Name: Key

Chemistry 20
Acids and Bases Workbook

Properties of Strong and Weak Acids and Bases

1. Fill in the chart of expected results for acids that all have a concentration of 0.1 mol/L.

Acid	Chemical formula	pH (slightly less than 7 or much less than 7)	Conductivity (high or low)	Reactivity with magnesium metal (high or low)
hydrochloric acid	$HCl(aq)$	much	high	high
ethanoic acid	$CH_3COOH(aq)$	slightly	low	low
boric acid	$H_3BO_3(aq)$	slightly	low	low
hydrofluoric acid	$HF(aq)$	slightly	low	low
sulfuric acid	$H_2SO_4(aq)$	much	high	high
perchloric acid	$HClO_4(aq)$	much	high	high
phosphoric acid	$H_3PO_4(aq)$	slightly	low	low
hydrobromic acid	$HBr(aq)$	much	high	high
sulfurus acid	$H_2SO_3(aq)$	slightly	low	low

* strong acids much & weak slightly

2. Two different acidic solutions have a concentration of 0.1 mol/L. Solution A conducts electricity extremely well, while solution B conducts very poorly. Which of the solutions will have a lower pH? Explain using a description of what is happening on a molecular level.

Solution A is a strong acid which means it dissociates completely to produce hydronium ions and solution B is a weak acid so it doesn't dissociate much. The hydronium ions cause conductivity. More hydronium ions (Solution A) means lower pH.

3. You have two basic solutions. One has a concentration of 1.0 mol/L and one has a concentration of 0.1 mol/L. You know one is a strong base and one is a weak base. Can you determine which solution is which based on pH? If so, explain how. If not, explain why not.

Yes because 14 - pH = pOH and when you know the pOH you can calculate $[OH^{1-}(aq)]$. If the solutions dissociates completely to $OH^{1-}(aq)$ then it is a strong acid.

Writing Acid and Base Reactions

1. How is the hydronium ion formed? Use a sketch and label.

a $H^+(aq)$ combines with water

$$H^+(aq) + H_2O(l) \rightarrow H_3O^+(aq)$$

2. Give the Arrhenius definition of an acid and a base.

modified - acid substance that reacts with water to produce $H_3O^+(aq)$

- base substance that reacts with water to produce $OH^-(aq)$

3. Using the Arrhenius definition, show how one could prove the following as forming an acidic solution.

a. $HCl_{(g)}$ $HCl(g) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-$

b. $H_2SO_{4(l)}$ $H_2SO_4(l) + H_2O(l) \rightarrow HSO_4^-(aq) + H_3O^+(aq)$

c. $NaHSO_{4(aq)}$ $HSO_4^-(aq) + H_2O(l) \rightarrow SO_4^{2-}(aq) + H_3O^+(aq)$

2 steps → d. $CO_{2(g)}$ $H_2O + CO_3^{-1} \rightarrow H_2CO_3 + H_2O^{-2} \rightarrow HCO_3^-(aq) + H_3O^+(aq)$

4. Using the Arrhenius definition, show how one could prove the following as forming a basic solution.

a. $NaOH_{(s)}$ $NaOH \rightarrow Na^+(aq) + OH^-(aq)$

b. $NH_{3(g)}$ $NH_3(g) + H_2O(l) \rightarrow NH_4^+(aq) + OH^-(aq)$

c. $Na_2CO_{3(s)}$ $CO_3^{2-}(aq) + H_2O(l) \rightarrow HCO_3^-(aq) + OH^-(aq)$

5. Write a net ionic equation of a strong acid reacting with a strong base.

$$H_3O^+(aq) + OH^-(aq) \rightarrow H_2O(l) + H_2O(l)$$

H_3O^+: strong acid

OH^-: strong base

Calculating pH

1. What is the pH of the following solutions given their hydronium ion concentrations?

   (a) $[H_3O^+(aq)] = 5.32 \times 10^{-7}$ mol/L 6.274

   $pH = -\log[H_3O^+(aq)]$

   (b) $[H_3O^+(aq)] = 6.1 \times 10^{-5}$ mol/L 4.21

   (c) $[H_3O^+(aq)] = 2.679 \times 10^{-14}$ mol/L 13.5720

   (d) $[H_3O^+(aq)] = 0.23$ mol/L 0.64

2. Which of the above solutions would be considered acidic? a, b & d (pH < 7)

3. Fill in the following chart:

$[H_3O^+(aq)]$ (mol/L)	pH
1.37×10^{-2}	1.863
2.38×10^{-5}	4.623
2.38×10^{-6}	5.623
1.00×10^{-7}	7.000
3.45×10^{-9}	8.462
3.45×10^{-10}	9.462
3.45×10^{-11}	10.462
5.33×10^{-12}	11.273

4. Notice in the chart that the concentration of $H_3O^+(aq)$ is continually decreasing. What do you notice about the pH values? Getting higher

5. Generalize what happens to pH as acidity decreases.

   - pH increases as acidity decreases.

6. What do you think happens to pH as basicity decreases?

   - pH decreases as basicity decreases

7. Find some spots on the table when the pH increases by exactly 1 pH unit. What do you notice about the change in concentration of hydronium ions at these points?

   - X 10 different each time

8. What is the pH of a solution made by the following methods?

(a) Dissolving 3.62 g of pure hydrogen perchlorate, $HClO_4(aq)$, in 2.0 L of water.

$m = 100.46\ g/mol$

$HClO_4(aq) + H_2O(l) \rightarrow H_3O^+(aq) + ClO_4^{1-}(aq)$

$\frac{100.46\ g}{1\ mol} = \frac{3.62\ g}{x\ mol}$

$x = 0.0360\ mol$

$\frac{0.036\ mol}{2.0\ L} = 0.018\ mol/L$

$pH = -\log(0.018)$

$\boxed{pH = 1.74}$

(b) Dissolving 2.357 g of pure hydrobromic acid, HBr(aq), in 50.0 L of water.

$HBr(aq) + H_2O(l) \rightarrow H_3O^+(aq) + Br^{1-}(aq)$

$\frac{80.91\ g}{1\ mol} = \frac{2.357\ g}{x\ mol}$

$x = 0.0291\ mol$

$\frac{0.0291\ mol}{50.0} = \frac{x\ mol}{1\ L}$

$x = 5.826 \times 10^{-4}\ mol/L$

$pH = -\log 5.826 \times 10^{-4}$

$\boxed{= 3.235}$

(c) Dissolving 8 μg of pure nitric acid, $HNO_3(aq)$, in 20.0 mL of water.

$HNO_3(aq) + H_2O(l) \rightarrow NO_3^{1-}(aq) + H_3O^+(aq)$

$\frac{63.02\ g}{1\ mol} = \frac{8 \times 10^{-6}\ g}{x\ mol}$

$x = 1.2694 \times 10^{-7}\ mol$

$\frac{1.26943 \times 10^{-7}\ mol}{0.020\ L} = \frac{x}{1\ L}$

$x = 6.34715 \times 10^{-6}\ mol/L$

$pH = -\log(6.34715 \times 10^{-6})$

$\boxed{= 5.2}$

pOH and pH Calculations

1. What is the pOH of the following solutions given their hydroxide ion concentrations?

   (a) $[OH^-(aq)] = 4.67 \times 10^{-3}$ mol/L

   pOH = $-\log [OH^-(aq)]$ 2.331

   (b) $[OH^-(aq)] = 5.84 \times 10^{-8}$ mol/L 7.234

   (c) $[OH^-(aq)] = 1.478 \times 10^{-14}$ mol/L 13.8303

   (d) $[OH^-(aq)] = 3.4 \times 10^{-2}$ mol/L 1.47

2. Which of the above solutions are considered acidic?

   b, c - pOH greater than 7.

3. If given the pH of the following solution, give the pOH, or vice versa:

   pH + pOH = 14

   (a) pH = 12.3 pOH = 1.7

   (b) pOH = 5.5 pH = 8.5

   (c) pOH = 2.95 pH = 11.05

   (d) pH = 6.629 pOH = 7.371

   (e) pOH = 1.1 pH = 12.9

4. Fill in the following chart:

$[OH^-(aq)]$ mol/L	pOH	pH
1.28	-0.107	14.107
5.35×10^{-3}	2.272	11.728
8.459×10^{-5}	4.0727	9.9273
9.6×10^{-8}	7.02	6.98
1.934×10^{-15}	14.7135	-0.7135

5. What is the pOH of a 3.2 mol/L solution of lithium hydroxide, LiOH(aq)?

$LiOH(aq) \rightarrow Li^{1+}(aq) + OH^{1-}(aq)$

3.2 mol/L

$pOH = -\log(3.2)$

$= \boxed{-0.51}$

6. What is the pOH of a 5.467 mol/L solution of strontium hydroxide, $Sr(OH)_2(aq)$?

$Sr(OH)_2(aq) \rightarrow Sr^{2+}(aq) + 2OH^{1-}(aq)$

$C = 5.467$ mol/L $\qquad C = 10.934$ mol/L

$pOH = -\log(10.934)$

$= \boxed{-1.0388}$

7. What is the pH of a 3.45 mol/L solution of sodium hydroxide, NaOH(aq)?

$NaOH(aq) \rightarrow Na^{1+}(aq) + OH^{1-}(aq)$

3.45 mol/L $\qquad$ 3.45 mol/L

$pOH = -\log 3.45$

$= -0.538$

$pH = 14 - (0.538)$

$= \boxed{14.538}$

8. What is the pOH of a solution made by dissolving 4.95 g of potassium hydroxide, KOH(aq), in 4.50 L of water?

$KOH(s) \rightarrow K^{+}(aq) + OH^{1-}(aq)$

0.0196 mol/L $\qquad$ 0.0196 mol/L

$\frac{56.11\ g}{1\ mol} = \frac{4.95\ g}{x\ mol}$

$x = 0.0882$ mol

$\frac{0.0882\ mol}{4.5\ L} = 0.0196$ mol/L

$pOH = -\log(0.0196\ mol/L)$

$= \boxed{1.708}$

Calculating Concentration from pH and pOH

1. What is the concentration of hydronium ions in the following solutions given their pH values?

   (a) pH = 2.34 $[H_3O^+] = 10^{-2.34} = 4.6 \times 10^{-3}$ mol/L

   (b) pH = 15.6 3×10^{-16} mol/L

   (c) pH = 4.4 4×10^{-5} mol/L

   (d) pH = 1.892 1.28×10^{-2} mol/L

   (e) pH = 5.63 2.3×10^{-6} mol/L

2. What is the concentration of hydroxide ions in the following solutions given the following information?

   (a) pOH = 1.45 $[OH^-(aq)] = 10^{-1.45} = 3.5 \times 10^{-2}$ mol/L

   (b) pOH = 10.672 2.13×10^{-11} mol/L

   (c) pOH = 7.3 5×10^{-8} mol/L

   (d) pH = 2.982 pOH = 11.018 $[OH^-(aq)] = 9.59 \times 10^{-12}$ mol/L

   (e) pH = 4.932 pOH = 9.068 $[OH^-(aq)] = 8.55 \times 10^{-10}$ mol/L

   (f) pH = 10.2 pOH = 3.8 $[OH^-(aq)] = 2 \times 10^{-4}$ mol/L

3. What is the concentration of hydrochloric acid, HCl(aq), that gives a solution with a pH of 3.69?

   $HCl(aq) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$

   pH = 3.69

   $[H_3O^+] = 2.0417 \times 10^{-4}$ mol/L

   Concentration of HCl(aq) is same **2.0 mol/L**

4. What is the concentration of lithium hydroxide, LiOH(aq), that gives a solution with a pOH of 4.674?

   $LiOH(aq) \rightarrow Li^+(aq) + OH^-(aq)$

   $[OH^-(aq)] = 10^{-4.674}$

   $[OH^-(aq)] = 2.12 \times 10^{-5}$ mol/L

   $LiOH(aq) = [OH^-(aq)]$

   $= 2.12 \times 10^{-5}$ mol/L

5. What is the concentration of barium hydroxide, $Ba(OH)_2(aq)$, that gives a solution with a pH of 11.836?

$Ba(OH)_2(aq) \rightarrow Ba^{2+}(aq) + 2OH^-(aq)$

$pH = 11.836$

$pOH = 2.164$

$[OH^-] = 10^{-2.164} = 0.006859\ mol/L$

$$\frac{2OH^-}{Ba(OH)_2} = \frac{0.00685}{x}$$

$x = \boxed{0.00343\ mol/L \text{ or } 3.43 \times 10^{-3}\ mol/L}$

6. What mass of hydrogen chloride gas, HCl(g), needs to be dissolved in 2.00 L of water to create a solution with a pH of 3.298?

$HCl(g) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$

$pH = 3.298$

$[H_3O^+(aq)] = 10^{-3.298} = 5.035006 \times 10^{-4}\ mol/L$

$$\frac{5.035 \times 10^{-4}}{1L} = \frac{x\ mol}{2L}$$

$x = 0.001007\ mol$

$$\frac{36.46\ g}{1\ mol} = \frac{x\ g}{0.001007\ mol}$$

$\boxed{x = 0.0367\ g}$

7. What mass of rubidium hydroxide, RbOH(s), needs to be dissolved in 1.50 L of water to create a solution with a pH of 9.35?

$RbOH(s) \rightarrow Rb^+(aq) + OH^-(aq)$

$pOH = 4.65$

$[OH^-] = 2.238 \times 10^{-5}\ mol/L$

$$\frac{2.238 \times 10^{-5}\ mol}{1L} = \frac{x\ mol}{1.50L}$$

$x = 3.358 \times 10^{-5}\ mol$

$$\frac{102.48\ g}{1\ mol} = \frac{x\ g}{3.358 \times 10^{-5}}$$

$\boxed{x = 0.00344\ g}$

8. What mass of strontium hydroxide, $Sr(OH)_2(s)$, needs to be dissolved in 3.0 L of water to create a solution with a pH of 8.34?

$Sr(OH)_2(s) \rightarrow Sr^{2+}(aq) + 2OH^-(aq)$

$C = 1.09388 \times 10^{-6}$

$pOH = 5.66$

$[OH^-] = 2.18776 \times 10^{-6}$

$$\frac{1.09388 \times 10^{-6}\ mol}{1L} = \frac{x\ mol}{3L}$$

$x = 3.28 \times 10^{-6}\ mol$

$$\frac{121.04\ g}{mol} = \frac{x\ g}{3.28 \times 10^{-6}\ mol}$$

$\boxed{x = 4.0 \times 10^{-4}\ g}$

Acid-Base Indicators

Use your table of indicators to answer the following questions:

1. Fill in the spaces in the following table:

pH	colour of orange IV	colour of bromocresol green	colour of bromothymol blue	colour of phenol red
1.0	red	yellow	yellow	yellow
4.2	yellow	green	yellow	"
5.8	"	blue	yellow	"
9.0	"	blue	blue	red

2. Use the results displayed below to determine the pH ranges of the solutions.

Solution	colour of bromocresol green	colour of bromothymol blue	colour of phenolphthalein	pH
A	yellow <3.8	yellow <6.0	colourless <8.2	< 3.8
B	blue >5.4	blue >7.6	pink >10.0	> 10.0
C	blue >5.4	blue >7.6	colourless < 8.2	7.6 – 8.2
D	green	yellow	colourless	3.8 - 5.4
	3.8-5.4	<6	< 8.2	

3. What indicator could you use to distinguish between two solutions, one that has a pH of 8 and one that has a pH of 11?

phenolphthalein – colorless @ 8
pink @ 11

4. Using three indicators, design a procedure that would be able to identify four solutions that have pHs of 3, 6, 8, and 11, respectively.

methyl orange would be orange only in pH of 3
phenol red, would be yellow in the pH of 6
phenolphthalein would be colorless in the 8.2 & pink in the 11

5. What colour would bromocresol green be in an acid solution made by dissolving 4.3 g of pure hydrochloric acid in 20 L of water?

$C = [HCl(aq)] = [H_3O^+(aq)]$

$\frac{36.46\,g}{1\,mol} = \frac{4.3\,g}{x}$

$x = 0.1179\,mol$

$\frac{0.1179\,mol}{20\,L} = 0.00589\,mol/L$

$pH = -\log(0.00598)$

$= \boxed{2.23}$

Calculating pH after Dilution Don't worry about doing these!

1. A 35.0 mL volume of a 0.489 mol/L solution of hydrochloric acid is diluted to a volume of 300 mL.

   (a) What is the pH of the concentrated solution?

   (b) What is the concentration of the diluted solution?

   (c) What is the pH of the diluted solution?

   (d) Compare your answers to **(a)** and **(c)**. Considering the acid solution has been diluted, do your answers make sense?

2. A 50 mL volume of a 0.798$\bar{3}$ mol/L solution of sodium hydroxide, NaOH(aq), is diluted to a volume of 1.50L.

   (a) What is the pOH of the concentrated solution?

   (b) What is the pH of the concentrated solution?

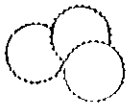
   (c) What is the concentration of the dilute solution?

   (d) What is the pOH of the dilute solution?

   (e) What is the pH of the dilute solution?

   (f) Compare your answers for **(b)** and **(e)**? Do they make sense considering the basic solution was diluted?

3. A 20 mL volume of a 3.52×10^{-3} mol/L solution of nitric acid is diluted to a volume of 25 L. What is the pH of the diluted solution?



4. A concentrated solution is made by dissolving 3.5 g of hydrobromic acid in 20.0L of water. A 50.0 mL volume of the concentrated solution is then used to make 100 L of a new solution. What is the pH of the new solution?