.71
$Ca^{2+} + 2e^-$	→	$Ca(s)$	−2.87
$Sr^{2+} + 2e^-$	→	$Sr(s)$	−2.89
$Ba^{2+} + 2e^-$	→	$Ba(s)$	−2.90
$Rb^+ + e^-$	→	$Rb(s)$	−2.92
$K^+ + e^-$	→	$K(s)$	−2.92
$Cs^+ + e^-$	→	$Cs(s)$	−2.92
$Li^+ + e^-$	→	$Li(s)$	−3.05

ADVANCED PLACEMENT CHEMISTRY EQUATIONS AND CONSTANTS

ATOMIC STRUCTURE

$$E = h\nu \qquad c = \lambda\nu$$

$$\lambda = \frac{h}{m\upsilon} \qquad p = m\upsilon$$

$$E_n = \frac{-2.178 \times 10^{-18}}{n^2} \text{ joule}$$

EQUILIBRIUM

$$K_a = \frac{[H^+][A^-]}{[HA]}$$

$$K_b = \frac{[OH^-][HB^+]}{[B]}$$

$$K_w = [OH^-][H^+] = 1.0 \times 10^{-14} \text{ @ } 25^\circ\text{C}$$
$$= K_a \times K_b$$

$$pH = -\log[H^+], \; pOH = -\log[OH^-]$$

$$14 = pH + pOH$$

$$pH = pK_a + \log\frac{[A^-]}{[HA]}$$

$$pOH = pK_b + \log\frac{[HB^+]}{[B]}$$

$$pK_a = -\log K_a, \; pK_b = -\log K_b$$

$$K_p = K_c(RT)^{\Delta n},$$

where Δn = moles product gas − moles reactant gas

THERMOCHEMISTRY/KINETICS

$$\Delta S^\circ = \sum S^\circ \text{ products} - \sum S^\circ \text{ reactants}$$

$$\Delta H^\circ = \sum \Delta H_f^\circ \text{ products} - \sum \Delta H_f^\circ \text{ reactants}$$

$$\Delta G^\circ = \sum \Delta G_f^\circ \text{ products} - \sum \Delta G_f^\circ \text{ reactants}$$

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$$
$$= -RT\ln K = -2.303RT\log K$$
$$= -n\mathcal{F}E^\circ$$

$$\Delta G = \Delta G^\circ + RT\ln Q = \Delta G^\circ + 2.303RT\log Q$$

$$q = mc\Delta T$$

$$C_p = \frac{\Delta H}{\Delta T}$$

$$\ln[A]_t - \ln[A]_0 = -kt$$

$$\frac{1}{[A]_t} - \frac{1}{[A]_0} = kt$$

$$\ln k = \frac{-E_a}{R}\left(\frac{1}{T}\right) + \ln A$$

E = energy
υ = velocity
ν = frequency
n = principal quantum number
λ = wavelength
m = mass
p = momentum

Speed of light, $c = 3.0 \times 10^8 \text{ m s}^{-1}$

Planck's constant, $h = 6.63 \times 10^{-34} \text{ J s}$

Boltzmann's constant, $k = 1.38 \times 10^{-23} \text{ J K}^{-1}$

Avogadro's number $= 6.022 \times 10^{23} \text{ mol}^{-1}$

Electron charge, $e = -1.602 \times 10^{-19}$ coulomb

1 electron volt per atom $= 96.5 \text{ kJ mol}^{-1}$

Equilibrium Constants

K_a (weak acid)
K_b (weak base)
K_w (water)
K_p (gas pressure)
K_c (molar concentrations)

S° = standard entropy
H° = standard enthalpy
G° = standard free energy
E° = standard reduction potential
T = temperature
n = moles
m = mass
q = heat
c = specific heat capacity
C_p = molar heat capacity at constant pressure
E_a = activation energy
k = rate constant
A = frequency factor

Faraday's constant, $\mathcal{F}$ = 96,500 coulombs per mole of electrons

Gas constant, $R = 8.31 \text{ J mol}^{-1}\text{ K}^{-1}$
$= 0.0821 \text{ L atm mol}^{-1}\text{ K}^{-1}$
$= 62.4 \text{ L torr mol}^{-1}\text{ K}^{-1}$
$= 8.31 \text{ volt coulomb mol}^{-1}\text{ K}^{-1}$

GASES, LIQUIDS, AND SOLUTIONS

$$PV = nRT$$

$$\left(P + \frac{n^2 a}{V^2}\right)(V - nb) = nRT$$

$$P_A = P_{total} \times X_A, \text{where } X_A = \frac{\text{moles A}}{\text{total moles}}$$

$$P_{total} = P_A + P_B + P_C + \ldots$$

$$n = \frac{m}{\boldsymbol{M}}$$

$$\text{K} = {}^\circ\text{C} + 273$$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$D = \frac{m}{V}$$

$$u_{rms} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3RT}{\boldsymbol{M}}}$$

$$KE \text{ per molecule} = \frac{1}{2} m\upsilon^2$$

$$KE \text{ per mole} = \frac{3}{2} RT$$

$$\frac{r_1}{r_2} = \sqrt{\frac{\boldsymbol{M}_2}{\boldsymbol{M}_1}}$$

molarity, M = moles solute per liter solution

molality = moles solute per kilogram solvent

$$\Delta T_f = iK_f \times \text{molality}$$

$$\Delta T_b = iK_b \times \text{molality}$$

$$\pi = iMRT$$

$$A = abc$$

P = pressure
V = volume
T = temperature
n = number of moles
D = density
m = mass
υ = velocity

u_{rms} = root-mean-square speed
KE = kinetic energy
r = rate of effusion
$\boldsymbol{M}$ = molar mass
π = osmotic pressure
i = van't Hoff factor
K_f = molal freezing-point depression constant
K_b = molal boiling-point elevation constant
A = absorbance
a = molar absorptivity
b = path length
c = concentration
Q = reaction quotient
I = current (amperes)
q = charge (coulombs)
t = time (seconds)
E° = standard reduction potential
K = equilibrium constant

OXIDATION-REDUCTION; ELECTROCHEMISTRY

$$Q = \frac{[\text{C}]^c\,[\text{D}]^d}{[\text{A}]^a\,[\text{B}]^b}, \text{ where } a\,\text{A} + b\,\text{B} \rightarrow c\,\text{C} + d\,\text{D}$$

$$I = \frac{q}{t}$$

$$E_{\text{cell}} = E^\circ_{\text{cell}} - \frac{RT}{n\mathcal{F}} \ln Q = E^\circ_{\text{cell}} - \frac{0.0592}{n} \log Q \;\; @\; 25^\circ\text{C}$$

$$\log K = \frac{nE^\circ}{0.0592}$$

Gas constant, R = 8.31 J mol^{-1} K^{-1}
= 0.0821 L atm mol^{-1} K^{-1}
= 62.4 L torr mol^{-1} K^{-1}
= 8.31 volt coulomb mol^{-1} K^{-1}

Boltzmann's constant, k = 1.38×10^{-23} J K^{-1}

K_f for H_2O = 1.86 K kg mol^{-1}

K_b for H_2O = 0.512 K kg mol^{-1}

1 atm = 760 mm Hg
= 760 torr

STP = 0.00 °C and 1.0 atm

Faraday's constant, $\mathcal{F}$ = 96,500 coulombs per mole of electrons

APPENDIX - ANSWERS

AP CHEMISTRY 1989

Multiple-choice key transcribed from the matching supplied source.

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

MCQ key follows the supplied third-party solution compilation.

Original matching FRQ marking material follows.

Matching original FRQ scoring material follows in this appendix.

Part A — QUESTION 1 (Scale 0-9 points)

1. a) Molec. Weight $= \dfrac{1.3717\ g}{0.2211\ mole/L \times .03523\ L}$

1 pt. for calculating moles of OH^-

$= \dfrac{1.3717\ g}{7.789 \times 10^{-3}\ mole}$

1 pt. for g/mole $\longrightarrow$ M.W.

$= 176.1\ g/mole$

b) pH = 4.23; $[H^+] = 5.89 \times 10^{-5} = 5.9 \times 10^{-5}\ M$

$[A^-] = \dfrac{0.02000\ L \times 0.2211\ mole/L}{0.07000\ L} = \dfrac{.004422\ moles}{0.07000\ L}$

1 pt. for calc. $[A^-]$ or moles A^-.

$= 0.06317\ M$

$[HA] = \dfrac{0.01523\ L \times 0.2211\ mole/L}{0.07000\ L} = \dfrac{.003367\ moles}{0.07000\ L}$

1 pt. for calc. [HA] or moles HA

$= 0.04811\ M$

$K_a = \dfrac{[H^+][A^-]}{[HA]}$

1 pt. for calc. K_a from $[H^+]$, $[A^-]$, [HA]

$= \dfrac{(5.9 \times 10^{-5})(.06317)}{(.04811)}$

(1 pt. allowed for pH $\longrightarrow$ $[H^+]$ if $[A^-]$, [HA] and K_a are incorrect)

$= 7.7 \times 10^{-5}$

c) $A^- + H_2O \longrightarrow HA + OH^-$

$K_h = \dfrac{[HA][OH^-]}{[A^-]} = \dfrac{K_w}{K_a}$

$= \dfrac{1.0 \times 10^{-14}}{7.7 \times 10^{-5}} = 1.3 \times 10^{-10}$

1 pt. for calc. of K_h from K_w/K_a

d) $[A^-]$ at equiv. pt. $= \dfrac{7.789 \times 10^{-3}\ moles}{0.08523\ L}$

1 pt. for $[A^-]$ from moles / total vol.

$= 9.14 \times 10^{-2}\ M$

$[OH^-] = (1.3 \times 10^{-10})(9.14 \times 10^{-2})$

$= 1.2 \times 10^{-11}$

$= 3.4 \times 10^{-6}$

$pOH = -\log [OH^-]$

$= -\log (3.4 \times 10^{-6})$

$= 5.47$

1 pt. for calc. $[OH^-]$

$pH = 14 - pOH = 14 - 5.47$

$= 8.53$

1 pt. for $[OH^-] \longrightarrow$ pH

Copying & Math Errors –1 point ONLY ONCE PER PROBLEM

Significant Fig. Error if > ±1 of correct # of sig. fig. –1 point ONLY ONCE

Part B — QUESTION 2 (Scale 0-9 points)

2. a) moles $S_2O_3^{2-}$ = (0.225 M) (.0373 L)
= 8.39×10^{-3} moles

(1) M x vol ⟶ mole

moles I_2 = 1/2 mole $S_2O_3^{2-}$

= 4.20×10^{-3}

(1) $I_2/S_2O_3^{2-}$ stoichiometry

b) $P_{H_2} = P_T - P_{H_2O}$
= 752 – 24
= 728 mm Hg

(1) P_{H_2} calculations

moles H_2 = moles I_2

(1) moles H_2 = moles I_2

$PV = nRT$

$$V = \frac{(4.20 \times 10^{-3})\ (.0821\ \text{L-atm})\ 298\ \text{deg}}{[728/760\ \text{atm}]\ \text{mol deg}}$$

= 0.107 liters

(1) correct substitution

c) anode: $2I^- \longrightarrow I_2 + 2e^-$

(1) anode equation

d) 4.20×10^{-3} mole I_2 (or H_2) = 8.40×10^{-3} mole e^-

(1) moles chemicals ⟶ moles of electrons (i.e., Faradays)

$$8.40 \times 10^{-3}\ \text{F} \times 96{,}500\ \frac{\text{coul}}{\text{F}} = 810.6\ \text{coul}$$

(1) Faradays ⟶ coulombs

coul = amp x sec

$$\text{amp} = \frac{810.6\ \text{coul}}{3\ \text{min} \times 60\ \text{sec/min}}$$

= 4.50 amp

(1) coulombs ⟶ amperes

Copying & Math Errors –1 point ONLY ONCE PER PROBLEM
Significant Fig. Error if > ±1 of correct # of sig. fig. –1 point ONLY ONCE

Part B — QUESTION 3 (Scale 0-9 points)

3. a) $\Delta G^\circ = -RT\ln K$

$= (-8.31 \text{ J/mole K})(298 \text{ K}) \ln 0.281$ — (1) correct equations

$= 3.14 \times 10^3 \text{ J/mole}$ — (1) correction substitution work and sign

b) $\Delta H^\circ = (193 \text{ J/g})(159.8 \text{ g/mole})$ — (1) correct relationship (1) correct molec. wt.

$= 3.08 \times 10^4 \text{ J/mole}$

$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$

$\Delta S^\circ = \dfrac{\Delta H^\circ - \Delta G^\circ}{T}$ — (1) correct equation (may be implicit in work)

$= \dfrac{(3.084 \times 10^4 - 3.14 \times 10^3) \text{ J/mole}}{298}$

$= 2.770 \times 10^4/298$ — (1) correct substitution and work

$= 92.9 \text{ J/mole deg}$

c) at. b.p. $\Delta G^\circ = 0$ and $T = \Delta H^\circ / \Delta S^\circ$ — (1) correct relationship

$T = \dfrac{3.08 \times 10^4}{92.9}$ — (1) calculation of T

$= 332^\circ\text{K}$

d) V.P. $= 0.281$ atm — (1) recognizing V.P. = p

Penalty for 2 incorrect or missing units, –1 point
Copying & Math Errors –1 point ONLY ONCE PER PROBLEM
Significant Fig. Error if > ±1 of correct # of sig. fig. –1 point ONLY ONCE

Part C — QUESTION 4, Choice of 5, 3 points each (Scale 0-15 total points)

4. a) $Zn^{2+} + PO_4^{3-} \longrightarrow Zn_3(PO_4)_2$

(1) (2)

b) $Ag^+ + Br^- \longrightarrow AgBr$

(1) (2)

c) $Cl_2 + 2OH^- \longrightarrow OCl^- + Cl^- + H_2O$

(1) (2)

1 redox product correct, 1 pt.
all 3 products correct, 2 pts.

d) $H^+ + SO_3^{2-} \longrightarrow H_2O + SO_2$ or H_2SO_3

(1) (1) (1)

e) $Sn^{2+} + H^+ + MnO_4^- \longrightarrow Sn^{4+} + Mn^{2+} + H_2O$

(1) (2)

1 redox product correct, 1 pt.
all 3 products correct, 2 pts.

f) $Fe^{3+} + SCN^- \longrightarrow Fe(SCN)^{2+}$

(1) (2)

$FeSCN^{2+} \longrightarrow Fe(SCN)_6^{3-}$
ok if charges are
correct

g) $BCl_3 + NH_3 \longrightarrow Cl_3BNH_3$

(1) (2)

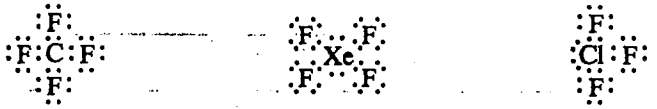
h) $CS_2 + O_2 \longrightarrow CO_2 + SO_2$ or SO_3

(1) (1) (1)

1 pt. maximum for correct approach on options a, b, d; e.g., $Zn^{2+} + PO_4^{2-} \longrightarrow ZnPO_4(s)$

PART D — QUESTIONS 5-9, Choice of 3, 8 points each (Scale 0-24 total points)

QUESTION 5 (Scale 0-8 points)

5. a) 

tetrahedral square planar T-shaped

(1) point for each correct electron dot structure
(1) point for any 2 structure names or unambiguous drawing
(1) points for all 3 structure names

5 points total

b) i. 4 bond pairs around C will be directed toward corners of regular tetrahedron to minimize repulsion (or maximize bond angles)

ii. 6 electron pairs around Xe will assume octahedral shape with 2 lone pairs on opposite sides of Xe to minimize repulsion

iii. 5 electron pairs Cl will produce a trigonal bipyramid; 2 lone pairs will occupy equatorial positions (120° apart) where repulsion will be minimized

(1) point for each satisfactory explanation. A maximum of 1 point is deducted if repulsion of atoms (instead of valence electron pairs) is used in total explanations

QUESTION 6 (Scale 0-8 points)

6. a) Alkali metals contain metallic bonds — cations in sea of electrons. (1) point
As cations increase in size (from Li to Cs), charge density decreases and attractive forces (and melting points) also decrease. (1) point

b) Halogens are bonded by dispersion forces — bonds due to instantaneous dipoles caused by polarization of electron clouds. (1) point
As molecules increase in size (from F_2 to I_2), the larger electron clouds are more readily polarized and the attractive forces (and melting points) increase. (1) point

c) The melting points decrease; LiF>NaCl>KBr>CsI
The m.p.s. of ionic compounds vary with the charges and sizes of the ions;

$$F \propto \frac{q_1 q_2}{r}$$

As the ions increase in size, the distance r increases and the attractive forces (and melting points) decrease.

(1) point for correct trend
(1) point for recognizing ionic character
(1) point for change in size
(1) point for relationship between size and m.p.

QUESTION 7 (Scale 0-8 points)

7. a) i. Sodium is much softer than silver or magnesium.

ii. Sodium reacts with water to produce a basic solution and hydrogen gas. Mg and Ag do not react.

1 point for any 2 parts; 2 points for all 3

iii. $2Na + 2H_2O \longrightarrow 2Na^+ \ 2OH^- + H_2$

b) i. Magnesium reacts with HC1

ii. $Mg + 2H^+ + 2C1^- \longrightarrow Mg^{2+} + 2C1^- + H_2$

1 point for any 2 parts; 2 points for all 3

iii. Magnesium, with a reduction potential of –2.37 V will reduce HC1 to H_2 gas. Silver with a reduction potential of +0.80 will not.

c) $3Ag + 4H^+ + NO_3^- \longrightarrow 3Ag^+ + NO + 2H_2O$

or

$Ag + 2H^+ + NO_3^- \longrightarrow Ag^+ + NO_2 + H_2O$

1 point for unbalanced redox equation;
1 point for balancing

d) A white precipitate of AgC1 would form

1 point

$Ag^+ + C1^- \longrightarrow AgC1$

1 point

QUESTION 8 (Scale 0-8 points)

8. a) Increasing the pressure increases the effective concentration which increases the collision frequency and thus the reaction rate. (1) point (1) point

b) Increasing the temperature slightly increases the number of molecules which have the necessary activation energy which causes a large increase in the reaction rate. (1) point (1) point

c) Metallic nickel acts as a catalyst, lowering the activation energy by providing an alternate pathway. More molecules will have the activation energy needed and the reaction rate will increase. (1) point (1) point

d) Powdered nickel has a greater surface area than a single nickel piece, thus providing more catalytic sites and a greater reaction rate. (1) point (1) point

QUESTION 9 (Scale 0-8 points)

9. a) Type of decay: positron $\left({}^{0}_{1}\beta\right)$ 1 point

${}^{11}_{6}\mathrm{C} \rightarrow {}^{11}_{5}\mathrm{B} + {}^{0}_{1}\beta$ 1 point

or

electron capture 1 point

${}^{11}_{6}\mathrm{C} + {}^{0}_{-1}e \rightarrow {}^{11}_{5}\mathrm{B}$ 1 point

b) Type of decay: beta $\left({}^{0}_{-1}\beta\right)$ 1 point

${}^{14}_{6}\mathrm{C} \rightarrow {}^{0}_{-1}\beta + {}^{14}_{7}\mathrm{N}$ 1 point

c) Gamma rays have no mass or charge so do not affect the nuclear equation. 2 points

or

Gamma rays are energy so do not affect the nuclear equation.

d) By measuring the amount of ${}^{14}\mathrm{C}$ present in the object and comparing it with the amount of ${}^{14}\mathrm{C}$ in a similar living object and knowing the half-life for ${}^{14}\mathrm{C}$ decay, it is possible to determine when the object died. 2 points