Australian Islamic College 2021
ATAR Chemistry Units 3 and 4
Task 3
Weighting: 5% (1% Practical Work, 4% Validation Test)
Investigation: Hydrolysis of Salts

Time Available

Practical Work: 1 Period

Validation Test: 45 minutes

Please do not turn this page until instructed to do so.

First Name	Surname

Mark	Percentage

Equipment allowed: Pens, pencils, erasers, whiteout, rulers and non-programmable calculators permitted by the Schools Curriculum and Standards Authority.

**Practical Work**

Introduction:

When a base neutralises an acid, the result of the reaction is a salt and water. You would expect, therefore that the salt dissolved in the water would be neither acidic nor basic; that is, its pH should be 7 at 25 °C. However, some ions are known to undergo a reaction with water, in a process known as hydrolysis. When a positive ion reacts with water the process is called *cationic hydrolysis* and results in an acidic solution. When a negative ion reacts with water, the process is called *anionic hydrolysis* and results in a basic solution. In the case of some salts, both the anion and the cation hydrolyse and the resulting pH depends on which ion undergoes hydrolysis the most.

In this experiment, you will determine the pH of a number of salt solutions in water. From the results you will deduce information about which ions have hydrolysed. The type of hydrolysis is related to the relative strengths of the acid and the base from which a given salt is formed. In addition, you will measure the pH of the salt of an amphiprotic anion (an anion which can either gain or lose a proton) and use the result to deduce which occurs to a greater extent.

The pH of each solution will be determined by adding some universal indicator to the solution.

Universal indicator is a mixture of several different indicators which change colour at different pH values, so that a sequence of colour changes is observed over a large pH range. The sequence usually approximates the colours of the spectrum, with red at low pH, green near neutral, and blue or violet at high pH.

Salts formed from a strong acid and a strong base do not undergo hydrolysis. Anionic hydrolysis occurs when a salt is formed from a strong base and a weak acid. For example, consider the weak acid HF reacting with NaOH.

$$HF_{(aq)} + NaOH_{(aq)} \rightarrow NaF_{(aq)} + H_2O_{(l)}$$
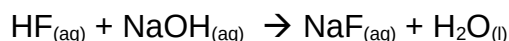
The NaF salt that is produced is a basic salt due to anionic hydrolysis.

$$F^-_{(aq)} + H_2O_{(l)} \leftrightarrow HF_{(aq)} + OH^-_{(aq)}$$
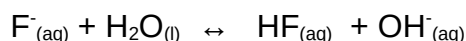
When we find the equilibrium constant for this equation, since we are starting with a base F^- we are determining a K_b value. K_b is the equilibrium constant for a base. Note: You can obtain the K_a value for F^- by calculating K_w / K_b.

Objectives:

1) To measure the pH of a number of salt solutions and identify those which have undergone hydrolysis.
2) To explain why hydrolysis occurs (or does not occur) in terms of relative strengths of the acid and base from which a given salt is made and to write an ionic equation for each hydrolysis.
3) To deduce which is greater for an amphiprotic anion, the K_a (the cationic hydrolysis and further ionisation of the ion) or the K_b (the anionic hydrolysis).

Materials:

Apparatus:

- Reaction plate with wells   - Colour chart for universal indicator used
- Safety goggles   - Lab coat
- Water bottle with distilled water   - Soap and paper towels

Reagents: 0.1 M solutions of each of the following

- Sodium ethanoate
- Sodium chloride
- Ammonium chloride
- Ammonium sulfate
- Calcium nitrate
- Iron(III) sulfate
- Sodium carbonate
- Sodium sulfate
- Potassium bromide
- Ammonium oxalate
- Ammonium ethanoate
- Sodium hydrogen carbonate ($NaHCO_3$)
- Sodium monohydrogen phosphate (Na_2HPO_4)
- Sodium dihydrogen phosphate (NaH_2PO_4)
- Universal indicator solution

Procedure:

1. Put on your safety glasses and lab coat.
2. Make sure you have a reaction plate and a water bottle with distilled water. Wash the reaction plate with tap water and then rinse it with distilled water.
3. Squeeze some of the distilled water into a well in a reaction plate and add two drops of universal indicator as a control.
4. Half fill a well in a reaction plate with one of the solutions. Add 2-3 drops of universal indicator.
5. Record the colour that the solution gives to the indicator. Consult the colour chart provided for your universal indicator and determine the pH of this solution.
6. Repeat this process for all the other solutions you have been provided.
7. Before you leave the laboratory wash your hands thoroughly with soap and water and return all equipment as directed by your teacher. Wipe clean and dry your bench.

Wash all solutions down the sink with lots of water.

Contamination of solutions: Listen to the teacher's instructions about avoiding cross-contamination of solutions.

Safety: At the teacher's discretion up to 20% of your marks for this assessment may be deducted for unsafe behaviour during the practical portion of this assessment.

Pay attention to your teacher's instructions about safety and contamination of solutions. This information may be examined in the validation test.

Data and Observations: (7 marks)

Marking: 1 mark off per mistake. Some flexibility is allowed with colour and pH results.

Solution	Colour of Universal Indicator	pH	Type of hydrolysis reaction (anionic, cationic, both, or neither)
Sodium chloride	**Green**	**7**	**Neither**
Sodium ethanoate (sodium acetate)	**Green/blue**	**8**	**Anionic**
Ammonium chloride	**Orange**	**5**	**Cationic**
Ammonium sulfate	**Orange**	**5**	**Both**
Calcium nitrate	**Green**	**7**	**Neither**
Iron(III) sulfate OR iron(II) sufate	**Red**	**3**	**Both**
Sodium carbonate	**Purple**	**10**	**Anionic**
Sodium sulfate	**Blue**	**7-8**	**Anionic**
Potassium bromide	**Green**	**7**	**Neither**
Ammonium oxalate	**Green**	**7**	**Both**
Ammonium ethanoate (ammonium acetate)	**Green**	**7**	**Both**

Table 2:

Solution	Colour of Universal Indicator	pH	Type of hydrolysis reaction (anionic, cationic, both, or neither)
Sodium hydrogen carbonate	**Purple**	**9**	**Anionic (Accept both)**
Sodium dihydrogen phosphate (aka mono-sodium phosphate)	**Orange**	**5**	**Anionic (Accept both)**
Sodium monohydrogen phosphate (aka sodium hydrogen orthophosphate)	**Blue**	**8**	**Anionic (Accept both)**

Australian Islamic College 2021

ATAR Chemistry Units 3 and 4

Task 3

Weighting: 5% (1% Practical Work; 4% This Validation Test)

Hydrolysis of Salts Validation Test

Test Time: 45 minutes

Please do not turn this page until instructed to do so.

First Name	Surname
ANSWERS	

Teacher

Mark / 31	Percentage

Equipment allowed: Pens, pencils, erasers, whiteout, rulers and non-programmable calculators permitted by the Schools Curriculum and Standards Authority.

Special conditions:

2 marks will be deducted for failing to write your full name on this test paper.

Teacher help: Your teacher can only help you during your test in one situation.

> If you believe there is a mistake in a question show your teacher and your teacher will tell you if there is a mistake in the question and if appropriate, how to fix that mistake.

Spelling of Science words must be correct. Unless otherwise indicated, science words with more than one letter wrong (wrong letter and/or wrong place) will be marked wrong. The spelling of IUPAC names must be exactly correct.

Equations must be written balanced, with correct state symbols and an appropriate type of arrow or they will be marked wrong.

For questions worth more than one mark involving calculations, your working out must be shown. Calculations that cannot be easily understood by the marker or do not follow a logical sequence from top of the page to the bottom of the page will lose marks.

Follow-on marks will not be paid.

Questions must be answered in this booklet.

1. Each of the following substances has been classified as the type of substance it is. Write an appropriate ionic reaction to show the behaviour of that substance, or part of that substance, in water that explains why it is that type of substance. The reactions you write could be Brønsted-Lowry reactions, dissociation reactions, hydrolysis reactions or other reactions.
The first one has been done for you as an example.
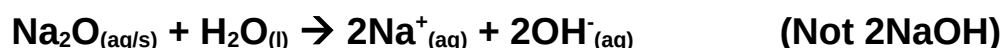
Substance: Hydrochloric acid
Classification: Strong acid
Reaction showing behaviour in water: $HCl_{(aq)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$

(4 marks)

a. Substance: Sodium oxide

Classification: Strong base

Reaction showing behaviour in water:

$$Na_2O_{(aq/s)} + H_2O_{(l)} \rightarrow 2Na^+_{(aq)} + 2OH^-_{(aq)} \qquad \textbf{(Not 2NaOH)}$$

b. Substance: Ammonium nitrate

Classification: Acidic salt

Reaction showing behaviour in water:

$$NH_4^+{}_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + NH_{3(aq/g)}$$
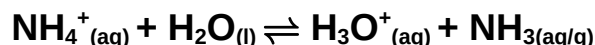
c. Substance: Aluminium bromide

Classification: Acidic salt

Reaction showing behaviour in water:

$$Al(H_2O)_6^{3+}{}_{(aq)} + H_2O_{(l)} \rightleftharpoons Al(H_2O)_5(OH)^{2+}{}_{(aq)} + H_3O^+_{(aq)}$$

d. Substance: Lithium sulfate

Classification: Basic salt

Reaction showing behaviour in water:

$$SO_4^{2-}{}_{(aq)} + H_2O_{(l)} \rightleftharpoons OH^-_{(aq)} + HSO_4^-{}_{(aq)}$$
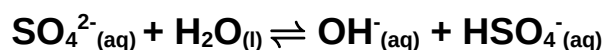
Each answer 1 mark. No half marks. All reactions must be balanced, with state symbols and correct type of arrow.

2. The colours produced with universal indicator at various pH values are given on the table below.

Colour	Dark Red	Red	Red	Orange Red	Orange	Orange yellow	Greenish yellow	Green	Greenish blue	Blue	Navy blue	Purple	Dark purple	Violet	Violet
pH	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14

You test the pH of 5 aqueous solutions using universal indicator. The colours you get are, in random order, as follows:

Red, orange, dark purple, greenish-yellow and greenish-blue.

The 5 aqueous solutions that you have tested are 0.1 mol L^{-1} solutions of the following substances:

KNO_3, $NaNO_2$, NH_4NO_2, NH_4Cl, KOH.

Match the substance to the colour of the universal indicator.

(4 marks)

| Formula of Substance	Colour of Universal Indicator
KNO_3	**Orange OR Greenish-yellow**
$NaNO_2$	**Greenish-blue**
NH_4NO_2	**Orange OR Greenish-yellow**
NH_4Cl	**Red**
KOH	**Dark purple**

1 mark off per mistake.

3. The formula for potassium cyanide is KCN. Given that potassium cyanide is a basic salt:
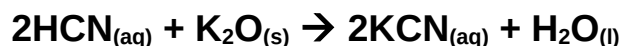
a. Write a reaction to show the formation of potassium cyanide by a neutralisation reaction between an acid and a base.

(1 mark)

$HCN_{(aq)} + KOH_{(aq/s)} \rightarrow KCN_{(aq)} + H_2O_{(l)}$
or
$2HCN_{(aq)} + K_2O_{(s)} \rightarrow 2KCN_{(aq)} + H_2O_{(l)}$
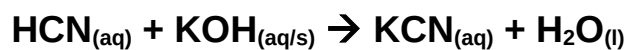
Equation must be balanced and with correct state symbols.

b. Classify the acid you used in your reaction in part (a) as a strong acid or a weak acid and explain your choice of answer.

(1 mark)

Weak acid
Because it is the conjugate acid of a weak base / the CN- ion.
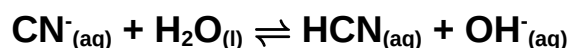**OR**
Because a strong base and a weak acid form a basic salt.
1 mark for correct classification with correct reason. No mark for 'weak acid' only.
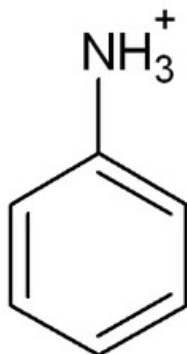**Other answers at the teacher's discretion may be accepted.**

c. Write a hydrolysis reaction that shows why potassium cyanide is a basic salt.

(1 mark)

$CN^-_{(aq)} + H_2O_{(l)} \rightleftharpoons HCN_{(aq)} + OH^-_{(aq)}$

Equation must be balanced with correct state symbols and reversible arrow.

4. The structure of the anilinium ion ($C_6H_5NH_3^+$) is shown below.

$$\overset{+}{NH_3}$$

a. The anilinium ion undergoes a weak hydrolysis reaction when dissolved in water. Does the anilinium ion undergo cationic hydrolysis or anionic hydrolysis? Explain how you know.
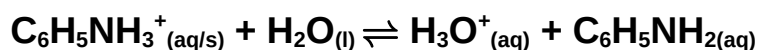
(1 mark)

Cationic hydrolysis
Because it is positively-charged / it is a cation
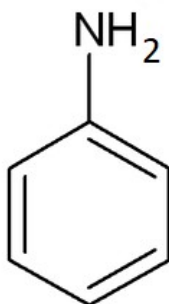**Or other correct reason at the teacher's discretion.**
1 mark for the entire answer. No mark for just 'cationic hydrolysis'.

b. Write the hydrolysis reaction between the anilinium ion and water. You do not need to draw the full structure of the anilinium ion.

(1 mark)

$$C_6H_5NH_3^+{}_{(aq/s)} + H_2O_{(l)} \rightleftharpoons H_3O^+{}_{(aq)} + C_6H_5NH_{2(aq)}$$

c. A substance closely related to the anilinium ion is aniline, which is shown below.

$$NH_2$$

What type of substance is aniline – a strong base, a weak base, a strong acid or a weak acid? Justify your answer.

(1 mark)

It is a weak base
Because it is the conjugate base of a weak acid
Or other correct answer at the teacher's discretion.
1 mark for the full answer. No mark for just 'weak base'.

5. Solid ammonium phosphate is dissolved in water.
   a. Write the reaction showing the dissociation of ammonium phosphate as it dissolves in water.

   (1 mark)

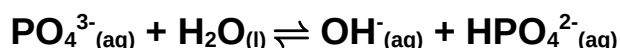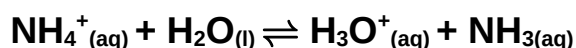 $$(NH_4)_3PO_4(_{aq/s}) \rightarrow 3NH_4^+{}_{(aq)} + PO_4^{3-}{}_{(aq)}$$

   b. Will the ammonium phosphate undergo cationic hydrolysis, anionic hydrolysis, both cationic and anionic hydrolysis, or neither?

   (1 mark)

   Both

   c. Write equation/s for the cationic and/or anionic hydrolysis that will occur after the ammonium phosphate is dissolved in water.

   (2 marks)

   $$NH_4^+{}_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+{}_{(aq)} + NH_{3(aq)}$$

   $$PO_4^{3-}{}_{(aq)} + H_2O_{(l)} \rightleftharpoons OH^-{}_{(aq)} + HPO_4^{2-}{}_{(aq)}$$

   1 mark per equation with mistake.

   d. The values of K_a and K_b for the relevant reactions are as follows:

   Value of K_a for cationic hydrolysis = 5.6×10^{-10}.
   Value of K_b for anionic hydrolysis = 5.9×10^{-3}.

   After the ammonium phosphate is dissolved in water, the pH of the water is tested. Will the pH be more than 7 or less than 7? Justify your answer.

   (1 mark)

   More than 7 because $K_b > K_a$.
   1 mark for full answer. No mark for just 'more than 7'.
   No mark for solution will be basic because $K_b > K_a$.

6. Give the formula of a salt that contains two different ions that can both undergo cationic hydrolysis.

   (1 mark)

   NH_4HSO_4
   Or any other correct answer
   e.g. a salt containing the ammonium ion, aluminium ion etc paired with an amphiprotic species.
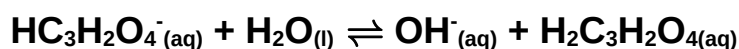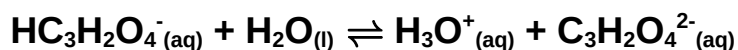
7. The formula of malonic acid is $H_2C_3H_2O_4$.
   a. Write the formula of the amphiprotic species that will result from the ionisation of malonic acid in water.

   (1 mark)

   $HC_3H_2O_4^-$ **(Also grudgingly accept $H_2C_3HO_4^-$ and H_3O^+)**

   b. For the amphiprotic species you identified in part (a) above, write two hydrolysis reactions, one that produces hydronium ions and the other that produces hydroxide ions.

   (2 marks)

   $HC_3H_2O_{4(aq)}^- + H_2O_{(l)} \rightleftharpoons H_3O_{(aq)}^+ + C_3H_2O_{4(aq)}^{2-}$

   $HC_3H_2O_{4(aq)}^- + H_2O_{(l)} \rightleftharpoons OH_{(aq)}^- + H_2C_3H_2O_{4(aq)}$

   1 mark per equation with any mistakes. No half marks.
   No follow-on marks.

8. When you test the pH of an aqueous solution of sodium chloride you expect the colour of the universal indicator to be green. Describe in detail a scenario resulting from contamination of solutions that could result in the universal indicator turning orange when added to your sodium chloride solution. Identify the substances involved.

   (3 marks)

   Any acceptable answer at the teacher's discretion.

   e.g. Before testing the pH of the sodium chloride solution the same test was done with ammonium chloride. When doing the test you touched the dropper from the universal indicator bottle to the ammonium chloride, contaminating the dropper. You used the same dropper to add universal indicator to your sodium chloride. The presence of ammonium chloride in the sodium chloride solution caused the orange colour, because ammonium chloride is acidic.

   Identifying means or instrument of contamination (1).

   Identifying contaminating substance (1).

   Explanation of how that contaminating substance caused the orange colour (1).

9. 100.0 g of barium hydroxide pellets are stirred into a beaker containing 2.0 L of 0.500 mol L^{-1} HCl. What is the pH of the resulting solution? During your calculations determine which reactant is the limiting reagent. Give your answer to the appropriate number of significant figures.

(5 marks)

$2HCl_{(aq)} + Ba(OH)_{2(aq)} \rightarrow BaCl_{2(aq)} + 2H_2O_{(l)}$
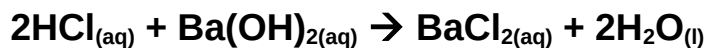
$n(HCl) = cV = 0.500 \times 2.0 = \underline{1.000}$ mol

(1)

$n(Ba(OH)_2) = \dfrac{m}{M} = \dfrac{100.0}{(137.3 + (2 \times 16.00) + (2 \times 1.008))} = \underline{0.5837}$ mol

(1)

$SR = \dfrac{HCl}{Ba¿¿} = \dfrac{2}{1} = 2$

$AMR = \dfrac{HCl}{Ba¿¿} = \dfrac{1.000}{0.5837} = 1.7132$

SR > AMR

Therefore <u>HCl is limiting reagent</u>.   **No mark for a lucky guess.**

(1)

$n(Ba(OH)_2$ used in reaction$) = ½ \times n(HCl) = ½ \times 1.000 = 0.500$ mol

$n(Ba(OH)_2$ remaining after reaction$) = 0.5837 - 0.500 = 0.0837$ mol

$n(OH^-) = 2 \times 0.0837 = 0.1674$ mol

$c(OH^-) = \dfrac{n}{V} = \dfrac{0.1674}{2.000} = \underline{0.0837}$ mol L^{-1}

(1)

$pOH = -\log[OH^-] = -\log(0.0837) = 1.0773$

$pH = 14 - pOH = 14 - 1.0773 = 12.9227$

$pH = \underline{13}$ (2 SF)

(1)

Final mark not awarded if SF wrong.

SF do not need to be correct except for final answer.

Other methods of calculating LR and pH can be accepted at the teacher's discretion.

No follow-on marks.