**AP Chemistry Final Exam 2015 Updated, April 28th.**



**Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Chemistry**

**Section I**

**60 Multiple-choice Questions**

**(Time- 90 minutes)**

**YOU MAY NOT USE YOUR CALCULATOR FOR SECTION I**

**Record ALL answers on the student answer sheet**.

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



Base your answers to questions 1-3 on the simulated photoelectron spectrum (PES) of pure element “X” shown above. The energy is measured in megajoules per mole.

1. This diagram best represents the PES of

A) Si B) S C) Ar D) Ne

2. The first ionization energy of this element, in megajoules per mole, is closest to

 A) 300 B) 30 C) 5 D) 1

3. The PES of the element having an atomic number one greater than that of element” X” is plotted on the same axes. The spectrum would contain

 A) The same number of peaks, all placed to the left of the peaks of produced by X

 B) The same number of peaks, all placed to the right of the peaks produced by X

 C) One *additional* peak, located to the right of the 1 megajoule mark

 D) One *additional* peak, located to the left of the 1 megajoule mark.

4. The lattice energy of a salt is related to the energy required to separate the ions. For which of the following pairs of ions is the energy that is required to separate the ions largest? (Assume that the distance between the ions in each pair is equal to the sum of the ionic radii.)

 A) Na+(g) and Cl-(g) B) Cs+(g) and Br-(g) C) Mg2+(g) and O2- (g)

 D) Ca2+(g) and O2- (g)

5. Solutions containing the dark purple ion permanganate, MnO4- turn colorless when added

 to a flask containing sulfur dioxide gas, SO2. The balanced equation is

 2 MnO4- (aq) + 5 SO2 (g) + 2 H2O(l) ⭢ 2 Mn2+ + 5 SO42- + 4 H+

 Which element is oxidized in this reaction, and what is its change in oxidation state?

 A) Mn is oxidized from +7 to +2 B) S is oxidized from +4 to + 6

 C) S is oxidized from +4 to + 8 D) Mn is oxidized from +8 to +2

**GO ON TO THE NEXT PAGE**

|  |  |  |
| --- | --- | --- |
|  | Nitrogen | Oxygen |
| First Ionization Energy (kJ/mol) | 1400  | 1300  |
| Covalent Atomic Radius (pm) | 70  | 66  |
| Electronegativity | 3.0 | 3.5 |

Base your answers to questions 6 and 7 on the information in the table above.

6. The lower first ionization energy of oxygen, compared with that of nitrogen is best explained by A) a greater effective charge acting on the valence electrons in oxygen

 B) repulsions between the electrons in the filled “p” orbital of an oxygen atom

 C) repulsions between 2s and 2p electrons that are greater in oxygen than in nitrogen

 D) a greater effective charge acting on the valence electrons in nitrogen

7. Compared with the data for these two elements, we would expect the ionization energy, atomic radius, and electronegativity values for fluorine, to be, respectively

 A) larger, smaller, larger C) smaller, larger, smaller

B) larger, larger, larger D) smaller, smaller, larger



8. The mass spectrum of element X is presented in the diagram above. Based on the spectrum, which of the following can be concluded about element X?

* 1. X is a transition metal, and each peak represents an oxidation state of the metal.
	2. X contains five electron sublevels.
	3. The atomic mass of X is 90.
	4. The atomic mass of X is between 90 and 92.

Questions 9 -10 refer to the following molecules:

 A) CH2Cl2 B) ICl3 C) CBr4 D) SO3

10. In which molecule are the bond angles closest to 90̊ ?

 A) A B) B C) C D)D

11. Which molecule contains both sigma and pi bonds?

A) A B) B C) C D) D



12. Which of the following is the strongest type of interaction that occurs between the atoms within the circled areas of the two molecules represented above?

A) Polar covalent bond B) Nonpolar covalent bond C) Hydrogen bond

D)London dispersion forces

13. A hot iron ball is dropped into a 200. g sample of water initially at 50.0 C. If 8.4 kJ of heat is transferred from the ball to the water, what is the final temperature of the water? (The specific heat of water is 4.2 J/(g-0 C).)

(A) 40.°C (B) 51°C (C) 60.°C (D) 70.°C

14. A yellow solid melts at 700°C, and does not conduct electricity. However, when melted or when dissolved in water it does conduct electricity. Which of the following could be the

 identity of that solid? A) urea (CO(NH2)2 B) gold C) sodium chromate, Na2CrO4

 D) silicon dioxide, SiO2

15. When 100 mL of 2.00 M NaOH is added to 50 mL of 3.00 M HCl the pH of the resulting mixture is closest to A) 1.0 B) 7.0 C) 9.5 D) 13.5

Base your answers to questions 16-18 on the following information:

 For the reaction 2 SO2(g) + O2(g) ➞ 2 SO3(g)  at 298 K

 ΔGo = **–** 140. kJ/mol rxn

16. Based on the sign of ΔG°, and the given balanced equation, we can conclude that

 A) ΔH° and ΔS° are both negative in sign.

 B) ΔH° and ΔS° are both positive in sign

 C) ΔH° is positive, while ΔS° is negative

 D) ΔH° is negative, while ΔS° is positive.

17. The reaction reaches equilibrium in a closed system. What would be the effect of adding

 oxygen gas to the equilibrium system? (assume no change in temperatue.

 A) The amount of SO2 would increase, while the Kp would remain the same

 B) The amount of SO2 would decrease while the Kp would remain the same.

 C) The amount of SO2 would increase while the Kp would decrease

 D) The amount of SO2 would decrease while the Kp would increase

18. If the equilibrium constant of the reaction as written is K, then the equilibrium constant of

 the reaction SO3(g)  ➞ SO2(g) + ½O2(g) is

 A) 1/K B) – K C)  D) 0.5 K



At 27°C, four identical rigid 2.0 L vessels are filled with N2(g) and sealed. (**IGNORE vessel number 3, which has nothing to do with the questions.)** The four of vessels also contain a 0.050 mol sample of NaHCO3(s), NaBr(s), Cu(s), or I2(s), as shown in the diagram above. The volume taken up by the solids is negligible, and the initial pressure of N2(g) in each vessel is 720 mm Hg. All four vessels are heated to 127°C and allowed to reach a constant pressure.

19. At 127°C, the pressure in vessel 1 is found to be higher than that in vessel 2. Which of the following reactions best accounts for the observation?

* 1. NaHCOis) Na(s) + HCO3(s)
	2. NaHCOis) NaH(s) + CO3(s)
	3. 2 NaHCO 3 (s) Na 2CO3 (s ) + CO2 (g) + H2O(g)
	4. 2 NaHCO 3 (s) + N2 (g) 2 NaNO 3 (s) + C2H2 (g)

20. At 127°C, the entire sample of I2 is observed to have vaporized. How does the mass of vessel 5 at 127°C compare to its mass at 27°C?

A) The mass is less, since the I2 is in the vapor phase.

B) The mass is the same, since the number of each type of atom in the vessel is constant.

C) The mass is greater, since the 12 will react with N2 to form NI3 , which has a greater molar mass.

D) The mass is greater, since the pressure is greater and the particles have a higher average kinetic energy.

21. The enthalpy of vaporization of ethane, C2H6 is 14.7 kJ/mol, while that of water is 40.7

 kJ/mol. The best explanation of the higher value for water is that

 A) ethane does not exhibit hydrogen bonding, while water does

 B) the larger ethane molecules are more highly polarizable than the smaller water molecules

 C) ethane has a smaller density than water

 D) the O-H bonds in water have a higher bond energy than to the C-H bonds in ethane

Base your answers to questions 22-23 on the following reaction:

 4 HBr(g) + O2(g) ➞ 2 H2O(g) +2 Br2(g) (ΔHrx = – 427 kJ)

A suggested three step mechanism for this reaction is:

 1. HBr(g) + O2(g) ➞ HOOBr (g)

 2. HOOBr(g) + HBr(g) ➞ 2 HOBr(g)

 3. 2 HOBr(g) +2 HBr(g) ➞ 2 H2O(g) +2 Br2(g)

22. If the second step is the rate determining step, then the rate law is most likely to be

 A) Rate = k[HBr][O2] B) Rate = k[HBr]2[O2] C) Rate = k [HOOBr][HBr]2[O2]

 D) Rate = k[HBr]4[O2]

23. An increase in temperature would

A) increase the rate constant and the equilibrium constant for the reaction

B) decrease the rate constant and the equilibrium constant for the reaction

C) increase the rate constant while decreasing the equilibrium constant

D) decrease the rate constant and increase the equilibrium constant.

Base your answers to questions 24-25 on the following reaction:

2 NO (g) + O2(g) ➞ 2 NO2(g) is found to obey the rate law

 Rate = k[NO]2[O2].

At a certain temperature, the rate constant is 7.00 x 103 M–2s–1.

24. What is the initial rate of disappearance of O2(g) (in M/s) when the initial concentration of NO(g) is 0.50 M, and the initial concentration of O2(g) is 2.0 M ?

 A) 3.50 x 103 B) 7.00 x 103 C) 1.40 x 104 D) 2.80 x 104

25. What would be the initial effect on the rate of disappearance of O2 if the volume of the reaction vessel was suddenly halved? The reaction rate would become

 A) 2 times faster B) half as fast C) 4 times faster D) 8 times faster

26. In one of the earliest atomic theories, John Dalton stated that all atoms of the same element are identical. This statement can be most directly **disproved** using

 A) Photoelectron spectroscopy C) IR spectroscopy

B) Mass spectroscopy D) UV spectroscopy



27. The exothermic dissolution of Mg(OH)2(s) in water is represented by the equation above. The *Ksp* of Mg(OH)2 is 1.8 x 10-11. Which of the following changes will increase the solubility of Mg(OH)2 in an aqueous solution?

* 1. Decreasing the pH
	2. Increasing the pH
	3. Adding NH3 to the solution
	4. Adding Mg(NO3)2 to the solution

28. The first five ionization energies of a second-period element are listed in the table above. Which of the following correctly identifies the element and best explains the data in the table?

|  |  |
| --- | --- |
|  | Ionization Energy (kJ/mol) |
| First | 801 |
| Second | 2,430 |
| Third | 3,660 |
| Fourth | 25,000 |
| Fifth | 32,820 |

A) B, because it has five core electrons

B) B, because it has three valence electrons

C) N, because it has five valence electrons

D) N, because it has three electrons in the *p* sublevel



29. The exothermic dissolution of Mg(OH)2(s) in water is represented by the equation above. The *Ksp* of Mg(OH)2 is 1.8 x 10-11. Which of the following changes will increase the solubility of Mg(OH)2 in an aqueous solution?

A) Decreasing the pH B) Increasing the pH C) Adding NH3 to the solution

D) Adding Mg(NO3)2 to the solution

 

30. A certain gas, XY(g), decomposes as represented by the equation above. A sample of each of the three gases is put in a previously evacuated container. The initial partial pressures of the gases are shown in the table below.

|  |  |
| --- | --- |
| Gas | Initial Partial Pressure (atm) |
| **XY** | 0.010 |
| X2 | 0.20 |
| Y2 | 2.0 |
|  |

The temperature of the reaction mixture is held constant. In which direction will the reaction proceed?

A)The reaction will form more products. B)The reaction will form more reactant.

C) The mixture is at equilibrium, so there will be no change.

D) It cannot be determined unless the volume of the container is known.

31. For the reaction: HSO4−(aq) + F– (aq) → SO42– (aq)+ HF(aq) , Keq = 18.

It is evident from the information above that the strongest of the following Brønsted-Lowry bases is

A) HSO4– B) F– C) SO42– D) H2SO4

Base your answers to questions 32-33 on the following half reactions and the corresponding standard reduction potentials:

|  |  |
| --- | --- |
| Reaction | Eo (volts) |
| Fe3+(aq) + e- ➞ Fe2+ (aq)  | +0.77 |
| MnO4–(aq)  + 8 H+ (aq) + 5e– ➞ Mn2+(aq) + 4 H2O (*l*)  | +1.51  |

32. When the reaction below is balanced using the smallest possible whole number coefficients, the coefficient before the Fe2+ is

 MnO4– (aq) + Fe2+(aq) + H+(aq) ➞ H2O*(l)* + Fe3+ (aq) + Mn2+(aq)

A) 1 B) 2 C) 5 D) 10

33. What is the standard potential, Eo, for the reaction shown in question 32?

 A) +2.28 volts B) +0.74 volts C) +2.34 volts D) -2.28 volts

 ΔH° = -196 kJ/ molrxn

Questions 34-38 refer to the following information

The decomposition of H2O2(aq) is represented by the equation above. A student monitored the decomposition of a1. 0 L sample of H2O2 ( aq) at a constant temperature of 300. K and recorded the concentration of H2O2 as a function of time. The results are given in the table below.

|  |  |
| --- | --- |
| Time (s) | [H202] |
| 0 | 2.7 |
| 200. | 2.1 |
| 400. | 1.7 |
| 600. | 1.4 |

34. Which of the following identifies the element(s) being oxidized and reduced in the reaction?

* 1. Hydrogen is oxidized and oxygen is reduced.
	2. Oxygen is oxidized and hydrogen is reduced.
	3. Oxygen is both oxidized and reduced.
	4. No elements are oxidized or reduced; the reaction is not a redox reaction

35. The *O2 (g)* produced from the decomposition of the 1.0 L sample of *H2O2 ( aq)* is collected in a previously evacuated 10.0 L flask at 300. K. What is the approximate pressure in the flask after 400. s? (For estimation purposes, assume that 1.0 mole of gas in 1.0 L exerts a pressure of 24 atm at 300. K.)

 A) 1.2 atm B) 2.4 atm C) 12 atm D) 24 atm

36. Which of the following statements is a correct interpretation of the data regarding how the order of the reaction can be determined?

* 1. The reaction must be first order because there is only one reactant species.
	2. The reaction is first order if the plot of ln [H2O2] versus time is a straight line.
	3. The reaction is first order if the plot of 1/[H2O2] versus time is a straight line.
	4. The reaction is second order because 2 is the coefficient of H2O2 in the chemical equation.

37. Hydroxylamine, HONH2, has a Kb of 1.1 x 10-8. The molarity of HONH2 that would provide a [OH–] of 1.0 x 10-5 M is closest to

A) 0.10 M B) 0.010 M C) 0.0010 M D) 1.0 x 10–4- M

38. Which sentence correctly describes and explains the differences in first ionization energy

 between F and Ne?

 A) Fluorine has a higher ionization energy because of its greater electronegativity

 B) Fluorine has a higher ionization energy because of its higher electron affinity

 C) Neon has a higher ionization energy because of its greater nuclear charge

 D) Neon has a higher ionization energy because of its completely filled 2p sublevel

39. Which of the following accounts for the observation that the pH of pure water at 37°C is 6.8 ?

* 1. At 37°C water is naturally acidic.
	2. At 37°C the autoionization constant for water, *Kw,* is larger than it is at 25°C.
	3. At 37°C water has a lower density than it does at 25°C; therefore, [H+] is greater.
	4. At 37°C water ionizes to a lesser extent than it does at 25°C.

40. CO32– has a Kb of 1.8 x 10–4. In a 1.0 molar aqueous solution of K2CO3, which of the following ions is present in the greatest concentration?

 A) CO32– B) HCO3– C) OH– D) H3O+

Base your answers to questions 41-42 on the following :

A chemical cell is constructed using the reaction,

 Zn(s) + Cu2+(aq) ➞ Zn2+(aq) + Cu(s) (Eo = +1.10 volts)

A zinc strip immersed in 1.0 M Zn(NO3)2 is connected, by a wire, to a copper strip immersed in 1.0 M Cu(NO3)2 and the two solutions are connected via a salt bridge.

41. The voltage generated by the cell would **increase** if

A) a larger zinc electrode was used

B) the solid copper formed by the reaction was removed as it was formed

C) solid sodium carbonate is added to the zinc nitrate solution, causing a precipitate

 of ZnCO3 to form , removing zinc ions from the solution

 D) solid sodium hydroxide is added to the copper(II) nitrate solution, causing a precipitate of Cu(OH)2 to form, removing copper(II) ions from the solution.

42. ΔGo for the cell reaction, in kJ/mol is

A) (96.5)(1.1) B) (96.5)(2.2) C) – (96.5)(1.1) D) –( 96.5)(2.2)

43. When the reaction in the cell reaches equilibrium

 A) the concentrations of Cu2+ and Zn2+ are equal B) ΔG for the reaction = 0

 C) Keq for the reaction = 1 D) there are no longer any ions in the salt bridge

44. A student performed an experiment to determine the formula of a hydrated copper (II) sulfate. A sample of the hydrate was heated to drive off the water, and was weighed before and after the heating. The student obtained the formula CuSO4•6H2O, but the actual formula is CuSO4•5H2O. Which error best accounts for the difference in results?

 A) The hydrated sample was not reheated to a constant mass.

 B) Some of the solid hydrate was lost during heating.

 C) The initial sample of hydrate was contaminated with some anhydrous CuSO4.

 D) The balance gave masses that were consistently 0.20 grams too high.

45. A sample of a compound that contains only the elements C, H, and N is completely burned in 0 2 to 3compound is

* 1. CH2N B) CH5N C) C2H5N D) C3H3N2

## Questions 46 - 48.

When free Cl(g) atoms encounter 03 (g) molecules in the upper atmosphere, the following reaction mechanism is proposed to occur.

Cl(g) + 03 (g) →Cl0(g) + 0 2(g) slow step

Cl0(g) + 03 ( g) → Cl(g) + 2 0 2(g) fast step

2 O3(g) → 3 O2(g) net reaction.

46. Which of the following rate laws for the overall reaction corresponds to the proposed mechanism?

* 1. Rate= k [O3 ]2 (B) Rate= k[Cl] [0 3] (c) Rate= k[Cl0] [0 3] 2

(D) Rate = k [O2]3/[O3]2

47. Which of the following reaction energy profiles best corresponds to the proposed mechanism?

(A) B) C ) D)



 3

 X(g) + 2 Q(g) → R(g) + Z(g) *Kc=* 1.3 × 105 at 50°C

48. A 1.0 mol sample of X(g) and a 1.0 mol sample of Q(g) are introduced into an evacuated, rigid 10.0 L container and allowed to reach equilibrium at 50°C according to the equation above. At equilibrium, which of the following is true about the concentrations of the gases?

**(A) [R]** = **[Q] (B) [Q]** = ½ **[X] (C) [R]** = **[Z]** > **[Q] (D) [X]** = **[Q]** = **[R]** = **[Z]**

49. The times in the table are recorded at 25̊ C for the reaction below to produce a detectable amount of I2(aq).  S2O82– (aq) + 2 I– (aq) ➞ I2(aq) + 2 SO42– (aq)

|  |  |  |  |
| --- | --- | --- | --- |
| Experiment | Initial [S2O82-] (M) | Initial [I-] (M) | Time to appearance of I2 (sec) |
| 1 | 0.0400 | 0.0800 | 40 |
| 2 | 0.0400 | 0.0400 | 80 |
| 3 | 0.0100 | 0.0800 | 160 |
| 4 | 0.0200 | 0.0200 | **?** |

What is the expected time for experiment 4?

 A) 160 sec B) 240 sec C) 320 sec D) 640 sec

50. In trial 1 which of the reactants would be consumed more rapidly, and why?

1. I-, because it has a higher molar concentration.
2. I-, because the reaction is second order with respect to I-.
3. [S2O8]2-, because the reaction is second order with respect to . [S2O8]2-,
4. I-, because the rate of disappearance will be double that of [S2O8]2-,

51. According to the equation, N2O3(g) + 6 H2(g) ➞ 2 NH3(g) + 3 H2O(g), how many moles

 of NH3(g) could be formed from the reaction of 0.22 mol of N2O3 with 0.90 moles

 of H2? A) 0.30 B) 0.45 C) 0.60 D) 1.2

52. Aluminum is extracted from its ore through electrolysis: 2 Al2O3 ➞ 4 Al + 3 O2.

 How many moles of Al are produced from the passage of 1.50 moles of electrons?

 A) 0.500 moles B) 6.00 moles C) 4.50 moles D) 0.125 moles

53. Which of the following properties of liquids **decreases** as the strengths of intermolecular forces **increase** ?

A) boiling point B) vapor pressure C) viscosity D) heat of vaporization

54. What happens to the pH of a buffer solution when it is diluted with water by a factor of 10?

 A) pH increases by 1 unit B) pH decreases by 1 unit

 C) pH either increases or decreases 1 unit, depending on whether the buffer is an acid range buffer or a base range buffer. D) pH does not change appreciably



55. In the diagram above, nitrogen atoms are represented as filled circles and oxygen atoms as open circles. How much NO2 can be prepared from the mixture shown?

 A) 4 molecules B) 5 molecules C) 6 molecules D) 8 molecules.

56. Which pair of solutions forms a buffer when equal volumes of each are mixed?

 A) 0.20 M HCl and 0.20 M NaCl C) 0.20 M HCl and 0.20 M NH3

 B) 0.40 M HC2H3O2 and 0.20 M NaOH D) 0.40 M HCl and 0.20 M NH3

57. A student is attempting to standardize a NaOH solution with a 0.500 molar solution of oxalic acid, H2C2O4. The net ionic equation for the reaction is:

 H2C2O4(aq) + 2 OH–(aq) ➞ C2O42– (aq) + 2 H2O(*l*)

The student prepares three 20.0 mL samples of the 0.500 molar oxalic acid, adding phenolphthalein to each sample. The burette is thoroughly rinsed with distilled water, the NaOH solution is added to the burette, and then the student titrates each of the three samples, refilling the burette after each trial. The student finds the results are inconsistent. It is most likely that the determined concentration of NaOH would be

A) lower in the first run than in the other two

B) higher in the first run than in the other two.

C) the same in the first two runs, but lower in the third.

D) the same in the first two runs, but higher in the third.

58. The three groups on the periodic table in which **none** of the elements have any unpaired

 electrons in the ground state are groups

A) 2, 8, and 12 B) 2, 16 and 18 C) 2, 12, and 18 D) 12, 16 and 18

59. Which process requires the greatest amount of energy per mole of H2O ?

 A) breaking the O–H bonds C) subliming the solid

 B) evaporating the liquid D) melting the solid

60. Given these reactions: A ➞ 2 B ΔHo = +30 kJ

 B➞C ΔHo = -60 kJ

 2C ➞ D ΔHo = -20 kJ

 Calculate ΔHo for the reaction D + A ➞ 4 C

 A) –70 Kj B) –110 Kj C) –190 kJ D) + 110 Kj



