Chemistry Lab

Acids and Bases, Aqueous Solutions

Captains Tryouts Division C

John P. Stevens High School

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Score: ___/95

Multiple Choice: (30 points)

1. Which of the following is not a characteristic of an acid? (1)
   a. Corrosive
   b. Turns red litmus paper blue
   c. Tastes sour
   d. Conducts Electricity

2. In the following reaction, what does water act as? $H_2O + H_2O \rightarrow H_3O^+ + OH^-$ (1)
   a. An Arrhenius acid
   b. A Brønsted-Lowry base
   c. A Lewis acid
   d. All of the above

3. What is the pH of a 0.05 M hydrosulfuric acid given its $K_a = 1.0 * 10^{-7}$? (1)
   a. 3.0
   b. 4.0
   c. 4.4
   d. 5.7

4. Which of the following reactions will not result in a precipitate? (1)
   a. $Pb(NO_3)_2 + 2NaI \rightarrow PbI_2 + 2NaNO_3$
   b. $NaF + AgCl \rightarrow NaCl + AgF$
   c. $Na_2CO_3 + SrCl_2 \rightarrow 2Nacl + SrCO_3$
   d. $MgSO_4 + BaCl_2 \rightarrow MgCl_2 + BaSO_4$

5. Fill in the following table below: (2)

Model	Acids	Bases
Arrhenius	Produce H+ in solution	Produce OH- in solution
Bronsted-Lowry	Donate proton	Proton acceptor
Lewis	Electron pair acceptor	Electron pair donor

6. What volume of a 0.20 M sulfurous acid is needed to neutralize 150 mL of 1.70 M sodium hydroxide? (2)

a. 640 mL
b. 1280 mL
c. 520 mL
d. 870 mL

7. If in an aluminum hydroxide solution the $[Al^{3+}] = 2.4*10^{-2}$ and $[OH^-] = 8*10^{-3}$, which of the following best describes the solution? (K_{sp} of $Al(OH)_3$ is $1.8 * 10^{-5}$) (2)
   a. Unsaturated
   b. Concentrated
   c. Saturated
   d. Supersaturated

8. A precipitate will form if: (1)
   a. Ion product is less than the solubility product
   b. There is an excess of one reactant
   c. $Q > K_{sp}$
   d. K_{sp} is positive

9. Which of the following is the strongest base? (1)
   a. NO_3^-
   b. H_2CO_3
   c. NH_3
   d. LiOH

10. How many grams of NaCl are dissolved in 2.5 liters of a 0.7 M NaCl solution? (1)
    a. 72 g
    b. 217 g
    c. 35 g
    d. 102 g

11. Which of the following mixtures is a colloid? (Select all that apply) (3)
    a. Milk
    b. Muddy water
    c. Jelly
    d. Oil paint
    e. Dressing
    f. Whipped Cream

12. What is the molar mass of a covalent compound given that when 120 g of it is placed in 0.4 kg of water, the new freezing point is -5.84 °C? (2)
    a. 84 g
    b. 53 g
    c. 19 g
    d. 151 g

13. The $[OH^-]$ at the half-equivalence point in a titration was found to be $1.6 * 10^{-10}$. What is the value of K_a for this acid? (2)
    a. 1.8
    b. 4.2
    c. 8.0
    d. 6.7

14. The K_{sp} of PbI_2 is $1.4 * 10^{-8}$. What is its molar solubility? (1)
    a. $1.5 * 10^{-3}$ M
    b. $1.1 * 10^{-4}$ M
    c. $2.5 * 10^{-2}$ M
    d. $0.7 * 10^{-8}$ M

15. Which of the following would not increase the solubility of silver chloride? (1)
    a. Increasing the temperature
    b. Adding sodium chloride to the solution
    c. Agitation of the solution
    d. Grinding the solute into smaller sized particles

16. Mixing equal volumes of which of the following pairs of solutions would give an acidic solution? (2)
    a. 1.2 M barium hydroxide and 1.2 M nitric acid
    b. Carbonic acid with a pH of 5 and ammonia with a pH of 10
    c. An acid with a pH of 4.6 and a base with a pOH of 1.5
    d. 0.7 M cesium hydroxide and 0.5 M sulfuric acid

17. A solution with a concentration of 0.34 M is measured to have an absorbance of 0.57. Another solution of the same chemical has an absorbance of 0.23 when measured under the same conditions. What is its concentration? (2)
    a. 0.14 M
    b. 0.84 M
    c. 0.045 M

d. 1.3 M

18. Which of the following laws describe the relation between pressure and dissolved gas?(1)
    a. Charles' Law
    b. Raoult's Law
    c. Henry's Law
    d. Dulong–Petit Law

19. Which of the following pairs are not miscible? (1)
    a. CH_3CN and $(CH_3CH_2)_2NH$
    b. $CH_3CH_2OCH_2CH_3$ and CCl_2F_2
    c. C_5H_{12} and C_6H_{14}
    d. CCl_4 and H_2O

20. What is the molarity of a $Ca(NO_3)_2$ solution if it is 6.5% $Ca(NO_3)_2$ by mass and has a density of 1.19 g/ml? (2)
    a. 1.27 M
    b. 0.47 M
    c. 0.11 M
    d. 0.73 M

Free Response: (65 points)

Show your work whenever needed. Circle your answer.

1. Create the equilibrium expression of a solution of NH_3 (3)

Reaction: $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$
[Products]/[Reactants]
Ignore water in equilibrium expressions
$[NH_4^+][OH^-]/[NH_3]$

2. You performed two titrations to the endpoint. Calculate the molarity of the two following analytes given the data below: (4)
    a.

KOH	55 mL	0.6 M
HI	30 mL	? M

Formula: $M_aV_a = M_bV_b$

(30 mL)(x) = (55 mL)(0.6 M)
30x = 33
x= 1.1 M

b.

$Ca(OH)_2$	95 mL	? M
HCl	35 mL	1.6 M

Formula: $(M_aV_a)/C_a = (M_bV_b)/C_b$
Write out balanced equation:
$2HCl + Ca(OH)_2 \rightleftharpoons 2HOH + CaCl_2$
Isolate unknown variable:
$M_b = (M_aV_aC_b)/(C_aV_b)$
$M_b = (1.6\ M*35\ mL*1)/(2*95\ mL)$
$M_b = 0.29\ M$

3. A solution contains 1.5 M HF and 0.85 M F. Given the K_a of HF is 6.46×10^{-4} , calculate the pH. (5)

Create a RICE box:

	$HF + H_2O$ $\rightleftharpoons$	H_3O^+ +	F^-
Initial	1.5	0	0.85
Change	-x	+x	+x
Equilibrium	1.5-x	x	0.85+x

$K_a = [H^+][A^-]/[HA]$
$6.46*10^{-4} = [0.85+x][x]/[1.5-x]$
(Using 5 percent rule, assume that x is miniscule and that 0.85+x is 0.85)
$6.46*10^{-4} = [0.85x]/[1.5]$
x = 0.00114
$pH = -\log[H_3O^+]$
pH = -log[0.00114]
pH = 2.9

4. Calculate the percent dissociation of 0.05 M (theoretical acid) HA, given $K_a = 1.5*10^{-9}$ (5)

	HA	⇌	H^+	+	A^-
Initial	0.05		0		0
Change	-x		+x		+x
Equilibrium	0.05-x		x		x

$1.5*10^{-9} = (x^2)/(0.05-x)$
$1.5*10^{-9} = (x^2)/(0.05)$
$x = 8.66*10^{-6}$
$[H^+] = 8.66*10^{-6}$
Dissociation percentage: $([H^+]/[HA]_0) * 100$
$((8.66*10^{-6})/0.05) *100$
0.017%

5. Calculate the K_{sp} for the individual salts given molar solubility of Ag_2S: $9.2 * 10^{-23}$ (4)

Create RICE table:

Ag_2S	⇌	$2Ag^+$	+	S^{-2}
		0		0
		+2x		+x
		2x		x

$x = 9.2 * 10^{-23}$
$K_{sp} = (2x)^2(x)$
$K_{sp} = 4(9.2 * 10^{-23})^3$
$K_{sp} = 3.1*10^{-66}$

6. How much water would you need to add to 150 mL of a 7.25 M KCl solution to make a 2.00 M solution? (3)

$M_1V_1 = M_2V_2$
(7.25 M)(150 mL) = (2.00 M)(x)

x = 543.75 mL
393.75 mL

7. Describe briefly how to perform a titration. Be sure to use proper word choice. (5)

1 point for use of indicator
1 point for each instrument mentioned (up to 3 points)
1 point for mentioning equivalence point

8. A solution consists of 7.25 g of carbon tetrachloride mixed with 215.0 g water. Calculate the molality, molarity, mass percent, and mole fraction. (4)

Molarity:
7.25 g CCl_4 = 0.0471 mol CCl_4
215 mL = 0.215 L *ignore change of volume by solute*
0.0417/0.215 = 0.194 M
Mass percent: 7.25/215 = 3.37%
Mole fraction: 0.0417/(0.0417+11.934) = 0.00348
Molality: 0.0471/0.215 = 0.194 *m*

9. Calculate the pH of a buffer that is made from 0.52 M hydrocyanic acid (HCN) and 0.45 M cyanide (CN^-). Assume the K_a of HCN is $6.2*10^{-10}$ (5)

Use the Henderson-Hasselbach equation: $pH = pK_a + \log([A^-]/[HA])$
$pK_a = -\log(K_a)$
$pK_a = 9.207$
$pH = 9.207 + \log(0.45/0.52)$
pH = 9.14

10. 40.9 grams of sulfuric acid were added into 365 mL water. Calculate the change in freezing point. (K_f water = 1.86 °C kg*mol^{-1}, density of water = 0.994 g/mL) (3)

$\Delta T = iK_fm$
$H_2SO_4 \rightarrow 2H^+ + SO_4^{-2}$
i = 3
K_f = 1.86 kg/mol
0.417 mol/0.36281 kg
m = 1.15
$\Delta T = (3)(1.86)(1.15)$

$\Delta T = 6.42\ ^\circ C$

11. Order the following acids in terms of increasing acidity and explain your reasoning: $HSeO_4$, $HAsO_3$, $HBrO_4$, H_3AsO_4 (5)

H_3AsO_3, H_3AsO_4, $HSeO_4$, $HBrO_4$ (3 points)

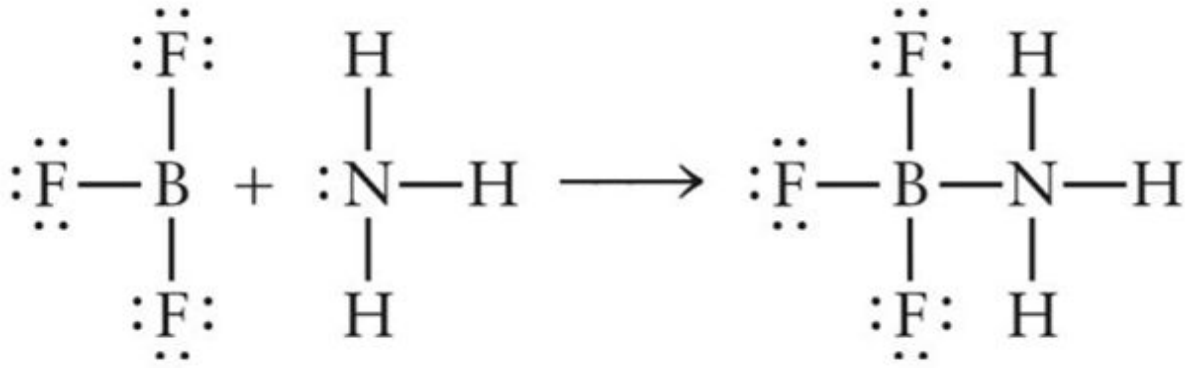
In H_3AsO_4, $HSeO_4$, and $HBrO_4$ arsenic, selenium, and bromine are the central atoms respectively, and the more electronegative the central atom, the more electron density is drawn out of the O-H bond, weakening it and resulting in a stronger acid. Their relative strengths thus follow the electronegativity of the central atom, which is As < Se < Br. (1 point)

Between H_3AsO_3 and H_3AsO_4, H_3AsO_4 is stronger because the more oxygens pull more of the electron density toward themselves and away from the O-H bond, making it weaker, and in turn making the acid stronger. (1 point)

12. Describe how a buffer functions, state an example, and write its respective dissociation reaction. (5)

A buffer is able to maintain a certain pH in a solution - specifically by maintaining the ratio of hydrogen/hydroxide ions. This ratio is maintained through chemical equilibrium, the reaction containing one side with an acid, and the other side with its conjugate base. When H+ is added into the solution, the reaction will shift towards (favor) the reactant side of the chemical equation. The OH- will then react with the H+, forming water. This will help maintain the pH of the solution. An example would be acetic acid ($CH_3COOH + H_2O \leftrightarrow CH_3COO^- + H_3O^+$)

13. Determine the Lewis acid and base in the following reaction. (2 points) Draw the Lewis structure for each reactant and product. (3 points) Reaction: $BF_3 + NH_3 \rightarrow NH_3BF_3$



NH_3 = base, BF_3 = acid

14. The table below shows the relationship between the absorbance of a solution and its concentration at some constant path length. (4)

Concentration	Absorbance
0.225 M	0.072
0.527 M	0.168
0.923 M	0.458
1.433 M	0.682

a. If the molar absorptivity constant for the solution is 0.30 L $mol^{-1}cm^{-1}$, what is the path length? (1)
b. What is the absorbance when the concentration is 0.432 M and the path length is doubled? (1)
c. Calculate the transmittance of the solution from part b. (1)
d. If the intensity of the light entering the detector for the solution from part b is 0.42 W/m^2, what is the intensity of the incident light on the sample? (1)

Use Beer-Lambert's Law: $A = \epsilon lc = \log(I_0/I) = \log(1/T)$

a) $0.072 = 0.30 * l * 0.225$
$l = 1.07$ cm
b) $A = 0.3 * (2*1.07) * 0.432 = 0.277$
c) $0.277 = -\log T$
$T = 0.528$
d) $1/T = I_0/I$
$1/0.527 = I_0 / 0.42$
$I_0 = 0.797\ W/m^2$

15. Calculate the pH of 3.5 M $H_2C_6H_6O_6$ in an aqueous solution. $K_{a1} = 7.9*10^{-5}$ and $K_{a2} = 1.6*10^{-12}$ (5)

	$H_2C_6H_6O_6$	$\rightleftharpoons$	H^+	+	$HC_6H_6O_6^-$
Initial	3.5		0		0

Change	-x	+x	+x
Equilibrium	3.5-x	x	x

$K_{a1} = x^2/(3.5-x)$
$7.9*10^{-5} = x^2/(3.5)$
$x = 0.01662$ M → $[HC_6H_6O_6^-] = [H^+] = 0.01662$ M

	$HC_6H_6O_6^-$ ⇌	H^+ +	$HC_6H_6O_6^{2-}$
Initial	0.01662	0.01662	0
Change	-y	+y	+y
Equilibrium	0.01662-x	y	y

$K_{a2} = y^2/(0.01662-y)$
$1.6*10^{-12} = y^2/(0.01662)$
$y = 1.631*10^{-7}$
$[H^+]_{total} = 1.631*10^{-7} + 0.01662 = 0.0166$ M
pH = -log$[H^+]$ = -log(0.0166) = 1.78

Periodic Table of the Elements

amu to 4 significant figures

1 1A												13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1 **H** 1.008	2 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	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	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** 65.39	31 **Ga** 69.72	32 **Ge** 72.61	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** 183.8	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 **Rf** (261)	105 **Db** (262)	106 **Sg** (263)	107 **Bh** (262)	108 **Hs** (265)	109 **Mt** (266)	110 **Ds** (281)	111 **Rg** (272)	112 **Cn** (285)	113 (Uut) (284)	114 **Fl** (289)	115 (Uup) (288)	116 **Lv** (293)	117 (Uus) (294)	118 (Uuo) (294)

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	**Lanthanide Series**
90 **Th** 232.0	91 **Pa** 231.0	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** (262)	**Actinide Series**