ACID BASE REVIEW

1. Identify Lewis Acid, in the following reactions:

a. $Zn^{+2} + 4\ H_2O \rightleftharpoons Zn(H_2O)_4^{+2}$

b. $BF_3 + F^{-1} \rightleftharpoons BF_4^{-1}$

c. $Ag^{+1} + 2NH_3 \rightleftharpoons Ag(NH_3)_2^{+1}$

2. Identify the acid – base conjugate pairs in each of the following reactions according with the Bronsted – Lowry framework:

a) $CH_3COO^- + HCN \rightleftharpoons CH_3COOH + CN^-$

b) $NO_2^- + H_2O \rightleftharpoons HNO_2 + OH^-$

c) $H_2PO_4 + NH_3 \rightleftharpoons HPO_4^- + NH_4^+$

d) $HClO + CH_3NH_2 \rightleftharpoons CH_3NH_3^+ + ClO^-$

3. The ionization constant for hypobromous acid, HOBr is:

$HOBr_{(aq)} + H_2O_{(aq)} \rightleftharpoons H_3O^+ + OBr^-$ $\quad Ka = 2.0 * 10^{-9}$

What is the value of the equilibrium constant for the following reaction?

$H_3O^+ + OBr^- \rightleftharpoons HOBr_{(aq)} + H_2O_{(aq)}$

(Answer: $5.0 * 10^8$)

4. Given the K_a for HOCN is $3.3*10^{-4}$. What is K_b for OCN^-?

5. Boric acid, H_3BO_3, is commonly used in eyewash solution in chemistry laboratories to neutralize bases splashed in the eye. It acts as a monoprotic acid, but the dissociation reaction is slightly different from other acids:

$B(OH)_{3(aq)} + H_2O \rightleftharpoons B(OH)_4^-{}_{(aq)} + H^+{}_{(aq)}$

Calculate the pH of a 0.50 $moldm^{-3}$ solution of boric acid. The K_a for the boric acid is $5.8 * 10^{-10}$.

6. What is the pH of a solution that is 0.10 mol dm^{-3} KNO_2 and 0.15 mol dm^{-3} HNO_2 (nitrous acid)?

7. Use Le Chatêlier's Principle to predict the effect of the following changes on the extent of the hydrolysis of the $NaNO_2$ (sodium nitrite) solution, upon the addition of:

a) HCl b) NaOH c) NaCl d) the solution is diluted

Explain each answer.

(Recall the important equation is the hydrolysis of the nitrite ion, NO_2^-.)

$NO_2^- + H_2O \rightleftharpoons HNO_2 + OH^-$)

8. Calculate:

a) pH of a 0.2 mol dm^{-3} $NaHSO_3$ (K_a for $HSO_3^- = 6.2 * 10^{-8}$).

b) pH of a 0.2 $moldm^{-3}$ phenoxide ion, $C_6H_5O^-$, a weak base ($K_b = 7.7 *10^{-5}$)

c) pH of a 0.2 $moldm^{-3}$ NH_4Cl? (K_b (NH_3) = $1.8 *10^{-5}$)

d) pH of a 0.2 $moldm^{-3}$ KCN (K_a (HCN = $4.9 *10^{-10}$)

9. Which of the following would form a:

(1) Neutral Solution (2) Acidic Solution (3) Basic Solution

i) NaH_2PO_4 ii) Na_3PO_4 iii) KCl iv) $FeCl_3$ v) KCN

10. Calculate the pH of a buffer solution that contains:
    a) 0.25 mol dm^{-3} benzoic acid (C_6H_5COOH) acid 0.15 mol dm^{-3} sodium benzoate (C_6H_5COONa) given ($K_a = 6.5*10^{-10}$).

    b) 500 cm^3 of 0.10 $moldm^{-3}$ NaOCl and 500 cm^3 of 0.20 $moldm^{-3}$ HOCl, what is the pH of the solution? (Ka (HOCl) = $3.2*10^{-8}$)
    (Answer: 7.19)

11. You are asked to go into the laboratory and prepare an ethanoic acid – sodium ethanoate buffer solution, with a pH of 4.00 ± 0.02. What mole ratio of CH_3COOH to CH_3COONa should be used (K_a (CH_3COOH) = $1.8*10^{-5}$)
(**Answer = 5.50)**

12. Over what range of pH is a HOCl – NaOCl buffer effective?
(K_a (HOCl) = $3.2*10^{-8}$)
(Answer: 6.5 - 8.5)

13. Assuming equal concentrations of conjugate base to acid, which one of the following mixture is suitable for making a buffer solution with an optimum pH of 4.6 – 4.8.

a)	CH_3COOH / CH_3COONa	$K_a = 1.8 * 10^{-5}$
b)	NH_3 / NH_4Cl	$K_a = 5.6 * 10^{-10}$
c)	NaOCl / HOCl	$K_a = 3.2 * 10^{-8}$
d)	$NaNO_2$ / HNO_2	$K_a = 4.5 * 10^{-4}$

14. Consider the carboxylic acids, (acids that contain the general formula –COOH group): ethanoic acid, (CH_3COOH) and chloroethanoic acid, ($CH_2ClCOOH$).
From the equation: $? G^o = ? H^o - T? S^o$
We see that the contributions to the ($? G^o$) term are the enthalpy term ($? H^o$) and a temperature time entropy term ($T? S^o$). These contributions are listed below for the two acids at 298 K.

Acid	$? H^o$ (mol dm^{-3})	$T? S^o$ (mol dm^{-3})
CH_3COOH	- 0.57	27.6
$CH_2ClCOOH$	- 4.7	21.1

a) Calculate $? G^o$ for the ionization of these two acids at 25 °C.
b) Calculate the acid ionization constant, K_a of chloroethanoic acid at 25 °C. Recall:
$$? G^o = -RT \ln K$$
c) Which is the dominant term ($? H^o$ or $T? S^o$) in determining the value of $? G^o$, (and hence K_a) of the acid?
d) What processes contribute to the $? H^o$ in the ionization of these acids? (Consider the ionization of the acid as a Bronsted-Lowry acid – base reaction; ie, what bonds need to be broken and what bonds need to be formed.)

15. 50.0 cm^3 of 0.10 $moldm^{-3}$ nitrous acid, HNO_2, was titrated with of 0.10 $moldm^{-3}$ KOH solution. After 25.0 cm^3 KOH solution, what will be the pH in the titration flask?
($K_a = 4.50 *10^{-4}$)
(Answer: 2.41)

16. Calculate the pH at the equivalence point for the titration of 20.0 cm^3 of 0.20 $moldm^{-3}$ HCl with 30.0 cm^3 of 0.20 $moldm^{-3}$ NH_3 ($K_b = 1.82*10^{-5}$)

17. Rank the following 0.01 mol dm^{-3} solutions of the following three acids from the highest to

the lowest in acid strength. Explain your reasoning:
A. CH_3COOH B. $CH_2ClCOOH$ C. CCl_3COOH

18. In the reaction: $C_6H_5COOH + F^{-1} \rightleftharpoons C_6H_5COO^{-1} + HF$
$K_a (C_6H_5COOH) = 6.50 \times 10^{-5}$, $K_a (HF) = 3.50 \times 10^{-4}$
Explain if the products or the reactants will be favoured at equilibrium.

19. Which statements is true about solutions with pH of 2.0 and 4.0.
a) The $[H^+]$ when pH = 2.0 is the 100 times that when pH = 4.0.
b) The $[H^+]$ when pH = 4.0 is the 100 times that when pH = 2.0.
c) The $[H^+]$ when pH = 4.0 is the twice that when pH = 2.0.
d) The $[H^+]$ when pH = 2.0 is the twice that when pH = 4.0.

19. An aqueous solution of a weak monoprotic acid ($K_a = 1.0 * 10^{-5}$) exhibits a pH = 3. What is the concentration of the acid.
(a) 0.1M (b) 0.01M (c) 0.001M (d) $1 * 10^{-6}$M

20. Which one of the following species can function both as an acid and a base under the Bronsted-Lowry definition:
a) HS^- b) S^{2-} c) NH_4^+ d) Al^{3+}

21. The pK_a values of ethanoic acid CH_3COOH and trichloroethanoic acid, $CH_2ClCOOH$, are 5.0 and 1.0 respectively. What is the value of the ratio of the dissociation constants (trichloroethanoic acid / ethanoic acid)
a) 0.2 b) 5 c) 5000 d) 10000

22. Explain how an indicator works.

ANSWERS - ACID BASE REVIEW

1	a. Zn 2+ b. BF3 c. Ag 1+
2	a) B + A --> CA + CB b) B + A --> CA + CB c) A + B --> CB + CA d) A + B ÷ CA + CB
3	5.0×10^8
4	3.03×10^{-11}
5	4.77
6	can't do this common ion question because not given Ka Assuming Ka= 4.5×10^{-4}
7	a) Shift right (H^+bonds with OH- to form H2O, reducing product, and favouring forward) b) Shift left (increasing product OH-, favours reverse) c) Shift right (Na+ bonds with OH- to form NaOH, reducing product and favouring forward) *More Na+ ions in solution, shift left to form NaNO2. HNO2 +NaOH forms NaNO2 + H2O*
8	a. 11 b. 11.6 c. 5.0 d. 11.3

9	(i) Basic (ii) Basic (iii) Neutral (iv) Acidic (v) Basic
10	(a) pH = 8.97 (b) 7.19
11	5.56
12	6.49 < pH < 8.49
13	A CH_3COOH/CH_3COONa^-
14	a) -28.17 J, -25.8 J b) CH_2COOH ÄGº = -25.8J c) ? Hº885 d) the O-H bond must be weakened and the electronegativity of the halogen aids to lengthen and weaken the bond
15	pH = 2.41
16	*Number of mols of both reactants given: treat as LR/XS question*
17	CCl3COOH > CH2ClOOH > CH3COOH (Cl is electronegative, withdraws e density, weakens OH bond, dissociates easily, stronger acid)
18	Reactants (HF is more likely to be dissociated (larger Ka) than the Ka of C6H5COOH)
19	a
19	0.1 M
20	HS-
21	d

QUIZ: ACID - BASE

1) Which of HNO_3 or HNO_2 is a stronger acid. Explain.

2) Why is HOBr as weaker acid than HOCl?

3) Which is the stronger base: F^- or Cl^-? How do you know?

4) Calculate the pH of an aqueous solution of 0.55 mol dm^{-3} formic acid HCOOH and 0.63mol dm^{-3} sodium formate HCOONa. THe pK_a for formic acid is 3.14.

5) At normal body temperature 37 °C, K_w has a the value $2.38 * 10^{-14}$. Calculate the pH of a neutral aqeous solution in the body.
(Answer: pH = 6.81)

6) The $[OH^-]$ in a 0.0250 solution of HI at 25°C is:
   a) $2.5 * 10^{-12}$ M
   b) $4.00 * 10^{-12}$ M
   c) $2.50 * 10^{-2}$ M
   d) $1.60 * 10^{-2}$M

7) The pH of an aquous solution is 3.52. The $[H^+]$ is:
   a) $5.2 * 10^{-3}$
   b) $3.0 * 10^{3}$
   c) $4.7 * 10^{-4}$
   d) $3.0 * 10^{-4}$

8) The acid ionization constant K_a for HSO_3^- = $6.2 * 10^{-8}$. The base ionization constant, K_b for SO_3^{2-} is:
   a) $1.7 * 10^{-2}$
   b) $2.50 * 10^{-4}$
   c) $3.12 * 10^{-8}$
   d) $1.60 * 10^{-7}$

9) Formic acid HCOOH, a monoprotic acid was formerly obtained by distillation of red ants. At 25°C, K_a for HCOOH = $1.7 * 10^{-4}$. For a 2.32 solution HCOOH, calculate:
   a) pH of solution
   b) % Ionization of the solution.

10) Calculate the $[H^{+1}]$ of a 0.10 $moldm^{-3}$ solution of a weak base pyridinium chloride, $C_5H_5NHCl^-$. The K_b for pyridine (C_5H_5N) = $3.12 * 10^{-6}$.

ANSWERS : QUIZ: ACID - BASE

1	HNO3 is a stronger acid since each additional oxygen withdraws an electron density from the O--H bond, lengthening it and making it weaker, hence allowing the H^+ to dissociate.
2	Cl is more electronegative than Br, meaning that it will have a greater ability to withdraw electron density from the OH bond, which makes it weaker and thus making HOCl a stronger acid.
3	F- is a stronger base since it is the strong conj. base of HF, a weak acid. Cl- is a weak base since it is the weak conj. base of HCl, a strong acid.
4	pH = 3.20
5	$6.81 = [H_3O]^+ = \sqrt{K_w} = \sqrt{2.38 * 10^{-14}}$

6	b) 4.0×10^{-13}
7	d) $[H^+] = 3 \times 10^{-4}$
8	d) $Kb = 1.61 \times 10^{-7}$
9	a) pH = 1.70 b) %Ionization = 0.86%
10	1.79×10^{-11} M

REVIEW QUESTIONS: ACID – BASE TEST

1) Write the conjugate acid base pair for the following

a) $Fe(H_2O)_6^{3+} + H_2O \rightleftharpoons [Fe(H_2O)_5(OH)]^{2+} + H_3O^+$

b) $Ti(H_2O)_4^{4+} + H_2O \rightleftharpoons [Ti(H_2O)_3(OH)]^{3+} + H_3O^+$

c) $C_2H_5NH_2 + H_2O \rightleftharpoons C_2H_5NH_3^+ + OH^-$

2) Place the following in increasing acid strength:

a) $HBrO$, $HBrO_2$, $HBrO_3$

b) $HClO_2$, $HBrO_2$, HIO_2

c) H_3AsO_3, H_3AsO_4

3) What are the hydronium ion and hydroxide ion concentrations in a 0.050 $moldm^{-3}$ aqueous solution if hydrogen chloride.

4) a) What will be the pH of an aqueous solution containing 0.040 $moldm^{-3}$ NaOH?

b) 0.10 mol dm^{-3} solution of barium hydroxide.

c) 0.033 mol dm^{-3} solution of calcium hydroxide, $Ca(OH)_2$

5) What is the hydronium ion concentration of a solution with a pH of 2.50.

6) If the hydronium ion concentration $[H_3O^+] = 1.44*10^{-3}$ mol dm^{-3}, what is the pOH?

7) If the pOH = 7.41 what is the $[H_3O^+]$?

8) If the pH = 0.34, what is the $[OH^-]$?

9) If the pOH = 5.52, what is the $[H^+]$?

10) Acetylsalicylic acid, (asprin), is a weak monoprotic acid which can be abbreviated as Hasp. A 0.10 mol dm^{-3} solution of the acid has a pH of 2.24 . Calculate the acid ionization concentration constant, K_a for acetylsalicylic acid.

11) Ascorbic acid, (Vitamin C), is a weak monoprotic acid which can be a abbreviated as HAsc. It has an ionization constant of $8.0 * 10^{-3}$, calculate the pH of a 0.100 mol dm^{-3} solution.

12) A new drug obtained from seeds of a strange Colombian plant was found to be a weak organic base. A 0.100 mol dm^{-3} solution in H_2O of this drug has a pH of 10.8. What is the K_b of the drug?

13) Caffeine is a weak base that is related to NH_3. For the purposes of this example we can abbreviate its formula to CafN. It has a base ionization constant of $4.4*10^{-4}$. Calculate the pH of a 0.70 mol dm^{-3} solution.

14) What is the pH of 0.22 moldm^{-3} solution of formic, HCOOH, which has a $pK_a = 3.42$.

15) What is the pH of a weak base, diethyl amine $(C_2H_5)_2NH$, 0.226 mol dm^{-3} solution has a $pK_a = 2.62$.

16) A 0.32 mol dm^{-3} solution of chlorous acid, $HClO_2$ has a K_a of $1.22*10^{-4}$. What is the percent ionization of $HClO_2$.

17) When 0.0250 mol $NaNO_{2(s)}$ is added to :

a) 500 cm^3 solution of 0.100 mol dm^{-3} HNO_2, what is the resulting pH?

$$HNO_2 + H_2O \rightleftharpoons H_3O^+ + NO_2^- \qquad K_a = 5.15 * 10^{-4}$$

$$NaNO_2 \rightleftharpoons Na^+ + NO_2^-$$

18) What is the:

a) pH a 1.0 mol dm^{-3} solution.

b) pH in NH_3 and 0.10 mol dm^{-3} in NH_4NO_3

$K_b(NH_3) = 1.8 * 10^{-5}$

19) What is the pH of a solution, what is the % ionization of 0.10 moldm^{-3} HF in

a) H_2O

b) In the presences of 1.0 mol dm^{-3} aqueous solution of NaF. ($K_a(HF) = 7.22 * 10^{-2}$)

20) Calculate the [OH^-], pH, % ionization of a solution of 0.10 moldm^{-3} NH_3 $K_b=1.8*10^{-5}$.

21) Calculate the hydrogen ion concentration, and the pH of a 0.220 mol dm^{-3} solution of vitamin C, (ascorbic acid), with a K_a = 7.95 x 10^{-5} at 25 ^{O}C.

22) A solution of hydrofluoric acid contains 2.00 g of HF per dm^3 and has a pH of 2.22. What is the acid ionization constant for HF?

23) The formation of products is strongly favoured in this acid-base system:

$$HX + Y^{-1} \rightleftharpoons HY + X^{-1}$$

a) Identify the bases competing for protons.

b) Which base is stronger?

c) Which is the weaker acid HX or HY?

d) Does the K_a for this system have a large or small value?

e) How is the equilibrium affected by the addition of the soluble salt NaY?

ANSWERS - REVIEW QUESTIONS: ACID – BASE TEST

1a	Acid: $Fe(H_2O)_6^{3+}$ Conjugate Base: $[Fe(H_2O)_5(OH)]^{2+}$ Base: H_2O Conjugate Acid: H_3O^+
1b	Acid: $Ti(H_2O)_4^{4+}$ Conjugate Base: $[Ti(H_2O)^3(OH)]^{3+}$ Base: H_2O Conjugate Acid: H_3O^+
1c	Acid: H_2O Conjugate Base: OH^- Base: $C_2H_5NH_2$ Conjugate Acid: $C_2H_5NH_3^+$
2a	HBrO, HBrO2, HBrO3
2b	HIO_2, $HBrO_2$, $HClO_2$
2c	H3AsO3, H3AsO4
3	[H3O+] = 0.050M, [OH-] = 2.00 *10^{-13} M
4a	pH = 12.6
4b	pH = 13.3
4c	pH = 12.82
5	[H3O+] = 3.16 * 10^{-3} M

6	pOH = 11.16
7	$[H_3O^+] = 2.57 * 10^{-7}$ M
8	$[OH^-] = 2.19 * 10^{-14}$ M
9	$[H_3O^+] = 3.31x10^{-9}$M
10	$K_a = 3.31x10^{-4}$
11	pH = 1.55
12	$K_b = 3.98 \times 10^{-6}$
13	pOH = 12.24
14	pH = 2.04
15	pH = 1.63
16	% Ionization is 1.95 %
17	pH = 2.99
18	1.0 M NH_3/ 0.10M NH_4NO_3
19a	*Ka (HF) is 7.22 x 10^{-4}* pH= 2.07, % Ionization = 8.50
19b	pH= 4.14, 0.072% Ionization
20	$[OH^-]$ $1.34x10^{-3}$ M, pH = 11.1, % Ionization =1.34%
21	$[H_3O^+] = 4.18 * 10^{-3}$ M, pH = 2.38
22	$K_a = 3.63 * 10^{-4}$
23a	Bases: Y- and X-
23b	Stronger base : Y-
23c	Weaker acid: HY
23d	Ka smaller value since Reaction represents equilibrium reaction
23e	Adding soluble salt NaY affects the equilibrium as follows: NaY will dissociate because it is an ionic salt. Increase of$[Y^-]$ ions (reactant) dissociated in solution from NaY. By LeChatelier's principle, greater concentration of reactants (in this case $[Y^-]$) will cause the equilibrium to shift right and more products will be formed.

TEST: ACID BASE

1) Lactic acid (2-hydroxypropanoic acid), $C_6H_{12}O_3$, is a weak monoprotic acid. It is found in sour milk and in the blood after vigorous exercise.

a) Write the equilibrium expression for the dissociation of this acid and calculate the $[H_3O^+]$ for 0.12 mol dm^{-3} solution of lactic acid. (Ka (lactic acid =)

b) Find the %ionization of a 0.12 mol dm^{-3} solution of lactic acid.

c) Koumiss, a fermented beverage made from mare's milk contains 12.2 g of lactic acid in 25 cm^3 of water. Calculate the volume of 0.15 mol dm^{-3} NaOH that would be needed to neutralise the lactic acid.

2) a) The value of the pK of propanoic acid, C_2H_5COOH, is 4.87. What is the value of K_a?

b) Calculate the pH of a 0.240 moldm^{-3} aqueous solution of propanoic acid.

c) 9.60g of C_2H_5COONa is dissolved in 150 cm^3 of 0.24 moldm^{-3} propanoic acid. What will be the resulting pH of the solution. State any approximation you have made in obtaining the answer.

[Note: M_R (C_2H_5COONa) = 96 g mol^{-1}, .: n = 0.100 mol, .: c = n/V = 0.10/0.15 = 0.667 mol dm^{-3}]

d) Explain how the solution in (c) can act as a buffer solution if small amounts of acid or alkali are added.

3) A 0.10 mol dm^{-3} solution of which of the following acids will have the greater $[H^+]$?

a) HNO_2 $K_a = 1.3 * 10^{-4}$ b) H_2SO_3 $K_a = 1.3 * 10^{-2}$

c) H_3PO_4 $K_a = 7.7 * 10^{-3}$ d) H_2SiO_3 $K_a = 1.7 * 10^{-10}$

4) Only one of the following substances CANNOT function as a Lewis acid or Lewis base. Identify that substance on the basis of its structure.

a) NH_4^+ b) NH_2^- c) NH_3 d) BF_3 e) OH^-

5) A student determined the concentration of a solution of hydrochloric acid by an acid-base titration. When a 45.0 cm^3 sample of the acid was titrated to a phenolphthalein endpoint,

36.0 cm^3 of 0.15 mol dm^{-3} KOH was required. What was the molarity of the HCl solution?

a) 0.30 b) 0.24 c) 0.12 d) 0.06

6) A solution is prepared by adding 0.25 mol of CH_3COOH of solution. The pH of this solution is 2.67 and the % ionization 0.848 %. What will happen to the pH and the % ionization of this solution as it is diluted with H_2O to a volume of 2.0 dm^3.

a) The pH will increase, the % ionization it increase.

b) The pH will decrease, the % ionization it increase.

c) The pH will increase, the % ionization it decrease.

d) The pH will decrease, the % ionization it decrease.

7) Which of the following solutes at a concentration of 0.1M will produce an acidic solution?

I) NH_4Cl II) CH_3COONa III) $Fe_2(SO_4)_3$

A. I only B. II only C. I and II only D. I, II and III