Acid Base Chapter 14
AP Chemistry

Name : Key
Period : ________ Date: ________

Multiple Choice

C 1. At 25°C, aqueous solutions with a pH of 8 have a hydroxide ion concentration, $[OH^-]$, of...

(A) 1.0×10^{-14} M
(B) 1.0×10^{-8} M
(C) 1.0×10^{-6} M
(D) 8.0 M

pOH = 14 - 8 = 6
$[OH^-] = 10^{-6}$

D 2.

acid base conj. acid conj. base
$HSO_4^- + H_2O \rightleftarrows H_3O^+ + SO_4^{2-}$

In the equilibrium represented above, the species that act as bases include which of the following?

I. HSO_4^- II. H_2O III. SO_4^{2-}

(A) II only (B) III only (C) I and III (D) II and III

A 3. What is the pH of a 1.0 M aqueous solution of NaCl?

(A) 7.0
(B) greater than 7.0
(C) less than 7.0
(D) not enough information

neutral salt

C 4. What is the pH of a 1.0×10^{-2}-molar solution of HCN? ($K_a = 4.0 \times 10^{-10}$)

(A) 10 (B) Between 7 and 10 (C) Between 4 and 7 (D) 4

	HCN +	H_2O ⇌	H_3O^+ +	CN^-
I	0.010		0	0
C	-x		x	x
E	0.010-x		x	x

$4.0 \times 10^{-10} = \frac{(x)(x)}{(0.010-x)}$

$x = 2.0 \times 10^{-6} = H^+$

$pH = -\log(2.0 \times 10^{-6})$
$= 5.70$

B 5. Among the properties of strong acids, they are those which:

(A) have an equilibrium lying far to the left. False
(B) yield a negligibly weak conjugate base when reacting with water.
(C) have a conjugate base which is a stronger base than water. False
(D) are only slightly dissociated (ionized) at equilibrium. False

C 6. What is the $[H^+]$ in a solution which shows a pH of 2.30?

(A) 2.3M
(B) 11.7M
(C) 5.0×10^{-3}M
(D) 2.0×10^{-12}M

$[H^+] = 10^{-2.30}$
$= 5.0 \times 10^{-3}$

C 7. If Ka for HCN is 6.2×10^{-10}, what is Kb for CN^-?

(A) 6.2×10^{-24}
(B) 6.2×10^{4}
(C) 1.6×10^{-5}
(D) 1.6×10^{-23}

$K_b = \frac{K_w}{K_a} = \frac{1.0 \times 10^{-14}}{6.2 \times 10^{-10}} = 1.61 \times 10^{-5}$

C 8. Which of the following substances can be dissolved in water to give a basic solution?

(A) NH_4Cl $NH_4^+ + H_2O \rightleftharpoons H_3O^+ + NH_3$ (acidic)
(B) NaBr neutral
(C) KF $F^- + H_2O \rightleftharpoons HF + OH^-$ (basic)
(D) KNO_3 neutral

Salt with conj. base of weak acid will yield OH^- in solution since the conj base (A^-) will strip H+ from water.

A 9. The following acids are listed in order of decreasing acid strength in water.

HI > HNO_2 > CH_3COOH > HClO > HCN

According to Bronsted-Lowry theory, which of the following ions is the weakest base?

(A) I^-
(B) NO_2^-
(C) ClO^-
(D) CN^-

most likely to give H+ ∴ weakest conj. base

least likely to give H+ ∴ strongest conj. base

A 10. In a solution prepared by dissolving 0.10 mole of an acid HX in enough water to make 1.00 L of solution, the pH is observed to 1.35. What is the Ka for this acid?

(A) 2.0×10^{-2}
(B) 3.6×10^{-2}
(C) 4.5×10^{-2}
(D) 5.0×10^{-12}

$HX + H_2O \rightleftharpoons H_3O^+ + X^-$

$[H+] = 10^{-1.35} = 0.0447\ M$

$K_a = \frac{[H_3O^+][X^-]}{[HX]} = \frac{(0.0447)(0.0447)}{0.10\ M} = 0.01995$

C 11. Given

HCN (aq) + HCO_3^- (aq) <-----> CN^- (aq) + H_2CO_3 (aq)

acid base conj base conj. acid

If K< 1, what is the strongest base in this system?

(A) HCN
(B) HCO_3^-
(C) CN^-
(D) H_2CO_3

Response:
1. Lactic

~~ee Response:

1. Lactic acid ($HC_3H_5O_3$) forms within human muscles through extended exercise until its concentration reaches 0.0011M. The Ka for lactic acid = 1.4 x 10^{-4}.
   a. Write the dissociation equation for lactic acid in water.

   $$HC_3H_5O_{3(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + C_3H_5O_3^-{}_{(aq)}$$

   b. Write the equilibrium expression for lactic acid.

   $$K_a = \frac{[H_3O^+][C_3H_5O_3^-]}{[HC_3H_5O_3]}$$

   c. Determine the pH of the lactic acid in blood and its percent dissociation.

   $$HC_3H_5O_3 + H_2O \rightleftharpoons H_3O^+ + C_3H_5O_3^-$$

	$HC_3H_5O_3$	H_3O^+	$C_3H_5O_3^-$
I	0.0011	0	0
C	−x	+x	+x
E	0.0011 − x	x	x

not negligible

$1.4\times10^{-4} = \frac{(x)(x)}{(0.0011-x)}$

$1.54\times10^{-7} - 1.4\times10^{-4}x = x^2$

$x^2 + 1.4\times10^{-4}x - 1.54\times10^{-7}$

$x = 3.29\times10^{-4}$

$x = [H^+]$ $\quad -\log(3.29\times10^{-4})$ $\quad \boxed{pH = 3.48}$

$\% = \frac{3.29\times10^{-4}}{0.0011}\times100$ $\boxed{= 29.9\%}$

2. KCN is highly toxic; however, it is commonly used in gold mining as a means of extracting gold from a mixture in the presence of oxygen. A lethal dose for KCN, in terms of exposure, is 250 mg. (HCN has a Ka of 5.8 x 10^{-10}) $\quad K_b = \frac{K_w}{K_a} = \frac{1.0\times10^{-14}}{5.8\times10^{-10}} = 1.72\times10^{-5}$
   a. A KCN solution has a pH of 10.82. Determine the initial concentration of the solution.

Salt hydrolysis

$$CN^- + H_2O \xrightarrow{K_b} HCN + OH^-$$

$K_b = \frac{[HCN][OH^-]}{[CN^-]}$ $\quad [CN^-] = \frac{(6.61\times10^{-4})^2}{1.72\times10^{-5}}$ $\quad [KCN]\ \boxed{= 0.0254M}$

$pOH = 14 - 10.82$
$= 3.18$
$[OH^-] = 10^{-3.18}$
$= 6.61\times10^{-4}M$

   b. If the solution from part (a) has a volume of 850 mL, is the mass of KCN dissolved considered a lethal dose? Justify through calculations.

$0.850\cancel{L} \times \frac{0.0254\ \cancel{mol}}{\cancel{L}} \times \frac{65.2g}{1\cancel{mol}} = 1.41g$ yes!

$1.41g \gg 250mg$

3. A caustic mixture is obtained from an industrial waste runoff. The mixture contains two alkaline, 0.00750 M calcium hydroxide and 0.330 M $C_2H_5NH_2$ ($K_b = 5.6 \times 10^{-4}$).

a. Determine the $[OH^-]$ derived from calcium hydroxide.

$$\frac{0.00750 \text{ mol } Ca(OH)_2}{L} \times \frac{2\,OH^-}{1 \text{ mol } Ca(OH)_2} = 0.0150\,M\ OH^-$$

b. Determine the $[C_2H_5NH_3^{1+}]$ at equilibrium.

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

	$C_2H_5NH_2$		$C_2H_5NH_3^+$	OH^-
I	0.330		0	0.0150
C	$-x$		$+x$	$+x$
E	$0.330-x$		x	$0.0150+x$

$$5.6\times10^{-4} = \frac{(x)(0.0150)}{(0.330)}$$

$x = 0.0123$

$\boxed{[C_2H_5NH_3^+] = 0.0123\,M}$

c. Determine the $[OH^-]$ at equilibrium.

$$[OH^-] = (0.0150 + 0.0123)\,M$$
$$\boxed{= 0.0273\,M}$$

d. Determine the $[H^{1+}]$ at equilibrium.

$$[H^+] = \frac{1.0\times10^{-14}}{0.0273} = 3.66\times10^{-13}$$

e. Determine the pH of the mixture at equilibrium.

$$pH = -\log(3.66\times10^{-13})$$
$$\boxed{= 12.44}$$

Acid Base

AP Chemistry ~ Multiple Choice

Name Key

Period ______ Date ______

B 1. The value of the acid-dissociation, K_a, for a weak monoprotic acid HA is 2.5×10^{-6}. The pH of 0.40 M HA is closest to:

A) 2.0 B) 3.0 C) 4.0 D) 6.0

$\sqrt{10^{-6}} = 0.001$

B 2. In an aqueous solution with a pH of 11.50 at 25°C, the molar concentration of $OH^-_{(aq)}$ is approximately:

A) 3.2×10^{-12} M
B) 3.2×10^{-3} M
C) 2.5×10^{-1} M
D) ~~2.5 M~~

$[H^+] = 10^{-11.50} = 3.16 \times 10^{-12}$

$[OH^-] = \frac{1.0 \times 10^{-14}}{3.16 \times 10^{-12}} = 0.0032 M$

D 3.

$$\underset{B}{F^-_{(aq)}} + \underset{A}{H_2O_{(l)}} \leftrightarrow \underset{CA}{HF_{(aq)}} + \underset{B}{OH^-_{(aq)}}$$

Which of the following species, if any, acts as a Bronsted-Lowry base in the reversible reaction represented above?

A) $HF_{(aq)}$ B) $H_2O_{(l)}$ C) $F^-_{(aq)}$ only D) Both F^- and OH^-.

B 4. Commercial vinegar was titrated with NaOH solution to determine the content of acetic acid, $HC_2H_3O_2$. For 20.0 mL of the vinegar, 32.0 mL of 0.500 M NaOH was required. What was the concentration of acetic acid in the vinegar if no other acid was present?

A) 1.60 M B) 0.800 M C) 0.640 M D) 0.600 M E) 0.400 M

Vinegar + NaOH
20.0 mL 32.0 mL
0.500 M

$0.032 L \times \frac{0.500 mol}{L} = 0.016$ mol

@ equiv. point
mol H^+ = mol OH^-

$\frac{0.0160 \text{ mol vinegar}}{0.020 L} = 0.80$

A 5. A solution of calcium hypochlorite, a common additive to swimming pool water, is:

A) basic because of the hydrolysis of the OCl^- ion
B) basic because $Ca(OH)_2$ is a weak and insoluble base
C) acidic because of the hydrolysis of the Ca^{2+} ions
D) acidic because the acid HOCl is formed

NaClO
Na^+ ClO^-
$ClO^- + H_2O \rightleftharpoons HClO + OH^-$

E 6. A buffered solution is one which can be described by which of the following?

I. a solution which resists pH change. ✓
II. may contain a weak acid and its salt. ✓
III. contains species that can react with both H^+ and OH^-. ✓

A) I only B) II only C) III only D) I and II only E) I, II, and III

The next four questions refer to aqueous solutions containing 1:1 mole ratios of the following pairs of substances. Assume all concentrations are 1 M.

A) NH_3 and NH_4Cl base buffer **B) H_3PO_4 and NaH_2PO_4** acid buffer **C) HCl and NaCl** acid neutral salt
D) NaOH and NH_3 base **E) NH_3 and $HC_2H_3O_2$** WA, WB Buffer

C 7. The solution with the lowest pH overall – most acidic

E 8. The most nearly neutral solution

A 9. A buffer at a pH > 8 (neutral component is basic)

B 10. A buffer at a pH < 6 (neutral component is acidic)

Arrhenius | Br...

Acid	$H^+_{(aq)}$	H^+ ...	17.
Base	$OH^-_{(aq)}$	H^+ a... /	

B 11. The Arrhenius definition of a base is:

A) a substance that produces H^+ in water solution.
B) a substance that produces OH^- in water solution.
C) a substance that produces protons in water solution.
D) a substance that acts as a proton donor in any solution.

A 12.

$$\underset{A}{HC_2H_3O_{2\,(aq)}} + \underset{B}{CN^-_{(aq)}} \leftrightarrow \underset{CA}{HCN_{(aq)}} + \underset{CB}{C_2H_3O_2^-{}_{(aq)}}$$

The reation represented above has an equilibrium constant equal to 3.7×10^4. Which of the following can be concluded from this information?

$K = \frac{[prod]}{[react]}$ positive

A) CN^- is a stronger base than $C_2H_3O_2^-$. ✓
B) HCN is a stronger acid than $HC_2H_3O_2$.
C) The conjugate base of CN^- is $C_2H_3O_2^-$. x
D) The pH of a solution containing equimolar amounts of CN^- and $HC_2H_3O_2$ is 7.0. x

C 13. Titrating a strong acid with a strong base will give you a pH at the equivalence point of:

A) Greater than 7
B) Less than 7
C) Equal to 7
D) Depends on the strong base
E) Depends on the weak acid

A 14. Mixing Na_3PO_4 in water will give you a pH that is:

$PO_4^{3-} + H_2O \rightleftharpoons HPO_4^{-} + OH^-$

A) Basic
B) Neutral
C) Acidic
D) need more information

C 15. The equation for number 2 when mixed with water would be:

A) $Na^+ + H_2O \leftrightarrow Na^+ + OH^- + H_2$
B) $Na^+ + 2\,H_2O \leftrightarrow Na(H_2O)(OH) + H^+$
C) $PO_4^{3-} + H_2O \leftrightarrow HPO_4^{2-} + OH^-$
D) $PO_4^{3-} + H_2O \leftrightarrow H_3PO_4 + H_3O^+$

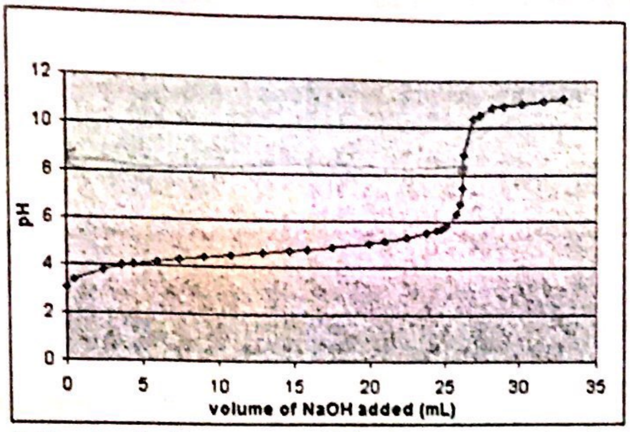
C 16. Which mixture should be chosen to prepare a buffer with a pH close to 7.2?

Acid	K_a
Acetic acid	1.8×10^{-5}
Ammonium ion	5.6×10^{-10}
Hypochlorous acid	3.5×10^{-8}
Nitrous acid	4.5×10^{-4}

pH closest to pKa
look at exponent
of K_a

A) $HC_2H_3O_2$ and $NaC_2H_3O_2$
B) NH_4NO_3 and NH_3
C) HOCl and NaOCl
D) HNO_2 and KNO_2

17.

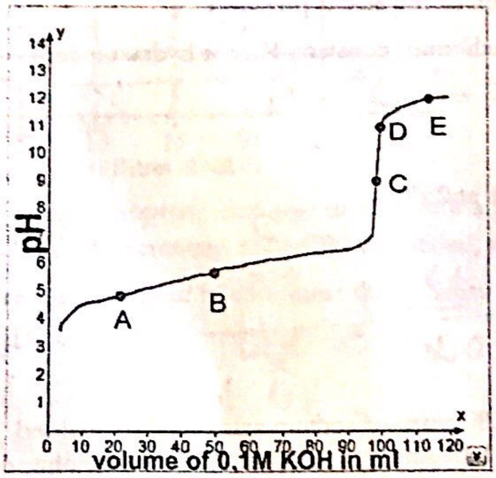


Which of the following indicators would be the best choice for this titration?

	Indicator	pK_a of Indicator
A)	Methyl orange	3.9
B)	Methyl red	5.5
C)	Bromocresol green	7.1
D)	o-cresolphthalein	8.9
E)	Alizarin yellow	11.5

Best indicator — pH of equiv. pt closest to pKa

A solution of a weak monoprotic acid is titrated with a solution of a strong base, KOH. Consider the points labeled A through E on the titration curve that results, as shown below. The questions (18-20) are based on the graph below.



C 18. The point at which the moles of the added strong base are equal to the moles of the weak acid initially present. Equivalence point

E 19. The point at which the pH is closest to that of the strong base being added End of titration

B 20. The point at which the identity and pK_a of the weak acid can be determined Halfway to equivalence point pH=pKa

Name ______________________

Acid Base

AP Chemistry ~ Free Response

1) A buffer solution contains 0.40 mole of formic acid, HCOOH, and 0.60 moles of sodium formate, NaCOOH, are in 1.00 Liter of solution. The ionization constant, K_a, for formic acid is 1.8×10^{-4}. Buffer

   a. Calculate the pH of this solution.

   $pH = pK_a + \log \frac{[B]}{[A]}$

   $[B] = \frac{0.60 mol}{1L}$ $[A] = \frac{0.40 mol}{1L}$

   $pH = -\log(1.8 \times 10^{-4}) + \log\left(\frac{0.60}{0.40}\right)$

   $= 3.74 + 0.176$

   $\boxed{= 3.92}$

   b. If 100. mL of this buffer solution is diluted to a volume of 1.00 Liter with pure water, the pH does not change. Discuss why the pH remains constant on dilution.

   The moles of acid remains constant as well as the moles of conjugate base so the ratio remains constant.

2) In water, hydrazoic acid, HN_3, is a weak acid that has an equilibrium constant, K_a, equal to 2.8×10^{-5} at 25°C. A 0.300 Liter sample of a 0.050 molar solution of the acid is prepared.

   (a) Write the expression for the equilibrium constant, K_a, for hydrazoic acid.

   $HN_3 + H_2O \rightleftharpoons H_3O^+ + N_3^-$ $K_a = \frac{[H_3O^+][N_3^-]}{[HN_3]}$

   (b) Calculate the pH of this solution at 25°C.

I	0.050	0	0
C	−x	+x	+x
E	0.050−x	x	x

   $2.8 \times 10^{-5} = \frac{(x)(x)}{(0.050 - x)}$

   $x = 1.18 \times 10^{-3} = [H^+]$

   $\boxed{pH = 2.93}$

   (c) To 0.150 liters of this solution, 0.80 gram of sodium azide, NaN_3, is added. The salt dissolved completely. Calculate the pH of the resulting solution at 25°C if the volume of the solution remains unchanged.

   Buffer

   $pH = pK_a + \log \frac{[N_3^-]}{[HN_3]}$

   $0.80g\ NaN_3 \times \frac{1mol}{65g} = 0.0123mol$

   $\frac{0.0123mol}{0.150L} = 0.082M$

   $= -\log(2.8 \times 10^{-5}) + \log\left(\frac{0.082}{0.050}\right)$

   $= 4.55 + 0.2148$

   $\boxed{pH = 4.76}$

weak acid / salt
weak base / salt

...n employer is interviewing four applicants for a job as a laboratory technician and asks each how to prepare a buffer solution with a pH close to 9.

a. Archie A. says he would mix acetic acid and sodium acetate solutions. – this buffer pH ~ 4.74
Beula B. says she would mix NH_4Cl ~~and HCl solutions.~~
Carla C. says she would mix NH_4Cl and NH_3 solutions.
Dexter D. says he would mix NH_3 ~~and NaOH solutions.~~

Which of these applicants has given an appropriate procedure? Explain your answer.
(The following acidity constants may be helpful: acetic acid, $K_a = 1.8\times10^{-5}$; NH_4^+, $K_a = 5.6\times10^{-10}$)

c) $pK_a\ NH_4^+ \sim 9$ $(-\log 5.6\times10^{-10})$.

b. Assume the base solution has a molarity of 0.250 M and 3.00 L of buffer solution must be prepared, calculate the number of moles of the acidic component of the buffer that are necessary for a pH of exactly 9.00.

$pH = pK_a + \log \frac{B}{A}$

$9.00 = 9.25 + \log\left(\frac{0.250}{x}\right) \longrightarrow -0.25 = \log\left(\frac{0.250}{x}\right)$

$-\log(5.6\times10^{-10}) = 9.25$

$10^{-0.25} = \frac{0.250}{x}$

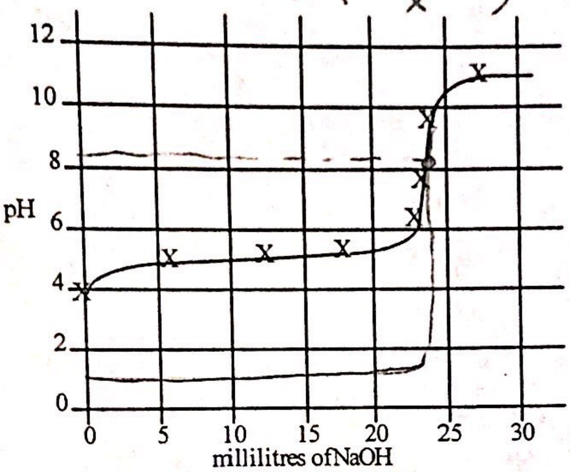
$x = 0.446 = [A]$

$M = \frac{mol}{L}$

$0.446\ M = \frac{x\ mol}{3.00\ L}$

$\boxed{x = 1.34\ mol\ acid}$

4)



A 30.00 milliliter sample of a weak monoprotic acid was titrated with a standardized solution of NaOH. A pH meter was used to measure the pH after each increment of NaOH was added, and the curve above was constructed.

(a) Explain how this curve could be used to determine the molarity of the acid.

Just like our labs - the equivalence point tells us when mol H^+ = mol OH^-. If you know mol of acid and volume of base @ equiv. pt you can calc. conc.

(b) If you were to repeat the titration using a indicator in the acid to signal the endpoint, which of the following indicators should you select? Give the reason for your choice.

Methyl red	$K_a = 1\times10^{-5}$
Cresol red	$K_a = 1\times10^{-8}$
Alizarin yellow	$K_a = 1\times10^{-11}$

pK_a near equiv. point

(c) Sketch the titration curve that would result if the weak monoprotic acid were replaced by a strong monoprotic acid, such as HCl of the same molarity. Identify two differences between this titration curve and the curve shown above.

- pH @ equivalence point would be 7
- no buffering region

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5) Aniline, a weak base, reacts with water according to the reaction represented below:

$$C_6H_5NH_2\ (aq) + H_2O\ (l) \leftrightarrow C_6H_5NH_3^+\ (aq) + OH^-\ (aq)$$

a) Write the equilibrium constant expression, K_b, for this reaction.

$$K_b = \frac{[C_6H_5NH_3^+][OH^-]}{[C_6H_5NH_2]}$$

b) A sample of aniline is dissolved in water to produce 25.0 mL of a 0.10 M solution. The pH of the solution is 8.82. Calculate the equilibrium constant, K_b, for this reaction.

$[H^+] = 10^{-8.82} = 1.51 \times 10^{-9}$

$[OH^-] = 10^{-5.18} = 6.61 \times 10^{-6}$

$K_b = \frac{(6.61 \times 10^{-6})^2}{0.10}$

$\boxed{= 4.37 \times 10^{-10}}$

c) The solution prepared in (b) is titrated with 0.10 M HCl. Calculate the pH of this solution when half of the weak base has been neutralized.

$pH = pK_a + \cancel{\log \frac{[B^-]}{[HA]}}$

$K_a = \frac{1.0 \times 10^{-14}}{4.37 \times 10^{-10}} = 2.29 \times 10^{-5}$

$= -\log(2.29 \times 10^{-5}) +$

$\boxed{= 4.64}$

d) Calculate the pH at the equivalence point of the titration in part (c).

Stoic:

	$C_6H_5NH_2$	+ H^+	⟶ $C_6H_5NH_3^+$
B	0.0025mol	0.0025	0
C	− 0.0025	− 0.0025	+ 0.0025
A	0	0	0.0025mol

$0.025 L \times \frac{0.10\ mol}{L}$

$\frac{0.0025\ mol}{(0.050 L)} = 0.050 M$

Equil:

$K_a = \frac{1.0 \times 10^{-14}}{4.37 \times 10^{-10}} = 2.29 \times 10^{-5}$

	$C_6H_5NH_3^+$ + H_2O	$\underset{}{\overset{K_a}{\rightleftharpoons}}$ H_3O^+	+ $C_6H_5NH_2$
I	0.050	0	0
C	− x	x	x
E	0.050 − x	x	x

e) The pKa values for several indicators are given below. Which of the indicators listed is most suitable for this titration? Justify your answer.

Indicator	pKa
Erythrosine	3
Litmus	7
Thymolphthalein	10

The best indicator changes color at equivalence point.

So you want your indicator to have a pKa near equivalence point.

$2.29 \times 10^{-5} = \frac{(x)(x)}{(0.050 - x)}$

$= 1.07 \times 10^{-3} = [H^+]$

$\boxed{pH = 2.97}$

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