

SI Chemistry - Full Discipline Demo

Acid-Base Chemistry

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.

Terms to match:

- A base
- A pH indicator
- An acid
- pH

Descriptions to match with:

- Changes color and suggests the amount of Hydrogen ions $[H^+]$ in a solution
- Accepts protons or produces hydroxide ions (OH^-) in an aqueous solution
- A measure of the concentration of hydrogen ions, $[H^+]$, in a solution
- Donates hydrogen ions (H^+) to other substances in a solution

Correct answers:

1 A pH indicator 2 A base 3 pH 4 An acid

Classify each chemical as an acid or base.

	Acid	Base
⚡ CH₃NH₂	1	2
⚡ HCOOH		
⚡ HF		
⚡ HNO₃		
⚡ KOH		
⚡ NH₃		

Correct answers:

1 HF HCOOH HNO₃ 2 CH₃NH₂ KOH NH₃

Predict the color that results from adding a drop of bromothymol blue (BTB) to each solution.

⚡ 1 M HCl ⚡ 1 M NaOH ⚡ A solution containing 10 mL of 1 M NaOH and 10.0 mL of 1 M HCl ⚡ A substance with a pH of 3 ⚡ A substance with a pH of 7 ⚡ A substance with a pH of 10		
Blue	Green	Yellow
1	2	3

Correct answers:

1 1 M NaOH A substance with a pH of 10

2 A solution containing 10 mL of 1 M NaOH and 10.0 mL of 1 M HCl
A substance with a pH of 7

3 1 M HCl A substance with a pH of 3

Label each substance in the chemical reaction.

⚡
Conjugate base

⚡
Hydronium ion

⚡
Strong acid

⚡
Water

$$\text{HCl}_{(aq)} + \text{H}_2\text{O}_{(l)} \rightleftharpoons \text{H}_3\text{O}^+_{(aq)} + \text{Cl}^-_{(aq)}$$

1

2

3

4

Correct answers:

1 Strong acid 2 Water 3 Hydronium ion 4 Conjugate base

Exploration

The greater the number of hydrogen ions in a solution, the more acidic the solution.

- ☐ True

☐ False
- ✓

Bases feel slippery to the skin because they degrade the ____ and ____ in the skin.

- ☐ fatty acids; dirt

☐ bacteria; oils

☐ fatty acids; oils

☐ All of the above
- ✓

The logarithm for pH is based on a scale of ____.

- ☐ 1
- ☒ 10 ✓
- ☐ 100
- ☐ 1000

A pH ____ changes color at a specific pH or over the course of a pH range.

- ☐ scale
- ☒ indicator ✓
- ☐ value
- ☐ None of the above

Strong acids and bases only partially dissociate in water.

- ☐ True
- ☒ False ✓

A conjugate acid is formed when the acid accepts a proton.

- ☐ True
- ☒ False ✓

Exercise 1

When you created hypotheses to guess whether each chemical was an acid or base, what specifically did you look for in the chemical formulas?

When the hypotheses were created, the students should have determined how they thought the original acid or base would ionize. If they thought it would create hydrogen ions, then they should

have guessed acid and if they thought it would create hydroxide ions, then they should have guessed base.

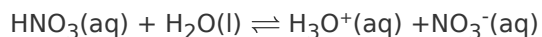
What is the value of using pH paper as an indicator?

pH paper is a quick method for determining pH and this paper shows a wide range of pH, precise to a pH of 2.

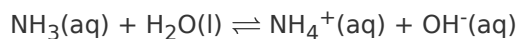
What is the value of using BTB as an indicator? When might BTB be a better choice than pH paper?

BTB was a good way to get a visual indication of whether the substance was an acid or a base. BTB may be a better choice than pH paper when measuring substances that have a relatively neutral pH.

Write the chemical equation of mixing nitric acid (HNO₃) with water.



Write the chemical equation of mixing ammonia (NH₃) with water.



What are the conjugate acids and conjugate bases of questions 4 and 5?

The conjugate acid and conjugate base for Question 4 is H_3O^+ and NO_3^- , respectively. The conjugate acid and conjugate base for Question 5 is NH_4^+ and OH^- , respectively.

Data Table 1: Tests with pH Paper and BTB
(SAMPLE ANSWER BELOW)

ID # - Chemical Name & Formula	Hypothesis: Acid or Base	pH	BTB Color	Acid or Base?
11A - Acetic acid (CH_3COOH)	No sample answer	No sample answer	No sample answer	No sample answer
11B - Nitric acid (HNO_3)	No sample answer	No sample answer	No sample answer	No sample answer
11C - Sulfuric acid (H_2SO_4)	No sample answer	No sample answer	No sample answer	No sample answer
11D - Phosphoric acid (H_3PO_4)	No sample answer	No sample answer	No sample answer	No sample answer
11E - Sodium acetate (CH_3COONa)	No sample answer	No sample answer	No sample answer	No sample answer
11F - Sodium bicarbonate (NaHCO_3)	No sample answer	No sample answer	No sample answer	No sample answer
11G - Sodium dihydrogen phosphate (NaH_2PO_4)	No sample answer	No sample answer	No sample answer	No sample answer
11H - Sodium hydrogen sulfate (NaHSO_4)	No sample answer	No sample answer	No sample answer	No sample answer
12A - Sodium hydrogen sulfite (NaHSO_3)	No sample answer	No sample answer	No sample answer	No sample answer
12B - Limewater ($\text{Ca}(\text{OH})_2$)	No sample answer	No sample answer	No sample answer	No sample answer
12C - Sodium phosphate (Na_3PO_4)	No sample answer	No sample answer	No sample answer	No sample answer
12D - Sodium hydrogen phosphate (Na_2HPO_4)	No sample answer	No sample answer	No sample answer	No sample answer
12E - Ammonium hydroxide (NH_4OH)	No sample answer	No sample answer	No sample answer	No sample answer
12F - Hydrochloric acid (HCl)	No sample answer	No sample answer	No sample answer	No sample answer
12G - Sodium carbonate (Na_2CO_3)	No sample answer	No sample answer	No sample answer	No sample answer

12H - Sodium hydroxide (NaOH)	No sample answer	No sample answer	No sample answer	No sample answer
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Exercise 2

Visually analyze the wells in the plate. What information can be gleaned from each well based on the color of the BTB indicator after each reaction has occurred? How do you know if neutralization has occurred? Cite examples from the well plate reactions to support your answer.

The students should notice that the wells containing solutions below pH 6.0 are yellow in color. In solutions in the pH range of 6.1 to 7.5, the indicator is bluish-green as observed in well D3 for the reaction between H_3PO_4 and NaOH. At a pH above 7.6, the BTB indicator is blue. Bromothymol blue indicator works in a pH range of 6.0 to 7.6. For example, in the reaction between HCl and NaOH, well A3 is yellow indicating that the resulting solution has a pH below 6.0. A strong acid-strong base neutralization occurs at pH = 7, so in well A3 neutralization has not yet happened. This is evidenced by the fact that well A3 is still yellow in color, and the pH paper shows a value of approximately pH = 4.

What factors determine if neutralization occurs during an acid-base reaction?

Neutralization depends on the concentration (molarity) and type (mono-, polyprotic) substances participating in the reaction. A neutralization reaction occurs when there is an exact stoichiometric ratio between the reactants. The moles of acid must equal the moles of base in the reaction.

Is the pH at the equivalence point always equal to 7? Explain your answer based on your experimental observations. Include a discussion of equivalence point pH values for strong versus weak acids.

The pH at the equivalence point for a reaction between a strong acid and a strong base is equal to 7. The pH is always greater than 7 for the reaction between a weak acid and a strong base because the conjugate base of the weak acid reacts with water to produce the weak acid and hydroxide ions, which increase the pH above neutral or pH = 7. For example, the equivalence point for the reaction between CH_3COOH and NaOH occurs at a pH of approximately 8.7. This is

indicated by the blue color in well B4 of the plate. For a polyprotic acid like H_3PO_4 , there is more than one equivalence point. As this acid has three protons to donate, there are three equivalence points. The second midpoint in this polyprotic acid/strong base titration curve occurs at a pH of 7.21. This happens prior to reaching the second equivalence point. In well D3 the solution is light green, and the pH paper test shows a pH of approximately 7. The third midpoint in this polyprotic acid/strong base reaction occurs at a pH greater than 12. Twelve drops of NaOH are required to neutralize H_3PO_4 according to the stoichiometry. Well D6 shows an approximate pH of 11 based on the universal pH strip test.

In all the chemical reaction performed in Exercise 2, neutralization occurs when the pH is neutral (7) or basic (>7). Did any of the reaction not result in a color change of the BTB indicator from yellow (acid) to blue (base)? Explain why neutralization may not have occurred in one or more reactions.

If either the acid or the base is slightly more concentrated than indicated on the pipet labels, then the calculated number of drops of NaOH required for neutralization may not be accurate. If the drop sizes are not equivalent, then reactions may require more drops than calculated based on the stoichiometry. For instance, in the reaction between 1.0 M HCl and 1.0 M NaOH, four drops of NaOH are required to neutralize four drops of HCl; however, students may realize that it will take an additional drop or more to neutralize the 1.0 M HCl, if drop volumes have varied. Trapped air bubbles in the pipet tip may result in non-equivalent drop volumes.

Data Table 2: Acid-Base Reactions
(SAMPLE ANSWER BELOW)

Well Plate Row	1	2	3	4	5	6
A, HCl	pH=2	pH=3	pH=4	NaOH drops and pH=4, 10		
B, $\text{CH}_3\text{CO}_2\text{H}$	pH=6	pH=6	pH=7	NaOH drops and pH=4, 10		
C, H_2SO_4	pH=2	pH=3	pH=3	pH=4	pH=5	NaOH drops and pH=8, 10
D, H_3PO_4	pH=5	pH=7	pH=7	pH=8	pH10	NaOH drops and pH=12, 10

Photo 1: Acid-Base Reactions Well Plate
(SAMPLE ANSWER BELOW)





Exercise 3

What types of properties about the substance that you tested did you use to determine whether you thought it was an acid or base?

Student answers will vary. They may say a sour taste, a bitter taste, slippery feel or not a slippery feel. Some they may not know since they are recommended not to touch or taste anything that they have not touched or tasted previously.

Did any of your findings surprise you? Why or why not?

Student answers will vary.

Data Table 3: Household Acids and Bases
(SAMPLE ANSWER BELOW)

Household Substance	Prediction: Acid, Base, or Neutral?	pH	Conclusion: Acid, Base, or Neutral
Student answers will vary.	No sample answer	No sample answer	No sample answer
No sample answer	No sample answer	No sample answer	No sample answer
No sample answer	No sample answer	No sample answer	No sample answer
No sample answer	No sample answer	No sample answer	No sample answer
No sample answer	No sample answer	No sample answer	No sample answer

Competency Review

Acids are substances that are characterized by their ability to donate ____, or ____ ions.

- ☐ neutrons; hydrogen

☒ protons; hydrogen

☐ protons; hydroxide

☐ None of the above
- ✓

The greater the number of hydroxide ions in a solution, the more ____ the solution.

- ☐ acidic

☒ basic
- ✓

Concentrated acids and bases are found in everyday substances such as coffee and hand soap.

- ☐ True
- ☒ False

✓

Based on the logarithm for pH, a pH of 2 is ____ times more acidic than a pH of 4.

- ☐ 2
- ☐ 10
- ☒ 100
- ☐ None of the above

✓

A neutral substance is a substance that has a pH of 0.

- ☐ True
- ☒ False

✓

A pH of ____ indicated an acidic solution.

- ☒ 3
- ☐ 7
- ☐ 12
- ☐ None of the above

✓

pH is a measure of the concentration of ____ ions in a solution.

- ☒ hydrogen
- ☐ hydroxide
- ☐ sodium
- ☐ None of the above

✓

In the presence of an acid, water behaves as a(n) ____ and accepts the proton donated by the acid to create a ____ ion.

- ☐ acid; hydrogen
- ☐ base; hydroxide
- ☒ base; hydronium ✓
- ☐ acid; hydronium

Weaker acids have a ____ pH than strong acids and ____ dissociate in water.

- ☒ higher; partially ✓
- ☐ higher; fully
- ☐ lower; partially
- ☐ lower; fully

In the presence of an acid, water will behave as a(n) _____. In the presence of a base, water will behave as a(n) _____.

- ☒ base; acid ✓
- ☐ acid; base
- ☐ acid; acid
- ☐ base; base

A(n) ____ reaction occurs when an acid and a base are present in the same solution.

- ☐ oxidation-reduction
- ☐ hydrolysis
- ☒ neutralization ✓
- ☐ None of the above

The reaction below is an example of dissociation of an acid in water.



☐ True



☐ False

Bromothymol blue turns ____ in a strong acidic solution.

☐ Blue

☐ Green

☐ Yellow



☐ None of the above

How might a scientist determine if a household substance is an acid or a base?

☐ Mix the substance with a base and observe it to see if it is neutral.

☐ Mix the substance with an acid and observe if it to see if it is neutral.

☐ Use pH paper to determine the pH.



☐ None of the above

Extension Questions

List the conjugate acid or conjugate base for each chemical.

a. The acid HF

b. The base KOH

c. The base NH₃

d. The acid HNO₃

e. The acid HCOOH

f. The base CH₃NH₂

(SAMPLE ANSWER BELOW)

a. The acid HF: F⁻

b. The base KOH: H₂O

c. The base NH₃: NH₄⁺

d. The acid HNO₃: NO₃⁻

e. The acid HCOOH: COOH^-

f. The base CH_3NH_2 : CH_3NH_3^+

List the conjugate acid or conjugate base for each chemical.

a. The acid HF

b. The base KOH

c. The base NH_3

d. The acid HNO_3

e. The acid HCOOH

f. The base CH_3NH_2

(SAMPLE ANSWER BELOW)

a. The acid HF: F^-

b. The base KOH: H_2O

c. The base NH_3 : NH_4^+

d. The acid HNO_3 : NO_3^-

e. The acid HCOOH: COOH^-

f. The base CH_3NH_2 : CH_3NH_3^+