(c) Litmus paper only provides a quick, inexpensive test to classify substances as being acidic, basic, or neutral. Wide-range pH test paper is useful when comparing the acidity of a wide range of substances. The advantage of the pH meter over test paper is that it can provide specific pH readings, useful when comparing solutions that have similar pH values, indistinguishable by the wide-range pH test paper.
(d) Calibration to a specific pH is necessary to ensure that the initial reading of the meter is correct.

INVESTIGATION 8.3.1 THE pH OF SALT SOLUTIONS

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Prediction

(a) According to the concept of hydrolysis, the pH of the salts tested in order from lowest to highest is:

1. $NaHSO_{4(aq)}$ pH = 1.50
2. $Fe(SO)_{4(aq)}$ pH > 1.76
3. $FeCl_{3(aq)}$ pH = 1.91
4. $Al_2(SO_4)_{3(aq)}$ pH > 2.85
5. $AlCl_{3(aq)}$ pH = 3.00
6. $CuSO_{4(aq)}$ pH > 4.50
7. $NH_4Cl_{(aq)}$ pH = 5.12
8. $NaCl_{(aq)}$ pH = 7.00
9. $(NH_4)_2SO_{4(aq)}$ pH < 7.50
10. $K_2SO_{4(aq)}$ pH = 7.50
11. $(NH_4)_2OOCCOO_{(aq)}$ pH < 8.63
12. $NH_4CH_3COO_{(aq)}$ pH < 8.87
13. $NaHCO_{3(aq)}$ pH < 9.68
14. $(NH_4)_2CO_{3(aq)}$ pH < 11.66
15. $Na_2CO_{3(aq)}$ pH = 11.66
16. $Na_3PO_{4(aq)}$ pH = 12.69

The reasoning behind the above prediction is provided in the examples below.

For $NaHSO_{4(aq)}$, $HSO_{4(aq)}^-$ is amphoteric but $HSO_{4(aq)}^-$ is a weaker base than water. Therefore, a calculation involving $HSO_{4(aq)}^-$ being only an acid is justified.

$$[H^+_{(aq)}] = \sqrt{K_a\,[HSO^+_{4(aq)}]}$$

$$= \sqrt{\frac{1.0 \times 10^{-2}\ \text{mol}}{1\ \text{L}} \times \frac{0.10\ \text{mol}}{1\ \text{L}}}$$

$$[H^+_{(aq)}] = 3.1 \times 10^{-2}\ \text{mol}$$

$$pH = -\log[H^+_{(aq)}]$$

$$= -\log(3.1 \times 10^{-2}\ \text{mol})$$

$$pH = 1.50$$

Procedure

(b)

1. Dip a strip of pH paper into the 1.0 mol/L solution for a controlled period of time.
2. Observe and record the pH.
3. Repeat steps 1 and 2 for each of the salt solutions.
4. Dispose of all solutions into the sink and flush with plenty of water.

Evidence

pH of Various Salts			
Salt	**pH**	**Salt**	**pH**
$Na_2CO_{3(aq)}$	11.8	$(NH_4)_2CO_{3(aq)}$	11.3
$Na_3PO_{4(aq)}$	12.4	$(NH_4)_2SO_{4(aq)}$	7.4
$Al_2(SO_4)_{3(aq)}$	3.0	$K_2SO_{4(aq)}$	7.6
$AlCl_{3(aq)}$	3.0	$CuSO_{4(aq)}$	4.9
$NaCl_{(aq)}$	6.8	$Fe(SO)_{4(aq)}$	2.1
$NH_4Cl_{(aq)}$	5.3	$FeCl_{3(aq)}$	2.1
$(NH_4)_2OOCCOO_{(aq)}$	8.2	$NaHCO_{3(aq)}$	9.5
$NH_4CH_3COO_{(aq)}$	8.5	$NaHSO_{4(aq)}$	1.9

Analysis

(c) According to the evidence gathered in this experiment, the order of pH from lowest to highest is:

1. $NaHSO_{4(aq)}$ pH = 1.50
2. $Fe(SO)_{4(aq)}$ pH > 1.76
3. $FeCl_{3(aq)}$ pH = 1.91
4. $Al_2(SO_4)_{3(aq)}$ pH > 2.85
5. $AlCl_{3(aq)}$ pH = 3.00
6. $CuSO_{4(aq)}$ pH > 4.50
7. $NH_4Cl_{(aq)}$ pH = 5.12
8. $NaCl_{(aq)}$ pH = 7.00
9. $(NH_4)_2SO_{4(aq)}$ pH < 7.50
10. $K_2SO_{4(aq)}$ pH = 7.50
11. $(NH_4)_2OOCCOO_{(aq)}$ pH < 8.63
12. $NH_4CH_3COO_{(aq)}$ pH < 8.87
13. $NaHCO_{3(aq)}$ pH < 9.68
14. $(NH_4)_2CO_{3(aq)}$ pH < 11.66
15. $Na_2CO_{3(aq)}$ pH = 11.66
16. $Na_3PO_{4(aq)}$ pH = 12.69

Evaluation

(d) The experimental design is judged to be adequate because it is simple, efficient, and economical with adequate controls. Without controlling the time, the results might be different. The temperature has to be assumed as controlled although there was no thermometer monitoring the temperature change during the experiment. The procedure is judged to be adequate because the evidence was reliably (consistently) collected. (If a pH meter is shared among the solutions, the Procedure needs to include the step of rinsing the pH meter between uses.) The skills employed are adequate because they are simple and have been practised before. (If one or more pH meters are used, more practice with a pH meter may be necessary.) There is sufficient confidence in the evidence provided by the design, procedure, and skills to proceed with judging the prediction and the hydrolysis concept.

The prediction is judged to be verified because the relative pH found is consistent with the prediction (in over 90% of the cases). The concept of hydrolysis is judged to be acceptable because the prediction, which is based upon the concept of hydrolysis, is verified. The concept of hydrolysis has survived another test and should be able to be used with more confidence in the future.