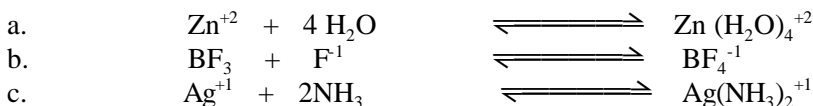
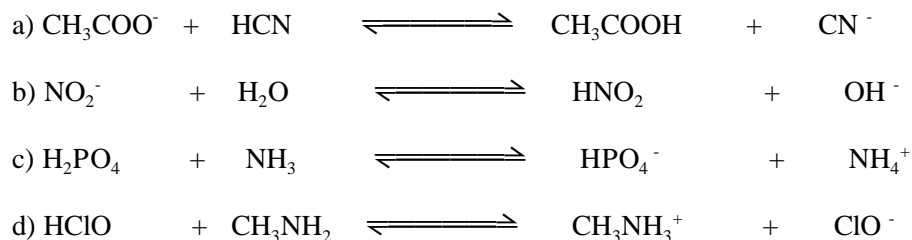


ACID BASE REVIEW

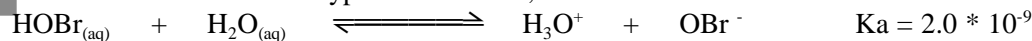
1. Identify Lewis Acid, in the following reactions:



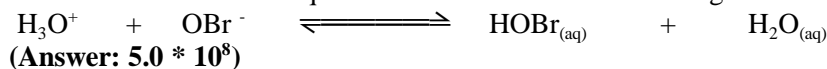
2. Identify the acid – base conjugate pairs in each of the following reactions according with the Bronsted – Lowry framework:



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

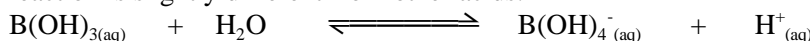


What is the value of the equilibrium constant for the following reaction?



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:



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

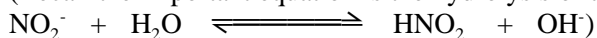
6. What is the pH of a solution that is $0.10 \text{ mol dm}^{-3} \text{ KNO}_2$ and $0.15 \text{ mol dm}^{-3} \text{ HNO}_2$ (nitrous acid)?

7. Use Le Chatelier'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^- .)



8. Calculate:

- a) pH of a $0.2 \text{ mol dm}^{-3} \text{ NaHSO}_3$ (K_a for $\text{HSO}_3^- = 6.2 * 10^{-8}$).
 b) pH of a 0.2 mol dm^{-3} phenoxide ion, $\text{C}_6\text{H}_5\text{O}^-$, a weak base ($K_b = 7.7 * 10^{-5}$)
 c) pH of a $0.2 \text{ mol dm}^{-3} \text{ NH}_4\text{Cl}$? (K_b (NH_3) = $1.8 * 10^{-5}$)
 d) pH of a $0.2 \text{ mol dm}^{-3} \text{ KCN}$ (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 ($\text{C}_6\text{H}_5\text{COOH}$) acid 0.15 mol dm^{-3} sodium benzoate ($\text{C}_6\text{H}_5\text{COONa}$) given ($K_a = 6.5 \times 10^{-10}$).
 b) 500 cm^3 of 0.10 mol dm^{-3} NaOCl and 500 cm^3 of 0.20 mol dm^{-3} HOCl , what is the pH of the solution? ($K_a (\text{HOCl}) = 3.2 \times 10^{-8}$)
(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 ($K_a (\text{CH}_3\text{COOH}) = 1.8 \times 10^{-5}$)
(Answer = 5.50)

12. Over what range of pH is a $\text{HOCl} - \text{NaOCl}$ buffer effective?
 ($K_a (\text{HOCl}) = 3.2 \times 10^{-8}$)
(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) $\text{CH}_3\text{COOH} / \text{CH}_3\text{COONa}$ | $K_a = 1.8 \times 10^{-5}$ |
| b) $\text{NH}_3 / \text{NH}_4\text{Cl}$ | $K_a = 5.6 \times 10^{-10}$ |
| c) $\text{NaOCl} / \text{HOCl}$ | $K_a = 3.2 \times 10^{-8}$ |
| d) $\text{NaNO}_2 / \text{HNO}_2$ | $K_a = 4.5 \times 10^{-4}$ |

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

Acid	$\Delta H^\circ (\text{mol dm}^{-3})$	$T \Delta S^\circ (\text{mol dm}^{-3})$
CH_3COOH	- 0.57	27.6
CH_2ClCOOH	- 4.7	21.1

- a) Calculate ΔG° 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:
 $\Delta G^\circ = -RT \ln K$
 c) Which is the dominant term (ΔH° or $T \Delta S^\circ$) in determining the value of ΔG° , (and hence K_a) of the acid?
 d) What processes contribute to the ΔH° 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 mol dm^{-3} nitrous acid, HNO_2 , was titrated with of 0.10 mol dm^{-3} KOH solution. After 25.0 cm^3 KOH solution, what will be the pH in the titration flask?
 ($K_a = 4.50 \times 10^{-4}$)
(Answer: 2.41)

16. Calculate the pH at the equivalence point for the titration of 20.0 cm^3 of 0.20 mol dm^{-3} HCl with 30.0 cm^3 of 0.20 mol dm^{-3} NH_3 ($K_b = 1.82 \times 10^{-5}$)
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: $\text{C}_6\text{H}_5\text{COOH} + \text{F}^- \rightleftharpoons \text{C}_6\text{H}_5\text{COO}^- + \text{HF}$
 $K_a(\text{C}_6\text{H}_5\text{COOH}) = 6.50 \times 10^{-5}$, $K_a(\text{HF}) = 3.50 \times 10^{-4}$
 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 $[\text{H}^+]$ when pH = 2.0 is the 100 times that when pH = 4.0.
 b) The $[\text{H}^+]$ when pH = 4.0 is the 100 times that when pH = 2.0.
 c) The $[\text{H}^+]$ when pH = 4.0 is the twice that when pH = 2.0.
 d) The $[\text{H}^+]$ when pH = 2.0 is the twice that when pH = 4.0.
19. An aqueous solution of a weak monoprotic acid ($K_a = 1.0 \times 10^{-5}$) exhibits a pH = 3. What is the concentration of the acid.
 (a) 0.1M (b) 0.01M (c) 0.001M (d) $1 \times 10^{-6}\text{M}$
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 $\text{p}K_a$ 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. BF_3 c. Ag^+
2	a) $\text{B} + \text{A} \rightarrow \text{CA} + \text{CB}$ b) $\text{B} + \text{A} \rightarrow \text{CA} + \text{CB}$ c) $\text{A} + \text{B} \rightarrow \text{CB} + \text{CA}$ d) $\text{A} + \text{B} \rightarrow \text{CA} + \text{CB}$
3	5.0×10^8
4	3.03×10^{-11}
5	4.77
6	can't do this common ion question because not given K_a Assuming $K_a = 4.5 \times 10^{-4}$
7	a) Shift right (H^+ bonds with OH^- to form H_2O , 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) <i>More Na^+ ions in solution, shift left to form NaNO_2. $\text{HNO}_2 + \text{NaOH}$ forms $\text{NaNO}_2 + \text{H}_2\text{O}$</i>
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	$6.49 < \text{pH} < 8.49$
13	A $\text{CH}_3\text{COOH}/\text{CH}_3\text{COONa}^-$
14	a) -28.17 J, -25.8 J b) $\text{CH}_2\text{COOH } \Delta G^\circ = -25.8\text{J}$ c) ? H ⁺ 885 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	<i>Number of mols of both reactants given: treat as LR/XS question</i>
17	$\text{CCl}_3\text{COOH} > \text{CH}_2\text{ClOOH} > \text{CH}_3\text{COOH}$ (Cl is electronegative, withdraws e density, weakens OH bond, dissociates easily, stronger acid)
18	Reactants (HF is more likely to be dissociated (larger K_a) than the K_a of $\text{C}_6\text{H}_5\text{COOH}$)
19	a
19	0.1 M
20	HS^-
21	d

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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 0.63 mol dm^{-3} sodium formate HCOONa . The $\text{p}K_a$ 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 aqueous solution in the body.
(Answer: $\text{pH} = 6.81$)
- 6) The $[\text{OH}^-]$ in a 0.0250 M solution of HI at 25°C is:
 - a) $2.5 \times 10^{-12} \text{ M}$
 - b) $4.00 \times 10^{-12} \text{ M}$
 - c) $2.50 \times 10^{-2} \text{ M}$
 - d) $1.60 \times 10^{-2} \text{ M}$
- 7) The pH of an aqueous solution is 3.52. The $[\text{H}^+]$ 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 $\text{HSO}_3^- = 6.2 \times 10^{-8}$. 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 $\text{HCOOH} = 1.7 \times 10^{-4}$. For a 2.32 M solution HCOOH , calculate:
 - a) pH of solution
 - b) % Ionization of the solution.
- 10) Calculate the $[\text{H}^+]$ of a 0.10 mol dm^{-3} solution of a weak base pyridinium chloride, $\text{C}_5\text{H}_5\text{NHCl}$. The K_b for pyridine ($\text{C}_5\text{H}_5\text{N}$) = 3.12×10^{-6} .

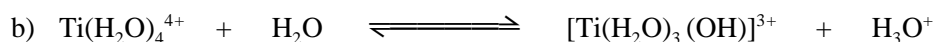
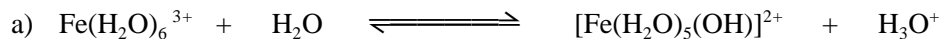
ANSWERS : QUIZ: ACID - BASE

- | | |
|---|--|
| 1 | HNO_3 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 | $\text{pH} = 3.20$ |
| 5 | $6.81 = [\text{H}_3\text{O}]^+ = \sqrt{K_w} = \sqrt{2.38 \times 10^{-14}}$ |

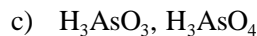
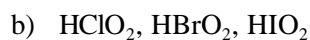
6	b) 4.0×10^{-13}
7	d) $[H^+] = 3 \times 10^{-4}$
8	d) $K_b = 1.61 \times 10^{-7}$
9	a) $pH = 1.70$ b) % Ionization = 0.86%
10	$1.79 \times 10^{-11} M$

REVIEW QUESTIONS: ACID – BASE TEST

1) Write the conjugate acid base pair for the following



2) Place the following in increasing acid strength:



3) What are the hydronium ion and hydroxide ion concentrations in a $0.050 \text{ mol dm}^{-3}$ aqueous solution of hydrogen chloride.

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

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

c) $0.033 \text{ mol dm}^{-3}$ 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 $[H_3O^+] = 1.44 \times 10^{-3} \text{ mol dm}^{-3}$, 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 $\text{pOH} = 5.52$, what is the $[\text{H}^+]$?

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 abbreviated as HAsc . It has an ionization constant of 8.0×10^{-3} , calculate the pH of a $0.100 \text{ mol dm}^{-3}$ solution.

12) A new drug obtained from seeds of a strange Colombian plant was found to be a weak organic base. A $0.100 \text{ mol dm}^{-3}$ 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.

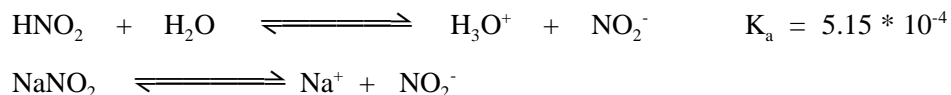
14) What is the pH of 0.22 mol dm^{-3} solution of formic, HCOOH , which has a $\text{p}K_a = 3.42$.

15) What is the pH of a weak base, diethyl amine $(\text{C}_2\text{H}_5)_2\text{NH}$, $0.226 \text{ mol dm}^{-3}$ solution has a $\text{p}K_a = 2.62$.

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 $0.0250 \text{ mol NaNO}_2(\text{s})$ is added to :

a) 500 cm^3 solution of $0.100 \text{ mol dm}^{-3} \text{ HNO}_2$, what is the resulting pH ?



18) What is the:

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

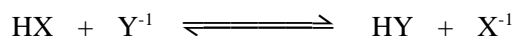
b) pH in NH_3 and 0.10 mol dm^{-3} in NH_4NO_3

$$K_b(\text{NH}_3) = 1.8 \times 10^{-5}$$

- 19) What is the pH of a solution, what is the % ionization of 0.10 mol dm^{-3} HF in
- H_2O
 - In the presence of 1.0 mol dm^{-3} aqueous solution of NaF. ($K_a(\text{HF}) = 7.22 \times 10^{-2}$)
- 20) Calculate the $[\text{OH}^-]$, pH, % ionization of a solution of 0.10 mol dm^{-3} NH_3 $K_b = 1.8 \times 10^{-5}$.
- 21) Calculate the hydrogen ion concentration, and the pH of a $0.220 \text{ mol dm}^{-3}$ solution of vitamin C, (ascorbic acid), with a $K_a = 7.95 \times 10^{-5}$ at 25°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:



- Identify the bases competing for protons.
- Which base is stronger?
- Which is the weaker acid HX or HY?
- Does the K_a for this system have a large or small value?
- How is the equilibrium affected by the addition of the soluble salt NaY?

ANSWERS - REVIEW QUESTIONS: ACID – BASE TEST

1a	Acid: $\text{Fe}(\text{H}_2\text{O})_6^{3+}$	Conjugate Base: $[\text{Fe}(\text{H}_2\text{O})_5(\text{OH})]^{2+}$
	Base: H_2O	Conjugate Acid: H_3O^+
1b	Acid: $\text{Ti}(\text{H}_2\text{O})_4^{4+}$	Conjugate Base: $[\text{Ti}(\text{H}_2\text{O})_3(\text{OH})]^{3+}$
	Base: H_2O	Conjugate Acid: H_3O^+
1c	Acid: H_2O	Conjugate Base: OH^-
	Base: $\text{C}_2\text{H}_5\text{NH}_2$	Conjugate Acid: $\text{C}_2\text{H}_5\text{NH}_3^+$
2a	HBrO , HBrO_2 , HBrO_3	
2b	HIO_2 , HBrO_2 , HClO_2	
2c	H_3AsO_3 , H_3AsO_4	
3	$[\text{H}_3\text{O}^+] = 0.050\text{M}$, $[\text{OH}^-] = 2.00 \times 10^{-13} \text{ M}$	
4a	pH = 12.6	
4b	pH = 13.3	
4c	pH = 12.82	
5	$[\text{H}_3\text{O}^+] = 3.16 \times 10^{-3} \text{ M}$	

6	$pOH = 11.16$
7	$[H_3O^+] = 2.57 \times 10^{-7} M$
8	$[OH^-] = 2.19 \times 10^{-14} M$
9	$[H_3O^+] = 3.31 \times 10^{-9} M$
10	$K_a = 3.31 \times 10^{-4}$
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	$K_a (HF)$ is 7.22×10^{-4}
	$pH = 2.07$, % Ionization = 8.50
19b	$pH = 4.14$, 0.072% Ionization
20	$[OH^-] 1.34 \times 10^{-3} M$, $pH = 11.1$, % Ionization = 1.34%
21	$[H_3O^+] = 4.18 \times 10^{-3} M$, $pH = 2.38$
22	$K_a = 3.63 \times 10^{-4}$
23a	Bases: Y- and X-
23b	Stronger base : Y-
23c	Weaker acid: HY
23d	K_a 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.

- 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. (K_a (lactic acid =)
- Find the %ionization of a 0.12 mol dm^{-3} solution of lactic acid.
- 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 $0.240 \text{ mol dm}^{-3}$ aqueous solution of propanoic acid.

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

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

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 $K_a = 1.3 \times 10^{-4}$

b) H_2SO_3 $K_a = 1.3 \times 10^{-2}$

c) H_3PO_4 $K_a = 7.7 \times 10^{-3}$

d) H_2SiO_3 $K_a = 1.7 \times 10^{-10}$

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

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