AP Questions: Acids and Bases

1970

(a) What is the pH of a 2.0 molar solution of acetic acid. K_a acetic acid = $1.8x10^{-5}$

(b) A buffer solution is prepared by adding 0.10 liter of 2.0 molar acetic acid solution to 0.1 liter of a 1.0 molar sodium hydroxide solution. Compute the hydrogen ion concentration of the buffer solution.

(c) Suppose that 0.10 liter of 0.50 molar hydrochloric acid is added to 0.040 liter of the buffer prepared in (b). Compute the hydrogen ion concentration of the resulting solution.

1972

Given a solution of ammonium chloride, what additional reagent or reagents are needed to prepare a buffer from the ammonium chloride solution?

Explain how this buffer solution resists a change in pH when:

(a) Moderate amounts of strong acid are added.

(b) Moderate amounts of strong base are added.

(c) A portion of the buffer solution is diluted with an equal volume of water.

1973

A sample of 40.0 milliliters of a 0.100 molar $HC_2H_3O_2$ solution is titrated with a 0.150 molar NaOH solution. K_a for acetic acid = $1.8x10^{-5}$

(a) What volume of NaOH is used in the titration in order to reach the equivalence point?

(b) What is the molar concentration of $C_2H_3O_2^-$ at the equivalence point?

(c) What is the pH of the solution at the equivalence point?

1974 A

A solution is prepared from 0.0250 mole of HCl, 0.10 mole propionic acid, C_2H_5COOH, and enough water to make 0.365 liter of solution. Determine the concentrations of H_3O^+, C_2H_5COOH, $C_2H_5COO^-$, and OH^- in this solution. K_a for propionic acid = $1.3x10^{-5}$

1975 A

(a) A 4.00 gram sample of NaOH*(s)* is dissolved in enough water to make 0.50 liter of solution. Calculate the pH of the solution.

(b) Suppose that 4.00 grams of NaOH*(s)* is dissolved in 1.00 liter of a solution that is 0.50 molar in NH_3 and 0.50 molar in NH_4^+. Assuming that there is no change in volume and no loss of NH_3 to the atmosphere, calculate the concentration of hydroxide ion, after a chemical reaction has occurred. [Ionization constant at 25ºC for the reaction $NH_3 + H_2O \rightarrow NH_4^+ + OH^-$; K = $1.8x10^{-5}$]

1977

The value of the ionization constant, K_a, for hypochlorous acid, HOCl, is 3.1×10^{-8}.

(a) Calculate the hydronium ion concentration of a 0.050 molar solution of HOCl.

(b) Calculate the concentration of hydronium ion in a solution prepared by mixing equal volumes of 0.050 molar HOCl and 0.020 molar sodium hypochlorite, NaOCl.

(c) A solution is prepared by the disproportionation reaction below. $Cl_2 + H_2O \rightarrow HCl + HOCl$

Calculate the pH of the solution if enough chlorine is added to water to make the concentration of HOCl equal to 0.0040 molar.

1978 D

Predict whether solutions of each of the following salts are acidic, basic, or neutral. Explain your prediction in each case

(a) $Al(NO_3)_3$ (b) K_2CO_3 (c) NaBr

1979 B

A solution of hydrochloric acid has a density of 1.15 grams per milliliter and is 30.0% by weight HCl.

(a) What is the molarity of this solution of HCl?

(b) What volume of this solution should be taken in order to prepare 5.0 liters of 0.20 molar hydrochloric acid by dilution with water?

1979 D

$$NH_4^+ + OH^- <=> NH_3 + H_2O$$
$$H_2O + C_2H_5O^- <=> C_2H_5OH + OH^-$$

The equations for two acid-base reactions are given above. Each of these reactions proceeds essentially to completion to the right when carried out in aqueous solution.

(a) Give the Bronsted-Lowry definition of an acid and a base.

(b) List each acid and its conjugate base for each of the reactions above.

(c) Which is the stronger base, ammonia or the ethoxide ion. $C_2H_5O^-$? Explain your answer.

1980 A

Methylamine CH_3NH_2, is a weak base that ionizes in solution as shown by the following equation.

$$CH_3NH_2 + H_2O <=> CH_3NH_3^+ + OH^-$$

(a) At 25ºC the percentage ionization in a 0.160 molar solution of CH_3NH_2 is 4.7%. Calculate $[OH^-]$, $[CH_3NH_3^+]$, $[CH_3NH_2]$, $[H_3O^+]$, and the pH of a 0.160 molar solution of CH_3NH_2 at 25ºC

(b) Calculate the value for K_b, the ionization constant for CH_3NH_2, at 25ºC.

(c) If 0.050 mole of crystalline lanthanum nitrate is added to 1.00 liter of a solution containing 0.20 mole of CH_3NH_2 and 0.20 mole of its salt CH_3NH_3Cl at 25ºC, and the solution is stirred until equilibrium is attained, will any $La(OH)_3$ precipitate? Show the calculations that prove your answer. (The solubility constant for $La(OH)_3$, $K_{sp} = 1x10^{-19}$ at 25ºC)

1981 D

$Al(NO_3)_3$ K_2CO_3 $NaHSO_4$ NH_4Cl

(a) Predict whether a 0.10 molar solution of each of the salts above is acidic, neutral or basic.

(b) For each of the solutions that is not neutral, write a balanced chemical equation for a reaction occurring with water that supports your prediction.

1982 A

A buffer solution contains 0.40 mole of formic acid, HCOOH, and 0.60 mole of sodium formate, HCOONa, in 1.00 litre of solution. The ionization constant, K_a, of formic acid is $1.8x10^{-4}$.

(a) Calculate the pH of this solution.

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

(c) A 5.00 millilitre sample of 1.00 molar HCl is added to 100. millilitres of the original buffer solution. Calculate the $[H_3O^+]$ of the resulting solution.

(d) A 800.-milliliter sample of 2.00-molar formic acid is mixed with 200. milliliters of 4.80-molar NaOH. Calculate the $[H_3O^+]$ of the resulting solution.

1983 C

(a) Specify the properties of a buffer solution. Describe the components and the composition of effective buffer solutions.

(b) An 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.

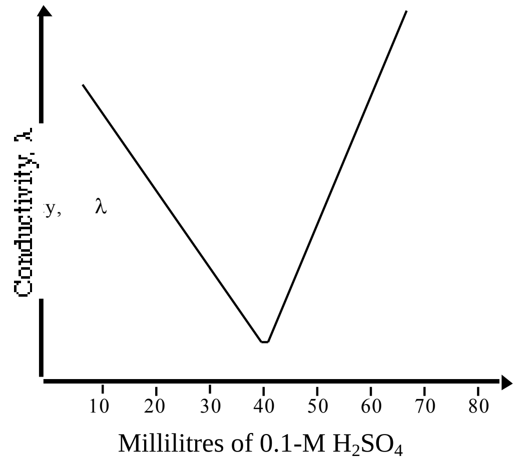
Archie A. says he would mix acetic acid and sodium acetate solutions.
Beula B. says she would mix NH_4Cl and HCl solutions.
Carla C. says she would mix NH_4Cl and NH_3 solutions.
Dexter D. says he would mix NH_3 and NaOH solutions.

Which of these applicants has given an appropriate procedure? Explain your answer, referring to your discussion in part (a). Explain what is wrong with the erroneous procedures.

(No calculations are necessary, but the following Ka’s may be helpful: acetic acid, $K_a = 1.8x10^{-5}$; NH_4^+, $K_a = 5.6x10^{-10}$)

1982 D

A solution of barium hydroxide is titrated with 0.1-M sulfuric acid and the electrical conductivity of the solution is measured as the titration proceeds. The data obtained are plotted on the graph below.



(a) For the reaction that occurs during the titration described above, write a balanced net ionic equation.

(b) Explain why the conductivity decreases, passes through a minimum, and then increases as the volume of H_2SO_4 added to the barium hydroxide is increased.

(c) Calculate the number of moles of barium hydroxide originally present in the solution that is titrated.

(d) Explain why the conductivity does not fall to zero at the equivalence point of this titration.

1984 A

Sodium benzoate, C_6H_5COONa, is the salt of a the weak acid, benzoic acid, C_6H_5COOH. A 0.10 molar solution of sodium benzoate has a pH of 8.60 at room temperature.

(a) Calculate the $[OH^-]$ in the sodium benzoate solution described above.

(b) Calculate the value for the equilibrium constant for the reaction:

$$C_6H_5COO^- + H_2O \Leftrightarrow C_6H_5COOH + OH^-$$

(c) Calculate the value of K_a, the acid dissociation constant for benzoic acid.

(d) A saturated solution of benzoic acid is prepared by adding excess solid benzoic acid to pure water at room temperature. Since this saturated solution has a pH of 2.88, calculate the molar solubility of benzoic acid at room temperature.

1984 C

Discuss the roles of indicators in the titration of acids and bases. Explain the basis of their operation and the factors to be considered in selecting an appropriate indicator for a particular titration.

1986 A

In water, hydrazoic acid, HN_3, is a weak acid that has an equilibrium constant, K_a, equal to 2.8×10^{-5} at 25ºC. A 0.300 litre 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.

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

(c) To 0.150 litre 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 25ºC if the volume of the solution remains unchanged.

(d) To the remaining 0.150 litre of the original solution, 0.075 litre of 0.100 molar NaOH solution is added. Calculate the $[OH^-]$ for the resulting solution at 25ºC.

1986 D

H_2SO_3 HSO_3^- $HClO_4$ $HClO_3$ H_3BO_3

Oxyacids, such as those above, contain an atom bonded to one or more oxygen atoms; one or more of these oxygen atoms may also be bonded to hydrogen.

(a) Discuss the factors that are often used to predict correctly the strengths of the oxyacids listed above.

(b) Arrange the examples above in the order of <u>increasing</u> acid strength.

1987 A

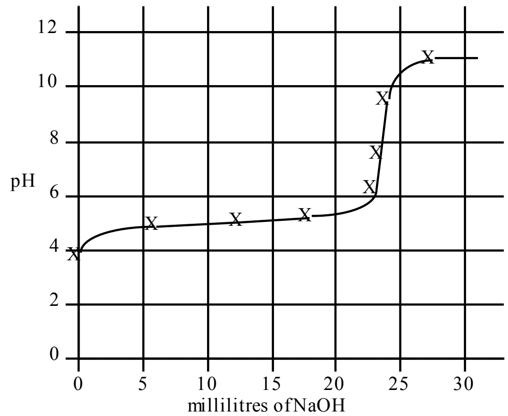
$NH_3 + H_2O <=> NH_4^+ + OH^-$ Ammonia is a weak base that dissociates in water as shown above. At 25ºC, the base dissociation constant, K_b, for NH_3 is 1.8×10^{-5}.

(a) Determine the hydroxide ion concentration and the percentage dissociation of a 0.150 molar solution of ammonia at 25ºC.

(b) Determine the pH of a solution prepared by adding 0.0500 mole of solid ammonium chloride to 100. millilitres of a 0.150 molar solution of ammonia.

(c) If 0.0800 mole of solid magnesium chloride, $MgCl_2$, is dissolved in the solution prepared in part (b) and the resulting solution is well-stirred, will a precipitate of $Mg(OH)_2$ form? Show calculations to support your answer. (Assume the volume of the solution is unchanged. The solubility product constant for $Mg(OH)_2$ is 1.5×10^{-11}.

1988 D



A 30.00 millilitre 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.

(b) Explain how this curve could be used to determine the dissociation constant K_a of the weak monoprotic acid.

(c) 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	$K_a = 1 \times 10^{-5}$
Cresol red	$K_a = 1 \times 10^{-8}$
Alizarin yellow	$K_a = 1 \times 10^{-11}$

(d) 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 differences between this titration curve and the curve shown above.

1990 D

Give a brief explanation for each of the following.

(a) For the diprotic acid H_2S, the first dissociation constant is larger than the second dissociation constant by about 10^5 ($K_1 \sim 10^5 K_2$).

(b) In water, NaOH is a base but HOCl is an acid.

(c) HCl and HI are equally strong acids in water but, in pure acetic acid, HI is a stronger acid than HCl.

(d) When each is dissolved in water, HCl is a much stronger acid than HF.

1991 A

The acid ionization constant, K_a, for propanoic acid, C_2H_5COOH, is 1.3×10^{-5}.

(a) Calculate the hydrogen ion concentration, $[H^+]$, in a 0.20-molar solution of propanoic acid.

(b) Calculate the percentage of propanoic acid molecules that are ionized in the solution in (a).

(c) What is the ratio of the concentration of propanoate ion, $C_2H_5COO^-$, to that of propanoic acid in a buffer solution with a pH of 5.20?

(d) In a 100.-milliliter sample of a different buffer solution, the propanoic acid concentration is 0.35-molar and the sodium propanoate concentration is 0.50-molar. To this buffer solution, 0.0040 mole of solid NaOH is added. Calculate the pH of the resulting solution.

1992 D

The equations and constants for the dissociation of three different acids are given below.

$HCO_3^- <=> H^+ + CO_3^{2-}$	$K_a = 4.2 \times 10^{-7}$
$H_2PO_4^- <=> H^+ + HPO_4^{2-}$	$K_a = 6.2 \times 10^{-8}$
$HSO_4^- <=> H^+ + SO_4^{2-}$	$K_a = 1.3 \times 10^{-2}$

(a) From the systems above, identify the conjugate pair that is best for preparing a buffer with a pH of 7.2. Explain your choice.

(b) Explain briefly how you would prepare the buffer solution described in (a) with the conjugate pair you have chosen.

(c) If the concentrations of both the acid and the conjugate base you have chosen were doubled, how would the pH be affected? Explain how the capacity of the buffer is affected by this change in concentrations of acid and base.

(d) Explain briefly how you could prepare the buffer solution in (a) if you had available the solid salt of the only one member of the conjugate pair and solution of a strong acid and a strong base.

1993 A

$$CH_3NH_2 + H_2O <=> CH_3NH_3^+ + OH^-$$

Methylamine, CH_3NH_2, is a weak base that reacts according to the equation above. The value of the ionization constant, K_b, is 5.25×10^{-4}. Methylamine forms salts such as methylammonium nitrate, $(CH_3NH_3^+)(NO_3^-)$.

(a) Calculate the hydroxide ion concentration, $[OH^-]$, of a 0.225-molar aqueous solution of methylamine.

(b) Calculate the pH of a solution made by adding 0.0100 mole of solid methylammonium nitrate to 120.0 milliliters of a 0.225-molar solution of methylamine. Assume no volume change occurs.

(c) How many moles of either NaOH or HCl (state clearly which you choose) should be added to the solution in (b) to produce a solution that has a pH of 11.00? Assume that no volume change occurs.

(d) A volume of 100. milliliters of distilled water is added to the solution in (c). How is the pH of the solution affected? Explain.

1993 D

The following observations are made about reaction of sulfuric acid, H_2SO_4. Discuss the chemical processes involved in each case. Use principles from acid-base theory, oxidation-reduction, and bonding and/or intermolecular forces to support your answers.

(a) When zinc metal is added to a solution of dilute H_2SO_4, bubbles of gas are formed and the zinc disappears.

(b) As concentrated H_2SO_4 is added to water, the temperature of the resulting mixture rises.

(c) When a solution of $Ba(OH)_2$ is added to a dilute H_2SO_4 solution, the electrical conductivity decreases and a white precipitate forms.

(d) When 10 milliliters of 0.10-molar H_2SO_4 is added to 40 milliliters of 0.10-molar NaOH, the pH changes only by about 0.5 unit. After 10 more milliliters of 0.10-molar H_2SO_4 is added, the pH changes about 6 units.

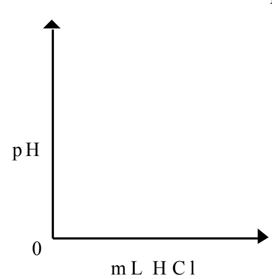
1994 D

A chemical reaction occurs when 100. milliliters of 0.200-molar HCl is added dropwise to 100. milliliters of 0.100-molar Na_3P0_4 solution.

(a) Write the two net ionic equations for the formation of the major products.

(b) Identify the species that acts as both a Bronsted acid and as a Bronsted base in the equation in (a), Draw the Lewis electron-dot diagram for this species.

(c) Sketch a graph using the axes provided, showing the shape of the titration curve that results when 100. milliliters of the HCl solution is added slowly from a buret to the Na_3PO_4 solution. Account for the shape of the curve.



(d) Write the equation for the reaction that occurs if a few additional milliliters of the HCl solution are added to the solution resulting from the titration in (c).

1996 A

$$HOCl <=> OCl^- + H^+$$

Hypochlorous acid, HOCl, is a weak acid commonly used as a bleaching agent. The acid-dissociation constant, K_a, for the reaction represented above is $3.2x10^{-8}$.

(a) Calculate the $[H^+]$ of a 0.14-molar solution of HOCl.

(b) Write the correctly balanced net ionic equation for the reaction that occurs when NaOCl is dissolved in water and calculate the numerical value of the equilibrium constant for the reaction.

(c) Calculate the pH of a solution made by combining 40.0 milliliters of 0.14-molar HOCl and 10.0 milliliters of 0.56-molar NaOH.

(d) How many millimoles of solid NaOH must be added to 50.0 milliliters of 0.20-molar HOCl to obtain a buffer solution that has a pH of 7.49? Assume that the addition of the solid NaOH results in a negligible change in volume.

(e) Household bleach is made by dissolving chlorine gas in water, as represented below.

$$Cl_2(g) + H_2O --> H^+ + Cl^- + HOCl(aq)$$

Calculate the pH of such a solution if the concentration of HOCl in the solution is 0.065 molar.

1997 A

The overall dissociation of oxalic acid, $H_2C_2O_4$, is represented below. The overall dissociation constant is also indicated.

$H_2C_2O_4 <=> 2\ H^+ + C_2O_4^{2-}$ $\quad K = 3.78x10^{-6}$

(a) What volume of 0.400-molar NaOH is required to neutralize completely a $5.00x10^{-3}$-mole sample of pure oxalic acid?

(b) Give the equations representing the first and second dissociations of oxalic acid. Calculate the value of the first dissociation constant, K_1, for oxalic acid if the value of the second dissociation constant, K_2, is $6.40x10^{-5}$.

(c) To a 0.015-molar solution of oxalic acid, a strong acid is added until the pH is 0.5. Calculate the $[C_2O_4^{2-}]$ in the resulting solution. (Assume the change in volume is negligible.)

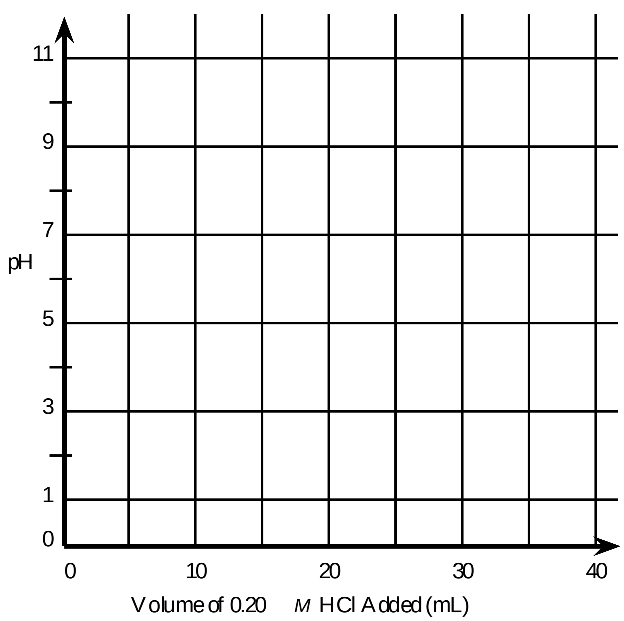
(d) Calculate the value of the equilibrium constant, K_b, for the reaction that occurs when solid $Na_2C_2O_4$ is dissolved in water.

2000 D

A volume of 30.0 mL of 0.10 M $NH_3(aq)$ is titrated with 0.20 *M* HCl*(aq)*. The value of the base-dissociation constant, K_b, for NH_3 in water is 1.8×10^{-5} at 25°C.

(a) Write the net-ionic equation for the reaction of $NH_3(aq)$ with HCl*(aq)*.

(b) Using the axes provided below, sketch the titration curve that results when a total of 40.0 mL of 0.20 *M* HCl*(aq)* is added dropwise to the 30.0 mL volume of 0. 10 *M* $NH_3(aq)$.



(c) From the table below, select the most appropriate indicator for the titration. Justify your choice.

Indicator	**pK_a**
Methyl Red	5.5
Bromothymol Blue	7.1
Phenolphthalein	8.7

(d) If equal volumes of 0.10 *M* $NH_3(aq)$ and 0.10 *M* $NH_4Cl(aq)$ are mixed, is the resulting solution acidic, neutral, or basic? Explain.

2001 B

Answer the following questions about acetylsalicylic acid, the active ingredient in aspirin.

(a) The amount of acetylsalicylic acid in a single aspirin tablet is 325 mg, yet the tablet has a mass of 2.00 g. Calculate the mass percent of acetylsalicylic acid in the tablet.

(b) The elements contained in acetylsalicylic acid are hydrogen, carbon, and oxygen. The combustion of 3.000 g of the pure compound yields 1.200 g of water and 3.72 L of dry carbon dioxide, measured at 750. mm Hg and 25°C. Calculate the mass, in g, of each element in the 3.000 g sample.

(c) A student dissolved 1.625 g of pure acetylsalicylic acid in distilled water and titrated the resulting solution to the equivalence point using 88.43 mL of 0.102 *M* NaOH*(aq)*. Assuming that acetylsalicylic acid has only one ionizable hydrogen, calculate the molar mass of the acid.

(d) A 2.00×10^{-3} mole sample of pure acetylsalicylic acid was dissolved in 15.00 mL of water and then titrated with 0.100 *M* NaOH*(aq)*. The equivalence point was reached after 20.00 mL of the NaOH solution had been added. Using the data from the titration, shown in the table below, determine

(i) the value of the acid dissociation constant, K_a, for acetylsalicylic acid and

(ii) the pH of the solution after a total volume of 25.00 mL of the NaOH solution had been added (assume that volumes are additive).

Volume of 0.100M NaOH Added (mL)	pH
0.00	2.22
5.00	2.97
10.00	3.44
15.00	3.92
20.00	8.13
25.00	?

2002 A

$HOBr(aq) \Leftrightarrow H^+(aq) + OBr^-(aq)$ $\qquad K_a = 2.3 \times 10^{-9}$

Hypobromous acid, HOBr, is a weak acid that dissociates in water, as represented by the equation above.

(a) Calculate the value of $[H^+]$ in an HOBr solution that has a pH of 4.95.

(b) Write the equilibrium constant expression for the ionization of HOBr in water, then calculate the concentration of HOBr*(aq)* in an HOBr solution that has $[H^+]$ equal to 1.8×10^{-5} *M*.

(c) A solution of $Ba(OH)_2$ is titrated into a solution of HOBr.

(i) Calculate the volume of 0.115 *M* $Ba(OH)_2(aq)$ needed to reach the equivalence point when titrated into a 65.0 mL sample of 0.146 *M* HOBr*(aq)*.

(ii) Indicate whether the pH at the equivalence point is less than 7, equal to 7, or greater than 7. Explain.

(d) Calculate the number of moles of NaOBr*(s)* that would have to be added to 125 mL of 0.160 *M* HOBr to produce a buffer solution with $[H^+] = 5.00 \times 10^{-9}$ *M*. Assume that volume change is negligible.

(e) HOBr is a weaker acid than $HBrO_3$. Account for this fact in terms of molecular structure.