Raffles Institution Raffles Programme
Year Three Chemistry

Name: _____ ( ) Class: _____ Date: _____

Notes – Concentration, Strength and Basicity of Acids

One model of an acid is that it reacts with water to give hydrogen ions (H^+), which then combine with water molecules to form hydronium or oxonium ions (H_3O^+).

For an acid 'HA' dissolving in water, it may be represented as follows:

$$\mathbf{HA\,(l) + H_2O\,(l) \rightarrow H_3O^+\,(aq) + A^-\,(aq)}$$

We say that the acid molecules have **"ionized"**.

The A in HA does not stand for a particular element, but for the atom or group of atoms bonded to hydrogen in the molecule.

So, for example, in hydrochloric acid 'HA' would be HCl, and 'A^-' would be Cl^-, whilst in ethanoic acid 'HA' would be CH_3COOH, and 'A^-' would be CH_3COO^-.

Classifying acid solutions

1 Acids (and alkalis) can be described as 'strong' or 'weak', and as 'concentrated' or 'dilute'.

2 The following diagrams are simplified representations of strong, weak, concentrated or dilute acid solutions. Only four types of particle are shown. (Note that there are other particles present which are not shown). The following key is used to distinguish between the different particles:

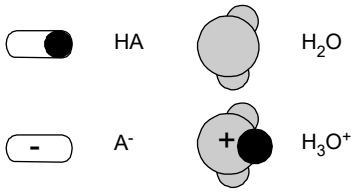
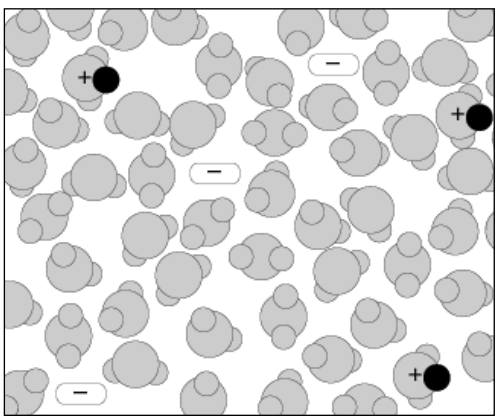


Diagram 1



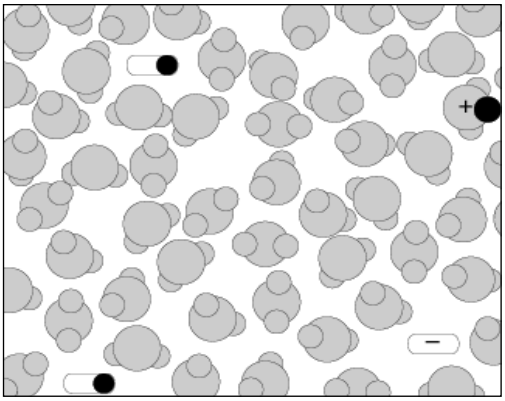
(a) What types of particles are shown in the solution represented in this diagram?

Mainly H_2O molecules with some H_3O^+ and A^-, but no HA.

(b) How would you describe this solution?

It is a dilute solution of a strong acid.

Diagram 2



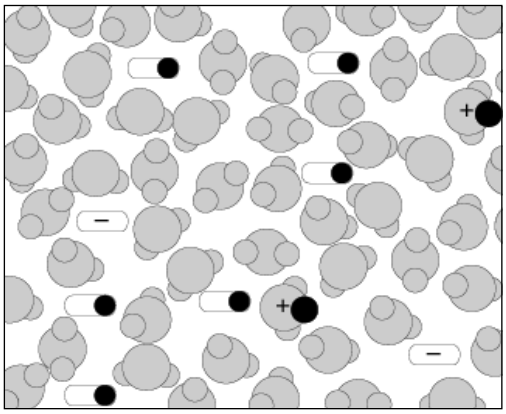
(c) What types of particles are shown in the solution represented in this diagram?

Mainly H_2O molecules with some acid (HA) molecules and even less H_3O^+ and A^-.

(d) How would you describe this solution (compared to diagram 1)?

It is a dilute solution of a weak acid.

Diagram 3



(e) What types of particles are shown in the solution represented in this diagram?

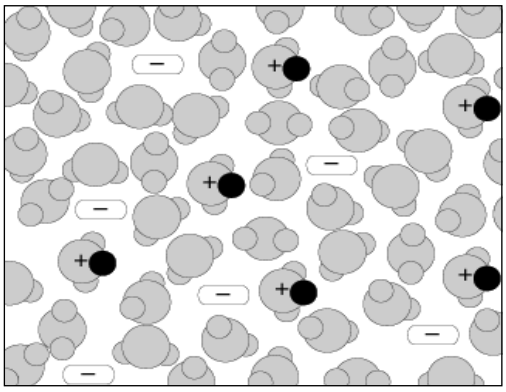
Mainly H_2O molecules, but more ……..... . molecules than in Diagram 2, and only a few H_3O^+ and A^-.

(f) How would you describe this solution (compared to diagrams 1 and 2)?

It is a more concentrated solution of a

…… acid.

Diagram 4



(g) What types of particles are shown in the solution represented in this diagram?

Mainly H_2O molecules, but a lot more H_3O^+ and A^- than in Diagram 1 and no …….. molecules

(h) How would you describe this solution (compared to diagrams 1 and 2)?

It is a more concentrated solution of a

…… acid.

3 The diagrams are meant to represent a concentrated solution of a strong acid, a dilute solution of a strong acid, a concentrated solution of a weak acid and a dilute solution of a weak acid. Use the table below to show which diagram is meant to represent each of the four solutions – write the number of the appropriate diagram in each box.

	Strong	**Weak**
Concentrated		
Dilute		

4 Hence, write down the definitions of a strong acid and a weak acid.

A **strong acid** has acid molecules that are …… ionized in aqueous solution

A **weak acid's** molecules are …… ionized in aqueous solution.

5 One way of representing a weak acid is to write its reaction with water as follows:

$HA + H_2O\ (l) \rightleftharpoons H_3O^+\ (aq) + A^-\ (aq)$ OR

$HA\ (aq) \rightleftharpoons H^+\ (aq) + A^-\ (aq)$ (simplified version)

where $\rightleftharpoons$ is a reversible arrow drawn because while HA molecules dissociate or ionize to form ions, a backward reaction also occurs to form the molecules again. This results in only very few acid molecules ionized at any one time to form hydronium ions (or hydrogen ions) in water.

Basicity of Acids

1 Acids are classified as monobasic, dibasic or tribasic depending on the number of H atoms in a molecule that are able to ionize to form H^+ ions.
(Sometimes they are named correspondingly as monoprotic, diprotic and triprotic).

2 Hydrochloric acid is able to provide 1 hydrogen ion per molecule:
$HCl \rightarrow H^+ + Cl^-$.
It is classified as a **monobasic** acid.

Sulfuric acid is **dibasic** – it provides 2 hydrogen ions per molecule:
$H_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$

Phosphoric acid is **tribasic** – it can provide up to 3 hydrogen ions per molecule when dissolved in water:
$H_3PO_4 \rightarrow 3H^+ + PO_4^{3-}$

3 Not all hydrogen atoms in a molecule will ionize to form H^+ ions. For example, in ethanoic acid, only one hydrogen out of four will ionize:
$CH_3COOH \rightleftharpoons H^+ + CH_3COO^-$

4 The basicity of an acid should **not** be confused with the strength of an acid. The number of hydrogen ions liberated per molecule of acid **does not** determine its strength. A dibasic or tribasic acid need **not** necessarily be a stronger acid than a monobasic acid. A good example is carbonic acid, H_2CO_3, which is a *weak dibasic* acid. On the other hand, both nitric acid and hydrochloric acid are strong monobasic acids.

Practice Questions

1 Consider the following equations:

I. $H_2SO_4 \longrightarrow 2H^+ + SO_4^{2-}$
II. $H_2CO_3 \rightleftharpoons 2H^+ + CO_3^{2-}$
III. $HCOOH \rightleftharpoons H^+ + HCOO^-$
IV. $HNO_3 \longrightarrow H^+ + NO_3^-$

(a) Which equations represent strong acids?

(b) Which equations represent weak acids?

(c) Which equations involve monobasic acids?

(d) Which equations involve dibasic acids?

(e) HNO_3 reacts with KOH according to the following equation:

$HNO_3 + KOH \rightarrow KNO_3 + H_2O$

Write the equation for the reaction of HCOOH with KOH.

……..

(f) When KOH is added to H_2SO_4, two reactions occur, consecutively (one after the other):

$H_2SO_4 + KOH \rightarrow KHSO_4 + H_2O$
$KHSO_4 + KOH \rightarrow K_2SO_4 + H_2O$

Following the pattern above, write the 2 equations for the reactions that occur when KOH is added to H_2CO_3.

……..

……..

2 A 1 mol dm^{-3} HCl solution ionizes completely to give 1 mol dm^{-3} of H^+. Would a 1 mol dm^{-3} ethanoic acid solution give 1 mol dm^{-3} of H^+, less than 1 mol dm^{-3} of H^+ or more than 1 mol dm^{-3} of H^+? Explain your choice.