SI Chemistry - Full Discipline Demo

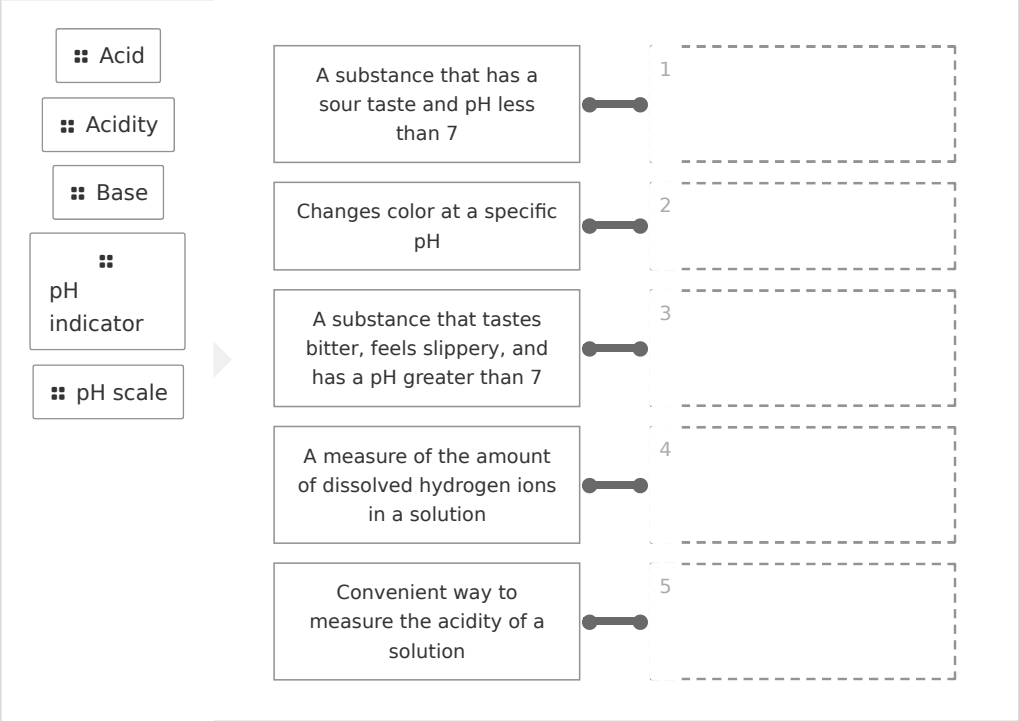
Determination of the Ka of a Weak Acid

Final Report - Answer Guide

Institution	Science Interactive University
Session	SI Chemistry - Full Discipline Demo
Course	SI Chemistry - Full Discipline Demo
Instructor	Sales SI Demo

Test Your Knowledge

Match each term with the best description.



Correct answers:

1 Acid 2 pH indicator 3 Base 4 Acidity 5 pH scale

Identify the statements as true or false.

- A solution with pH 4 is 100 times more acidic than a solution of pH 6.
- Bases are proton (H^+) donors.
- Household acids taste bitter and feel soapy.
- Low pH values are associated with basic solution.
- Strong acids have large K_a values.

True	False
1	2

Correct answers:

1 A solution with pH 4 is 100 times more acidic than a solution of pH 6.

Strong acids have large K_a values.

2 Bases are proton (H^+) donors.

Household acids taste bitter and feel soapy.

Low pH values are associated with basic solution.

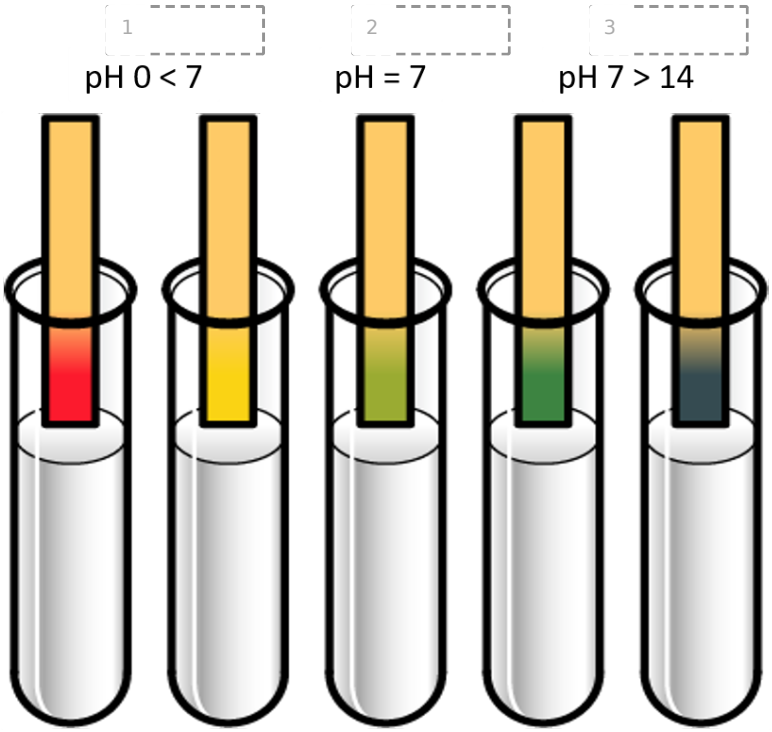
Determine if the pH values are acids, neutral, or bases.

Acid

Base

Neutral

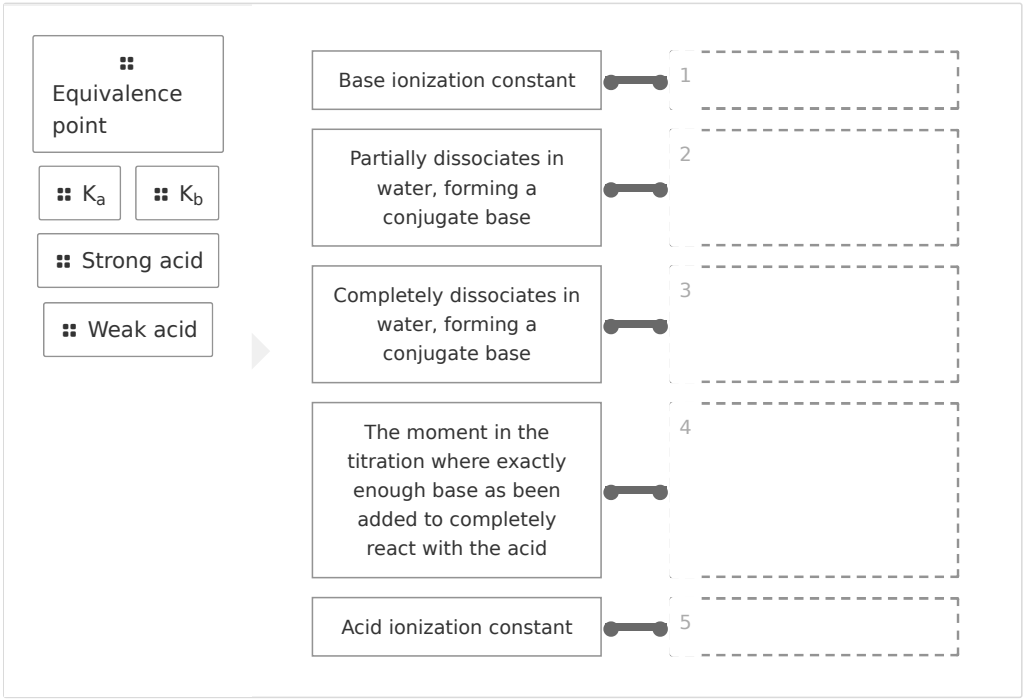
1 2 3



Correct answers:

1 Acid 2 Neutral 3 Base

Match each term with the best description.



Correct answers:

1 K_b 2 Weak acid 3 Strong acid 4 Equivalence point 5 K_a

Exploration

The generalized definition of a(n) _____ is a substance that tastes bitter, feels slippery, and interacts with _____.

- base; acids ✔
- acid; bases
- acid; substances
- base; substances

Acidity is a measure of the amount of dissolved hydroxide ions in a solution.

- True
- False ✔

The larger the value of K_a, the stronger the acid, and the smaller the value of K_a, the weaker the acid.

- [x] True
- [ ] False

The equivalence point of a weak acid titration is identified by a dramatic _____ in pH, resulting in a sharp _____ increase in the titration curve.

- [x] increase; vertical
- [ ] decrease; vertical
- [ ] increase; horizontal
- [ ] decrease; horizontal

Exercise 1

Looking at your results in Graph 1 and comparing them to the titration curve in Figure 4, does your data point for the equivalence point fall halfway between the "flatter" upper and lower regions of your graph as it should? Whether or not it does, is the pK_a calculated from it greatly affected?

Most students will not have a "perfect" equivalence point halfway up the vertical part of the graph. However, the pKa calculated from that should still be accurate, because no matter where their equivalence point lands on the vertical portion, compared to the perfect equivalence point the difference in "drops of NaOH" added is very small.

pH indicator strips work by changing color in the presence of solutions with varied pH values. Thinking about your procedure steps and results in Part 1, why do you think the pH of the unknown weak acid was not determined with pH indicator strips until Part 2?

that a rapid pH change would be difficult to determine with pH strips that would have to be used on the solution after every drop added.

Discuss possible causes of error in the experimental procedure. Why do you think there was error in the experimentally determined pK_a and K_a values of the unknown weak acid, in comparison to the values presented in Table 2?

The main possible cause of error is the degree to which the pH indicator strips can be read. As it is only possible to read the
pH strips to a degree of 0.5, it is not possible to obtain the correct pH reading of 4.75 – creating a definite percent error
between the experimental and accepted values. The level of error between pK_a and K_a differ by a factor of 10, as the K_a is 10-
fold greater in value, based on the pK_a value, increasing the error exponentially.

Do you think using a pH meter instead of pH indicator strips would have created a larger or smaller percent error? Explain your answer.

The use of a pH meter instead of pH indicator strips would have created a smaller percent error as there would have been a greater precision in pH readings. Additionally, over or undershooting the half equivalence point would not be likely as the pH would be read at the addition of each drop of NaOH, instead of every 10 drops of NaOH.

Why was phenolphthalein a good indicator to use for determining the equivalence point between the unknown weak acid and strong base?

Phenophthalein was a good indicator to use for determining the equivalence point between the unknown weak acid and the
strong base because the equivalence point of the unknown (acetic acid) is within the range in which phenolphthalein changes color (8.2-10)

Data Table 1: Determination of Equivalence Point
(SAMPLE ANSWER BELOW)

	Trial 1	Trial 2
Volume of Unknown Weak Acid (mL)	4	4
Total Number of Drops Required to Reach Equivalence Point	93	94
Average Number of Drops	93	

Data Table 2: Titration Curve Values
(SAMPLE ANSWER BELOW)

Drops NaOH Added	pH Value Trial 1	pH Value Trial 2	pH Value (Average)
Half-Equivalence Point	4.5	4.5	4.5
Equivalence Point	7.5	7.5	7.5
0	2.0	2.0	2.0
10	4.0	4.0	4.0
20	4.0	4.0	4.0
30	4.0	4.0	4.0
40	4.0	4.0	4.0
50	4.5	4.5	4.5
60	4.5	4.5	4.5
70	4.5	4.5	4.5
80	6.5	6.5	6.5
90	7.5	7.5	7.5
100	14.0	14.0	14.0
110	14.0	14.0	14.0
120	14.0	14.0	14.0

Panel 1: Equivalent Point Number of Drops
(SAMPLE ANSWER BELOW)

93 drops

Panel 2: Half-Equivalent Point Number of Drops
(SAMPLE ANSWER BELOW)

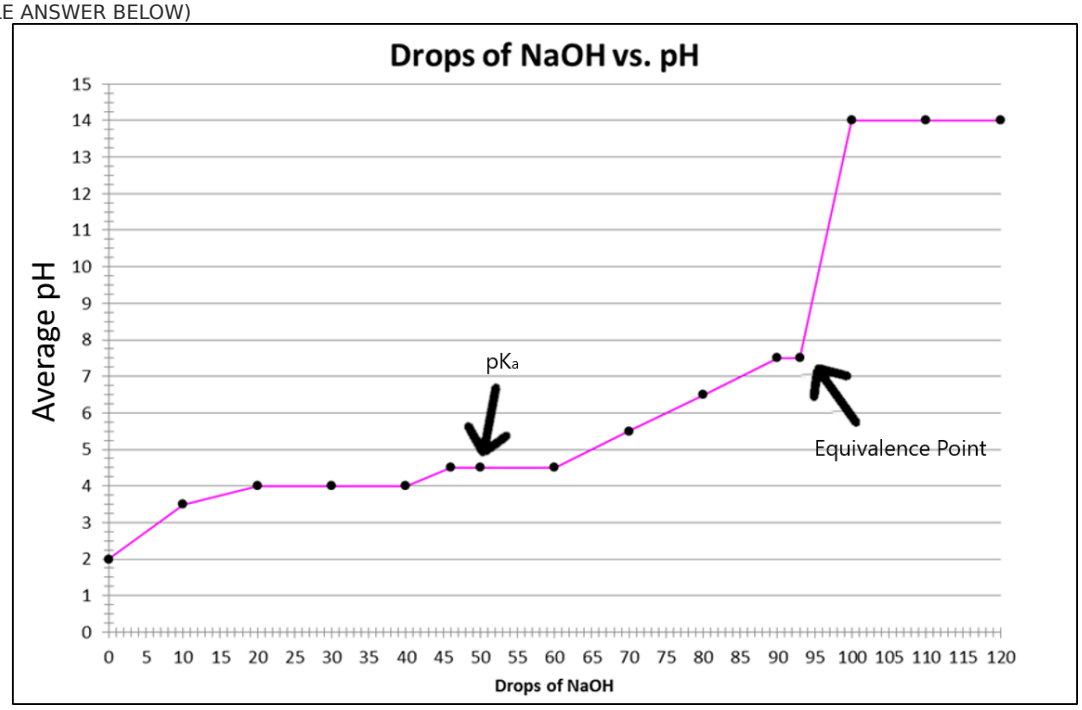
46 drops

Data Table 3: Determination of Unknown
(SAMPLE ANSWER BELOW)

pK_a of Unknown Weak Acid:	4.5

K_a of Unknown Weak Acid:	3.2×10^{-5}
Unknown Weak Acid Identity:	$Acetic\ Acid$
% Error pK_a:	5.26%
% Error K_a:	75.7%

Graph 1: Drops NaOH vs pH
(SAMPLE ANSWER BELOW)



Competency Review

Classification of an acid or a base is useful when predicting how a chemical will react with another chemical.

- [x] True ✔
- [ ] False

_____ donate H^+ ions to water and _____ accept H^+ ions from water.

- [x] Acids; bases ✔
- [ ] Bases; acids

The interaction of an acid and a base will result in a chemical reaction called _____.

- [ ] oxidation
- [ ] reduction
- [x] neutralization ✔

Acidity is a measure of the amount of dissolved _____ ions in a solution.

- [x] hydrogen ✔
- [ ] hydroxide
- [ ] sodium
- [ ] calcium

A pH of 6 is _____ times more acidic than a pH of 7.

- 2
- 10 ✔
- 50
- 100

Strong acids have _____ K_a values than weak acids.

- larger ✔
- smaller

A pH titration curve plots the change in pH that occurs as a base is titrated into an acid.

- True ✔
- False

Why is phenolphthalein added to an unknown acid before conducting a titration experiment?

- To speed the reaction of chemicals
- To serve as a pH indicator ✔
- To neutralize the acid

The half-equivalence point and the equivalence point should not be noted when measuring pH changes during a titration.

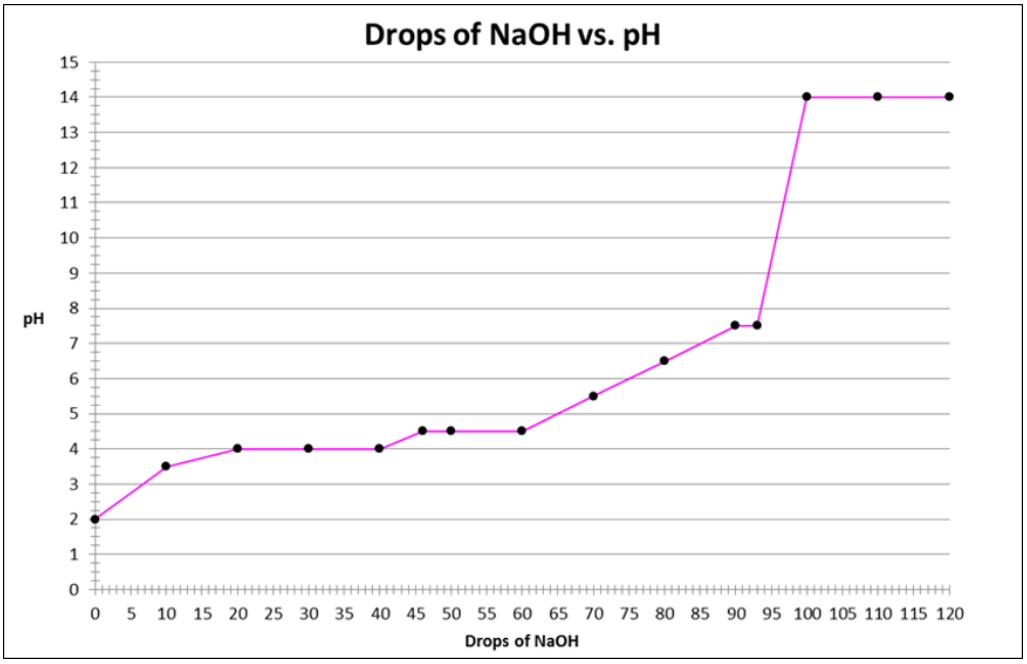
- True
- False ✔

An unknown acid was found to have a pK_a value of 6.28 and a K_a value of 5.2×10^{-7}. Use the table to identify the acid.

Acid Name	Acid Formula	K_a Value	pK_a Value
Chlorous acid	$HClO_2$	1.2×10^{-2}	2.92
Monochloracetic acid	$HC_2H_2ClO_2$	1.35×10^{-3}	3.87
Hydrofluoric acid	HF	7.2×10^{-4}	4.14
Acetic acid	$HC_2H_3O_2$	1.8×10^{-5}	4.75
Carbonic acid	H_2CO_3	4.3×10^{-7}	6.37
Hypochlorous acid	HOCl	3.5×10^{-8}	7.46
Hydrocyanic acid	HCN	6.2×10^{-10}	9.21

- ○ Chlorous acid
- ○ Acetic acid
- ○ Carbonic acid ✔
- ○ Hypochlorous acid

Refer to the titration graph to determine the volume of NaOH required to achieve the equivalence point.



- 55 drops
- 72 drops
- 93 drops ✔
- 107 drops

Extension Questions

An unknown acid was titrated two times with 0.10 M NaOH. The first titration was done using an indicator to determine the equivalence point volume. A second titration was carried out where the pH was determined throughout the entire titration. The data is given below.
Titration 1: mL unknown acid = 25.0, mL of NaOH needed to reach equivalence point = 30.00
Titration 2: mL unknown acid = 25.0

mL 0.1M NaOH Added	pH
0.0	3.72
5.0	5.82
10.0	6.22
15.0	6.52
20.0	6.82
25.0	7.22
30.0	9.63
35.0	11.92

a. What is the concentration of the unknown acid?
b. What is the K_a of the unknown acid?
c. Which of the indicators given below would be a good choice to use in the titration of this acid with the NaOH?

Indicator	pH Range of Color Change
Thymol Blue	1.2 - 2.8
Bromphenol Blue	3.0 - 4.6
Alizarin	5.6 - 7.2
Phenol Red	6.8 - 8.2
O-cresolphthalein	8.4 - 9.8
Alizarin Yellow R	10.0 - 12.0

(SAMPLE ANSWER BELOW)

$M_A \times V_A = M_B \times V_B$
$M_A = (0.10\ M)(30\ mL)/(25\ mL) = 0.12\ M$
pH = pK_a of acid at half equivalence point; since it takes 30 mL of NaOH to reach the equivalence point, it would take 15 mL to reach the half equivalence point. The pH at 15 mL is 6.52 which is equal to the pK_a of the acid. $K_a = 10^{-6.52} = 3.02 \times 10^{-7}$
The indicator should change color during the pH around the equivalence point. The pH at the equivalence point is 9.63 so the best choice of the indicators given is o-cresolphthalein.