2012 Academic Challenge

CHEMISTRY TEST - STATE FINAL

This Test Consists of 40 Questions

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GENERAL DIRECTIONS

Please read the following instructions carefully. This is a timed test; any instructions from the test supervisor should be followed promptly.

The test supervisor will give instructions for filling in any necessary information on the answer sheet. Most Academic Challenge sites will ask you to indicate your answer to each question by marking an oval that corresponds to the correct answer for that question. Only one oval should be marked to answer each question. Multiple ovals will automatically be graded as incorrect answers.

Be sure ovals are marked as  , not  ,  ,  , etc.

If you wish to change an answer, erase your first mark completely before marking your new choicE)

You are advised to use your time effectively and to work as rapidly as you can without losing accuracy. Do not waste your time on questions that seem too difficult for you. Go on to the other questions, and then come back to the difficult ones later if time remains.

***** TIME: 40 MINUTES *****

DO NOT OPEN TEST BOOKLET UNTIL YOU ARE TOLD TO DO SO!

Periodic Table of the Elements

1A												3A	4A	5A	6A	7A	8A
1 H 1.008	2A																2 He 4.003
3 Li 6.941	4 Be 9.012											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 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	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 65.38	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 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57 La* 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra 226	89 Ac** (227)	104 Unq	105 Unp	106 Unh	107 Uns	108 Uno	109 Une									

*Lanthanides	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
**Actinides	90 Th 232.0	91 Pa (231)	92 U 238.0	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 (260)

Potentially Useful Information

$q = m \bullet C_s \bullet \Delta T$

$\Delta T_f = - i K_f \bullet m$

$\Delta T_b = i K_b \bullet m$

$S_{gas} = k_H \bullet P_{gas}$

$P_{solvent} = C_{solvent} \bullet P°_{solvent}$

$k = Ae^{-Ea/RT}$

$$\ln\left(\frac{[A]_t}{[A]_0}\right) = -kt$$

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

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

$$\ln\left(\frac{k_2}{k_1}\right) = \frac{-E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

$$\ln\left(\frac{K_2}{K_1}\right) = \frac{-\Delta H_{rxn}}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

$$\ln\left(\frac{P_2}{P_1}\right) = \frac{-\Delta H_{vap}}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

$pH = -\log [H_3O^+]$

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

$pH = pK_a = \log\left(\frac{[A^-]}{[HA]}\right)$

$\Delta S_{surr} = \frac{-\Delta H_{sys}}{T}$

$\Delta G° = \Delta H° - T\Delta S°$

$E_{cell}° = E_{red}° + E_{ox}°$

$$\Delta E = B\left(\frac{1}{n_f^2} - \frac{1}{n_{fi}^2}\right)$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$F = 96485$ C/mol

$B = -2.18 \times 10^{-18}$ J

$R = 0.08206$ L atm/mol K; 8.3145 J/mol K

$N_A = 6.022 \times 10^{23}$

1.0 kg = 2.2 lb

1 atm = 101,325 Pa = 1.01325 bar

1.0 in = 2.54 cm

1 J = 1 N m = 1 kg m^2 s^{-2} = 0.239 cal

1 lb = 453.59 g

$E = hc/\lambda$

Assume all gases behave ideally unless specifically told to do otherwise
Assume all solutions are aqueous and at 25 °C unless specifically told otherwise
Assume all gases are at STP unless specifically told otherwise

Simple Rules for the Solubility of Salts in Water

1. Most nitrates are soluble
2. Most salts containing Group 1 ions or ammonium (NH_4^+) are soluble
3. Most chloride, bromide, and iodide salts are soluble except those of Ag^+, Pb^{2+}, and Hg_2^{2+}.
4. Most sulfates are soluble with the exception of Ba^{2+}, Pb^{2+}, Hg_2^{2+}, and Ca^{2+}
5. Most hydroxide salts are only slightly soluble with the exception of Group 1 hydroxides. Group 2 (Ba^{2+} to Ca^{2+}) are slightly soluble.
6. Most sulfides, carbonates, chromates, and phosphates are only slightly soluble.

WYSE – Academic Challenge
Chemistry Test (State Final) – 2012

1. A particular metal in a photoelectric cell has a threshold energy that corresponds to a photon of 500 nm. Which of the following statements is incorrect?

   A) If the metal is irradiated with 600 nm light, no electrons will be ejected.
   B) If the metal is irradiated with 250 nm light, twice as many electrons will be ejected than if it was irradiated with 500 nm light.
   C) If the metal is irradiated with 450 nm light, the ejected electrons will have a greater kinetic energy than if the metal was irradiated with 500 nm light.
   D) If the metal is irradiated with 500 nm light with an increased intensity, more electrons will be ejected.
   E) If the metal is irradiated with 10 photons of 500 nm light 10 electrons will be ejected.

2. Diethyl ether is a volatile organic compound. The vapor pressure of diethyl ether is 401 mm Hg at 18.0 °C and the ΔH_{vap} = 26.0 kJ/mol. Calculate the vapor pressure of diethyl ether at 40.0 °C.

   A) 401 mm Hg
   B) 517 mm Hg
   C) 598 mm Hg
   D) 605 mm Hg
   E) 853 mm Hg

3. How many O_2 molecules are in 1 mole of SO_2?

   A) 1
   B) $1*6.022 \times 10^{23}$
   C) $2*6.022 \times 10^{23}$
   D) $4*6.022 \times 10^{23}$
   E) None

4. Identify the element that forms an ion with a +2 charge and 10% more protons than electrons.

   A) Ca B) Ti C) V D) Sr E) Zr

5. A given xenon fluorine compound has the formula XeF_n, where n is some whole number. If 8.05×10^{21} molecules of XeF_n weigh 2.77 g, what is the value of n?

   A) 1 B) 2 C) 4 D) 5 E) 6

6. The concentration of commercially available nitric acid (HNO_3, MW = 63.02 g/mol) is 70.0% by mass, which is equivalent to 15.9 M. What is the density of this solution in g/mL?

   A) 0.699 g/mL
   B) 1.43 g/mL
   C) 1.92 g/mL
   D) 2.25 g/mL
   E) 3.32 g/mL

7. A 230. mL sample of a 0.275 M $CaCl_2$ solution is left on a hot plate overnight; the following morning, the solution is 1.10 M. What volume of water evaporated from the 0.275 M solution?

   A) 27.5 mL
   B) 57.5 mL
   C) 82.5 mL
   D) 147 mL
   E) 173 mL

8. To keep the fields green for Major League Baseball, the grounds keepers have to fertilize the outfields with ammonia based fertilizers. The ammonia is produced using the Haber process, which is shown below. If the fertilizer makers need 15.00 kg of ammonia to make the fertilizer for Opening Day, and the Haber process has an 82.0% yield, how many kilograms of nitrogen gas must be used?

   $$N_2(g) + H_2(g) \rightarrow NH_3(g) \text{ [unbalanced]}$$

   A) 10.1 kg
   B) 12.4 kg
   C) 15.0 kg
   D) 20.2 kg
   E) 30.1 kg

9. A sample of $Fe(NO_3)_3$ (M.W. = 241.86 g/mol) is added to 100.0 mL of 0.0900 M KOH and a white solid forms after all of the $Fe(NO_3)_3$ has reacted. If the remaining solution requires 50.00 mL of 0.125 M HCl to neutralize the excess KOH, what was the mass of the original $Fe(NO_3)_3$ sample?

   A) 9.16×10^{-4} g
   B) 2.75×10^{-3} g
   C) 2.22×10^{-1} g
   D) 5.04×10^{-1} g
   E) 6.65×10^{-1} g

10. In a particular experiment, 500 cm^3 of a 1.0 M NaOH(aq) solution is added to 500 cm^3 of 1.0 M HCl(aq) in a coffee-cup calorimeter and the solution is quickly stirred. The rise in temperature (ΔT_1) is measured. The experiment is then repeated using 100 cm^3 of the same solutions and the rise in temperature (ΔT_2) is measured. It is found that:

    A) ΔT_1 is equal to ΔT_2
    B) ΔT_2 is five times as large as ΔT_1
    C) ΔT_1 is five times as large as ΔT_2
    D) ΔT_2 is two times as large as ΔT_1
    E) It is impossible to tell from the data given

11. Analysis of a sample of pure caffeine, the active ingredient in sodas and coffee as well as NoDoz™, shows that a sample contains 18.26 g carbon, 6.081 g oxygen, 10.65 g nitrogen, and 1.91 g hydrogen and has a **molar mass** between 170. and 200. g/mol. What is the molecular formula of NoDoz™?

A) $C_4H_5ON_2$
B) $C_6H_{10}O_4N_3$
C) $C_8H_5O_2N_2$
D) $C_8H_{10}O_2N_4$
E) $C_9H_1O_3N_3$

12. An atom of element number 33 (As) is in its ground electronic state. Which one of the following sets of quantum numbers could not apply to any of its electrons?

A) $n = 2$, $l = 1$, $m_l = -1$, $m_s = +½$
B) $n = 3$, $l = 0$, $m_l = 0$, $m_s = -½$
C) $n = 3$, $l = 2$, $m_l = 2$, $m_s = +½$
D) $n = 4$, $l = 0$, $m_l = 0$, $m_s = -½$
E) $n = 4$, $l = 2$, $m_l = -2$, $m_s = +½$

13. An electron in the n=1 level of a hydrogen atom absorbs a photon of λ = 93.8 nm. To what energy level does the electron move to?

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

14. Two different compounds have the formula $KrCl_2I_2$ (with Kr as the central atom). Which of the following is <u>false</u> concerning these two compounds?

A) Both compounds of $KrCl_2I_2$ contain at least one exception to the octet rule.
B) All of the halogen atoms in both compounds of $KrCl_2I_2$ are terminal.
C) Both compounds of $KrCl_2I_2$ are square planar.
D) Both compounds of $KrCl_2I_2$ are nonpolar.
E) Both compounds of $KrCl_2I_2$ will have the same shape.

15. Which of the following is the correct order for decreasing bond length of the CO bond?

A) CO, CO_2, CO_3^{2-}
B) CO_2, CO, CO_3^{2-}
C) CO_3^{2-}, CO_2, CO
D) CO_3^{2-}, CO, CO_2
E) CO_2, CO_3^{2-}, CO

16. If the shape of XF_3O^- is square planar, which of the following could be atom X, where X is the central atom?

A) Ne
B) P
C) Cl
D) Se
E) Xe

17. What is the coefficient on $MnO_4^-(aq)$ when the following solution is balanced in acidic solution?

$$SO_3^{2-}(aq) + MnO_4^-(aq) \rightarrow SO_4^{2-}(aq) + Mn^{2+}(aq)$$

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

18. The following rate data were collected for the decomposition of NOBr:

$$2NOBr(g) \rightarrow 2NO(g) + Br_2(g)$$

[NOBr](mol L^{-1})	Rate (mol $L^{-1}s^{-1}$)
0.0450	1.62×10^{-3}
0.0310	7.69×10^{-4}
0.0095	7.22×10^{-5}

Based on the initial rate data above, what is the value of the rate constant?

A) 0.0360 L $mol^{-1}s^{-1}$
B) 0.800 L $mol^{-1}s^{-1}$
C) 1.25 L $mol^{-1}s^{-1}$
D) 27.8 L $mol^{-1}s^{-1}$
E) 277 L $mol^{-1}s^{-1}$

19. The rate law for the reaction below is rate = k $[NO_2]^2$.

$$NO_2 + CO \rightarrow NO + CO_2$$

Which mechanism is consistent with this rate law?

A) $NO_2 + CO \rightarrow NO + CO_2$

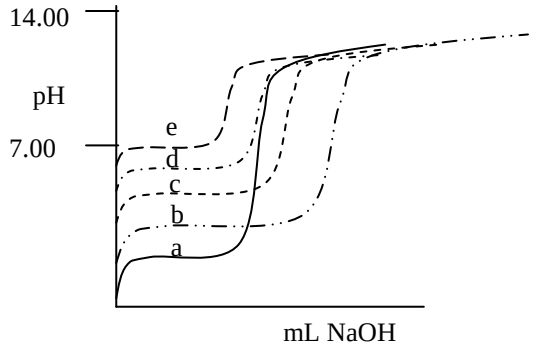
B) $NO_2 + NO_2 \rightarrow NO + NO_3$ (slow)
$NO_3 + CO \rightarrow NO_2 + CO_2$ (fast)

C) $NO_2 + NO_2 \rightarrow NO + NO_3$ (fast)
$NO_3 + CO \rightarrow NO_2 + CO_2$ (slow)

D) $NO_2 + CO \rightarrow NO_3 + C$ (slow)
$NO_3 + C \rightarrow NO_2 + CO$ (fast)

E) None of these are consistent

Use the following diagram for questions **20 and 21**. The results of the titrations of 100.0 mL samples of five different acids with 1.0 M NaOH are summarized in the following figure (acids are labeled a-e from bottom to top):



20. Which acid was the most concentrated before any NaOH was added?

A) acid a B) acid b C) acid c D) acid d E) acid e

21. Which acid has the strongest conjugate base?

A) acid a B) acid b C) acid c D) acid d E) acid e

22. Which of the following will be a buffer when dissolved in 1.0 L of water?

A) 0.1 mol NaOH and 0.2 mol HCl
B) 0.2 mol HBr and 0.1 mol NaOH
C) 0.3 mol KCl and 0.3 mol HCl
D) 0.2 mol CH_3COOH and 0.4 mol NaOH
E) 0.4 mol NH_3 and 0.2 mol HCl

23. A 1.35 m aqueous solution of compound X had a boiling point of 101.4 °C. Which one of the following could be compound X? The boiling point elevation constant for water is 0.52 °C/m.

A) CH_3CH_2OH
B) $C_6H_{12}O_6$
C) Na_3PO_4
D) KCl
E) $CaCl_2$

24. Following is a list of properties of a sample of solid sulfur:

    i. Brittle, crystalline solid.
    ii. Melting point of 113 ºC.
    iii. Density of 2.1 g/cm^3.
    iv. Combines with oxygen to form sulfur dioxide.

    Which, if any, of these properties would be the same for one single atom of sulfur obtained from the sample?

    A) i and ii only.
    B) iv only.
    C) iii and iv only.
    D) All of these properties would be the same.
    E) None of these properties would be the same.

25. In the lab one afternoon you perform a calorimetry experiment where you place 519 g of iron metal at 625 ºC into 101 g of water that is at 25.0 ºC. How much of the water will vaporize? Note that the specific heat capacity of iron is 0.450 J/gK and water is 4.184 J/gK. Also, the enthalpy of vaporization of water is 40.6 kJ/mol.

    A) 0.00 g
    B) 2.24 g
    C) 40.4 g
    D) 72.6 g
    E) 101 g

26. For the phosphorus halides, one can start with a molecule such as PCl_5 and sequentially replace each chlorine with a fluorine to eventually produce PF_5. How many of the 6 compounds possible compounds are polar? (PCl_5, PCl_4F, PCl_3F_2,…etc) (Note that the predicted VSEPR shapes are correct in each case.)

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

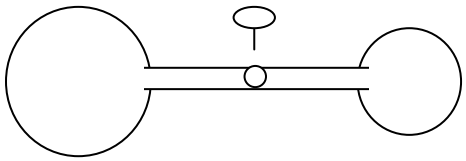
27. A lab technician adds 0.20 mol of NaF to 1.00 L of 0.35 M cadmium nitrate, $Cd(NO_3)_2$. Which of the following statements is correct? Ksp = 6.44×10^{-3} for CdF_2

    A) Cadmium fluoride precipitates until the solution is saturated.
    B) The solution is unsaturated and no precipitate forms.
    C) The solubility of cadmium fluoride is increased by the presence of additional fluoride ions.
    D) One must know Ksp for cadmium nitrate to make meaningful predictions on this system.
    E) $NaNO_3$ will precipitate out of solution.

28. A 0.622-g sample of a metal oxide with the formula M_2O_3 is converted to 0.685 g of the metal sulfide MS. What metal must M be?

A) Al B) Li C) Zn D) Mn E) Ca

29. The volume of the bulb on the right is 2.00 L and has a pressure of 1.00 atm when the valve is closed. The volume of the bulb on the left is 3.00 L and has a pressure of 1.50 atm when the valve is closed. What is the final pressure in the apparatus when the valve between them is opened and the gases can completely mix?



A) 0.900 atm
B) 1.25 atm
C) 1.30 atm
D) 2.25 atm
E) 2.50 atm

30. What volume of ammonia gas (NH_3) has the same number of ATOMS as 10.0 L of neon (Ne) at the same temperature and pressure?

A) 1.67 L
B) 2.50 L
C) 3.33 L
D) 7.50 L
E) 10.0 L

31. Rank the following atoms/ions by <u>increasing</u> ionization energy: Be, B, B^-, N, N^+, O

A) $O < N^+ < N < B < B^- < Be$
B) $Be < B^- < B < O < N < N^+$
C) $B^- < B < Be < N < N^+ < O$
D) $Be < B^- < B < N < N^+ < O$
E) $B^- < B < Be < O < N < N^+$

32. The normal boiling point for ammonia is -33°C. For the condensation reaction below, what would the signs of ΔG, ΔH, and ΔS be at -40°C?

$NH_3\ (g) \rightarrow NH_3\ (l)$

	ΔG	ΔH	ΔS
A)	-	-	-
B)	-	+	+
C)	+	+	+
D)	0	+	-
E)	+	-	-

33. Consider the decomposition reaction of carbon tetrachloride at 700 ^{o}C below. Which of the following statements concerning this reaction is <u>true</u>?

$$CCl_4\ (g) \rightleftharpoons C\ (s) + 2Cl_2\ (g) \qquad K = 1.0 \times 10^{-4}$$

A) $K_p = K_c$ for this reaction.
B) As long as some C (s) is present, the value of K does not depend on how much is present.
C) If solid carbon and gaseous chlorine are added to a reaction vessel, equilibrium cannot be reached since there is no reactant at the start.
D) Since K<<1, at equilibrium the rate of the reverse reaction will be much greater than the rate of the forward reaction.
E) If 2.0 moles of CCl_4 are allowed to decompose at 700 ^{o}C, the value of K will be 2.0×10^{-4}.

34. Vanadium forms several different ions. In the electrolysis of a solution of a vanadium salt, 2.00 moles of electrons plate out 25.5 g of vanadium. What ion is in the solution of this salt?

A) VO^{2+} B) V^{3+} C) V^{2+} D) VO_2^{+} E) V^{3-}

35. In aqueous solution, iodine reacts with acetone in a reaction that is catalyzed with acid as shown below. The experimental rate law shows that the reaction is 1st order in $[H^+]$. If the pH of the reaction is reduced from pH=6 to pH=3, what affect will this have on the rate?

$$I_2\ (aq) + CH_3COCH_3\ (aq) \xrightarrow{H^+} CH_3COCH_2I\ (aq) + H^+\ (aq) + I^-\ (aq)$$

A) the rate will increase by a factor of 2
B) the rate will decrease by a factor of 2
C) the rate will increase by a factor of 3
D) the rate will decrease by a factor of 3
E) the rate will increase by a factor of 1000

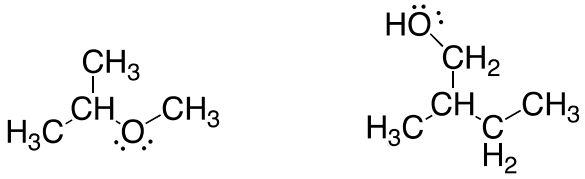
36. Which molecular substance will have the lowest normal boiling point? The vapor pressures given are at 25°C. If the vapor pressure is not given, then consider the substance non-volatile.

A) C_7H_{16} (44 mmHg)
B) $CH_3CH_2OCH_2CH_3$ (534 mmHg)
C) CH_3COOH (11 mmHg)
D) KBr
E) $Ca(NO_3)_2$

37. Which solute will dissolve in water to give the greatest boiling point at a 0.2 M concentration? The vapor pressures given are at 25°C. If the vapor pressure is not given, then consider the substance non-volatile.

A) C_7H_{16} (44 mmHg)
B) $CH_3CH_2OCH_2CH_3$ (534 mmHg)
C) CH_3COOH (11 mmHg)
D) KBr
E) $Ca(NO_3)_2$

38. What is the relationship between the 2 molecules below?



A) They are different molecules.
B) They are structural isomers.
C) They are cis-trans isomers.
D) They have the same empirical formula.
E) The are conformers.

39. What do the following molecules have in common?

SiH_4 XeF_2 PBr_5 CS_2 BH_3

A) All have at least one 120° bond angle.
B) All have a tetrahedral shape.
C) All have atoms that follow the octet rule and the duet rule for hydrogen
D) All are exceptions to the octet rule.
E) All are nonpolar.

40. How many moles of sulfate ions are there in a 0.20 L solution of 0.030 M aluminum sulfate?

A) 0.0030 moles
B) 0.0060 moles
C) 0.012 moles
D) 0.018 moles
E) 0.024 moles