Answers: Acids & bases and pH calculations:

QUESTION (2012:3)

(a) (i) Complete the table below showing the conjugate acids and bases.

Conjugate acid	Conjugate base
HCO_3^-	CO_3^{2-}
H_2O	OH^-
HCN	CN^-

   (ii) **$HPO_4^{2-}(aq)$**

   Write equations for the reactions of HPO_4^{2-} with water: one where it acts as an acid, and one where it acts as a base.

HPO_4^{2-} acting as	Equation
An acid	$HPO_4^{2-} + H_2O \rightleftharpoons PO_4^{3-} + H_3O^+$
A base	$HPO_4^{2-} + H_2O \rightleftharpoons H_2PO_4^- + OH^-$

(b) A solution contains 9.56×10^{-5} mol L^{-1} of hydroxide ions.

   (i) Calculate the concentration of hydronium ions, H_3O^+.
   $K_w = [H_3O^+][OH^-]$
   $[H_3O^+] = K_w/[OH^-]$ $= 1 \times 10^{-14}/9.56 \times 10^{-5} = 1.05 \times 10^{-10}$ mol L^{-1}

   (ii) Is this solution acidic, basic or neutral at 25°C? Basic
   Explain your answer. Basic since $[H_3O^+] < [OH^-]$ OR vice versa OR Basic since pH = $-\log(1.05 \times 10^{-10})$ = 9.98 OR pH > 7

(c) (i) Calculate the pH of a 0.133 mol L^{-1} solution of hydrochloric acid. pH = $-\log_{10}[H_3O^+]$
   pH = $-\log 0.133$ pH = 0.876

   (ii) Calculate the hydroxide ion concentration, $[OH^-]$, of a solution of sodium hydroxide with a pH of 12.8. $[H_3O^+] = 10^{-pH}$ $[H_3O^+] = 10^{-12.8}$ $[H_3O^+] = 1.58 \times 10^{-13}$ mol L^{-1}
   Therefore $[OH^-] = 1 \times 10^{-14}/1.58 \times 10^{-13}$ $[OH^-] = 0.0631$ mol L^{-1}

(d) Some properties of three aqueous solutions A, B and C, of equal concentration are shown in the table below.

Solution	A	B	C
pH	5.15	11.6	1.05
Electrical conductivity	good	poor	good

The labels of the three solutions have been removed.
It is known that the solutions are $NH_3(aq)$, $HCl(aq)$ and $NH_4Cl(aq)$.
Use the information in the table above to identify each of the three solutions.

Justify the identification of all three solutions. $NH_4Cl(aq)$ is solution **A,** $NH_3(aq)$ is solution **B,** $HCl(aq)$ is solution **C**

In your answer you should:

•   refer to both pH and electrical conductivity of the solutions

•   link your answers to appropriate chemical equations.

Answers: Acids & bases and pH calculations:

$NH_4Cl(aq)$ is solution **A**: good conductor of electricity – it fully dissociates in solution into ammonium and chloride ions, which conduct electricity.
$NH_4Cl \rightarrow NH_4^+ + Cl^-$ Its pH is that of a weak acid, as the ammonium ion is a weak acid and partially dissociates in water, producing hydronium ions: $NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$

$NH_3(aq)$ is solution **B**: its pH is that of a weak base as NH_3 is a weak base and it partially dissociates in water, producing hydroxide ions: $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$ Poor conductor of electricity as it is only partially dissociated into ions in water.

HCl(aq) is solution **C**: low pH is that of a strong acid, HCl fully dissociates in water, producing hydronium ions: $HCl + H_2O \rightarrow H_3O^+ + Cl^-$ Good conductor of electricity as it fully dissociates into ions in solution which conduct electricity.

QUESTION (2011:3)

(a) (i) Identify one conjugate acid / base pair for the following reaction:
$$NH_4^+ + PO_4^{3-} \rightleftharpoons NH_3 + HPO_4^{2-}$$
$$NH_4^+ / NH_3 \text{ OR } HPO_4^{2-} / PO_4^{3-}$$
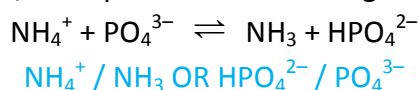
(ii) $HSO_4^-(aq)$ is a species that can act as an acid or a base.
Write two equations for reactions of HSO_4^- with water: one equation where it acts as an acid, and one where it acts as a base.
(as acid) $\rightarrow SO_4^{2-} + H_3O^+$
(as base) $\rightarrow H_2SO_4 + OH^-$

(b) (i) Calculate the pH of a 0.0498 mol L–1 solution of hydrochloric acid.   pH = –log 0.0498 **= 1.30**

(ii) Calculate the pH of an oven cleaner containing 0.251 mol L^{-1} sodium hydroxide.
pOH = –log $[OH^-]$ = 0.561   14 – 0.561 = 13.4 (3 s.f.)
OR $[H_3O^+]$ = $K_W/[OH^-]$ = = $1 \times 10^{-14}/0.251$ = 3.98×10^{-14} mol L^{-1}.
pH = –log $[H_3O^+]$ pH = –log 3.98×10^{-14}= 13.4 (3 s.f.)

(iii) The pH of a sample of rainwater, near a polluted city, is 4.62. Calculate the hydronium ion concentration, $[H_3O^+]$, and the hydroxide ion concentration, $[OH^-]$, in the rainwater.
$[H_3O^+] = 10^{-pH} = 10^{-4.62} = 2.40 \times 10^{-5}$ mol L^{-1}.
$[OH^-] = K_W / [H_3O^+] = 1 \times 10^{-14}/2.40 \times 10^{-5} = 4.17 \times 10^{-10}$ mol L^{-1}

(c) Three aqueous solutions, of equal concentration, have the following pH values:

Solution	$HNO_3(aq)$	HCOOH(aq)	KOH(aq)
pH	2.0	2.9	12

Compare and contrast both the strength and electrical conductivity of these aqueous solutions.
Include appropriate equations in your answer.
$HNO_3 + H_2O \rightarrow NO_3^- + H_3O^+$ strong acid OR fully dissociates   produces high(er) conc. of ions so higher conductivity
$HCOOH + H_2O \rightleftharpoons HCOO^- + H_3O^+$ weak acid OR partially dissociates   producing low(er) conc. Ions so lower conductivity
$KOH \rightarrow K^+ + OH^-$ Strong base OR fully soluble   produces high(er) conc. ions so higher conductivity

Answers: Acids & bases and pH calculations:

QUESTION (2010:2)

(a) (i) A beaker contains 0.108 mol L^{-1} hydrochloric acid.
Calculate the concentration of hydronium ions, [H$_3$O$^+$], and the concentration of hydroxide ions, [OH$^-$], in this solution.
[H$_3$O$^+$] = 0.108 mol L^{-1}. [OH$^-$] = 9.26 × 10^{-14} mol L^{-1}.

(ii) A beaker contains hydrochloric acid with a pH of 1.58.
Calculate the concentration of hydronium ions, [H$_3$O$^+$], and the concentration of hydroxide ions, [OH$^-$], in this solution.
[H$_3$O$^+$] = 0.0263 mol L^{-1}.   [OH$^-$] = 3.80 × 10^{-13} mol L^{-1}.

(iii) A beaker contains 0.362 mol L^{-1} sodium hydroxide.
Calculate the concentration of hydronium ions, [H$_3$O$^+$], the concentration of hydroxide ions, [OH$^-$], and the pH of this solution.
[OH$^-$] = 0.362 mol L-1. [H$_3$O$^+$] = 2.76 x 10^{-14} mol L^{-1}. pH = 13.6

(b) The concentration and pH of two acids HA and HB are shown in the table below.

Acid	Concentration / mol L−1	pH
HA	0.00100	3.00
HB	0.0100	3.40

(i) Identify which one of these acids is **weaker** HB
(ii) Explain the reasons for your choice.
You must include reference to both acids in your answer.
Acid strength is indicated by the ability to donate hydrogen ions. Strong acids are fully dissociated in solution and donate all the hydrogen ions. Weak acids are only partially dissociated in solution and donate only some hydrogen ions.
Acid HA has fully donated its protons as a pH of 3 indicates [H$_3$O$^+$] of 0.00100 mol L^{-1}. Acid HB has only donated some of the hydrogen ions since a pH of 3.40 suggests a [H$_3$O$^+$] of about 4 × 10^{-4} mol L^{-1} and since the actual acid concentration is 0.0100 mol L^{-1}, it is only partially dissociated and therefore the weak acid.

(c) A sample of sodium ethanoate, CH$_3$COONa, is dissolved in water. The solution is tested and found to be basic. Explain why the solution is basic. Include appropriate equation(s) in your answer. Sodium ethanoate dissolves in water, producing Na$^+$ ions and ethanoate ions, CH$_3$COO$^-$.
CH$_3$COONa(s) ⟶ CH$_3$COO$^-$ + Na$^+$. Then CH$_3$COO$^-$ reacts with water/accepts a proton and produces OH$^-$.
CH$_3$COO$^-$ + H$_2$O ⇌ CH$_3$COOH + OH$^-$. The concentration of hydroxide ions, OH$^-$, has increased meaning [OH$^-$] > [H$_3$O$^+$]. The resulting solution is basic.

QUESTION (2009:1)

(a) Complete the equations below to show how each species will react with water to form an acidic solution.

(i)   HCl + H$_2$O → H$_3$O$^+$ + Cl$^-$

(ii)   CH$_3$COOH + H$_2$O ⇌ CH$_3$COO$^-$ + H$_3$O$^+$

Answers: Acids & bases and pH calculations:

(b)　(i)　Determine the $[H_3O^+]$, $[OH^-]$, and pH in each of the following two solutions.

$[H_3O^+]$ for HCl has been listed.

0.0376 mol L^{-1} HCl solution

$[H_3O^+]$/mol L^{-1}	$[OH^-]$/mol L^{-1}	pH
0.0376	2.66×10^{-13}	1.42

2.48×10^{-4} mol L^{-1} NaOH solution

$[H_3O^+]$/mol L^{-1}	$[OH^-]$/mol L^{-1}	pH
4.03×10^{-11}	2.48×10^{-4}	10.4

(ii)　Explain why the concentration of the acid, HCl, is equal to the concentration of the hydronium ion, $[H_3O^+]$ For HCl, the $[H_3O^+]$ is equal to [HCl]. HCl is a strong acid and completely dissociates in solution. Consequently the $[H_3O^+]$ is equal to [HCl].

(iii)　The concentration of the hydronium ion, H_3O^+, in a 0.0376 mol L^{-1} solution CH_3COOH is less than 0.0376 mol L^{-1}.　Explain why the concentration of the hydronium ion is less than 0.0376 mol L^{-1}.　　For CH_3COOH, $[H_3O^+]$ is less than $[CH_3COOH]$. CH_3COOH is a weak acid and only partially dissociates in solution. Consequently, the $[H_3O^+]$ would be less than the concentration of the ethanoic acid.

(c)　Conductivity of solutions can be described as being high, low, or having no conductivity. Compare and contrast the conductivity of the three solutions shown below.

0.100 mol L^{-1} HCl, 0.100 mol L^{-1} CH_3COOH & 0.100 mol L^{-1} NaOH

Conductivity of NaOH and HCl are both high. Conductivity of CH_3COOH is low. HCl is a strong acid and it completely dissociates into H_3O^+ and Cl^- ions. This means the conductivity will be high, as there will be a large concentration of ions in solution. NaOH is a strong base, and in solution is completely ionised to Na^+ ions and OH^- ions. Because there are a large concentration of ions in solution, the conductivity will be high. The conductivity of both these will be the same, as they have the same concentration of ions in solution. Conductivity of CH_3COOH is low. CH_3COOH is a weak acid and only partially dissociates. Since there is a low concentration of ions, it will have low conductivity.

QUESTION (2008:3)

Complete the equations below to show how each species will react with water to form an acidic solution.

(a)　$NH_4^+(aq) + H_2O \rightleftharpoons NH_3(aq) + H_3O^+(aq)$

(b)　$HF(aq) + H_2O \rightleftharpoons H_3O^+(aq) + F^-(aq)$

QUESTION (2008:4)

Determine the $[H_3O^+]$, $[OH^-]$ and pH in each of the following solutions.

(a)　0.00112 mol L^{-1} HCl solution. $[H_3O^+]$ = 0.00112 mol L^{-1} , $[OH^-]$= 8.93×10^{-12} mol L^{-1} , pH = 2.95

(b)　3.68×10^{-2} mol L^{-1} NaOH solution. $[H_3O^+]$ = 2.72×10^{-13} mol L^{-1} , $[OH^-]$= 3.68×10^{-2} mol L^{-1} , pH = 12.6

*Answers: Acids & bases and pH calculations:*

QUESTION (2008:8)

Aqueous solutions of acids HA and HB both have the same concentration of 0.100 mol L^{-1}. The pH of the solution of acid HA is 3.5 and the pH of the solution of acid HB is 1.8.

(a)   (i) Identify which one of these acids is stronger and circle your choice. HA HB HB is circled.

(ii) Discuss the reasons for your choice.

You should include relevant equations in your answer, as well as reference to what is meant by the strength of an acid.

The strength of an acid is a measure of its ability to donate hydrogen ions. Both acids react with water and donate H+ ions to water.

$HA(aq) + H_2O \rightleftharpoons H_3O^+(aq) + A^-(aq)$, $HB(aq) + H_2O \rightleftharpoons H_3O^+(aq) + B^-(aq)$
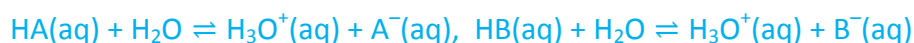
OR $[H_3O^+]$ from HA = $10^{-3.5}$ = 3.16 x 10^{-4} mol L^{-1} and $[H_3O^+]$ from HB = $10^{-1.8}$ = 1.58 x 10^{-2} mol L^{-1}. The lower pH of acid HB means there is a higher concentration of H_3O^+ ions in the solution. As the acids are of the same concentration, the position of equilibrium lies further to the right for this acid. Thus more H^+ ions have been donated to water making HB a stronger acid.

(b)   Describe what is observed when the following two tests are carried out on 5 mL samples of the acids HA and HB.

(i)   Identical small pieces of magnesium ribbon are placed in each acid. Bubbles of gas are produced with both acids but this is more vigorous with HB. Increase in temperature is noted in this reaction, and more heat is immediately produced by HB reaction. Magnesium disappears / dissolves / consumed with both acids but in less time with HB.

(ii)   Sodium hydroxide solution is slowly added to each acid. The volume of sodium hydroxide solution required to completely react with the acid is measured. There is no (visual) change, but both acids require the same volume of sodium hydroxide to completely react. Increase in temperature is noted in this reaction, and more heat is immediately produced by HB reaction.

(c)   Discuss the observations in (b) (i) and (ii).

Your answer must include reference to:

- similarities and / or differences in the observations of the tests on each acid
- equations for reactions.

Both acids react with magnesium as the reaction occurs between Mg and $H_3O^+(aq)$ ions.

$Mg + 2H_3O^+ \rightarrow Mg^{2+} + H_2(g) + 2H_2O$ OR $Mg + 2H^+ \rightarrow Mg^{2+} + H_2(g)$

Since H_2 gas is produced, bubbles are observed in each reaction. (The same volume of gas is produced with both acids, as the volume and concentration are the same). As $[H_3O^+(aq)]$ at equilibrium is greater in HB, there is increased collision rate with the Mg and so the reaction rate is increased, and the bubbles are formed more rapidly. As the reaction in HB is faster, the magnesium disappears in a shorter period of time. The total amount of $H_3O^+(aq)$ ions available in each acid is the same, as the volume and concentration is the same. This means the volume of sodium hydroxide required to completely react with the acid will be the same.

$H_3O^+ + OH^- \rightarrow 2H_2O$ OR $H^+ + OH^- \rightarrow H_2O$

Answers: Acids & bases and pH calculations:

QUESTION (2007:1)

(a)   The bicarbonate ion, HCO_3^-, can both accept and donate hydrogen ions (protons).

Complete the equations below.

$HCO_3^- + H_2O \rightleftharpoons H_3O^+ + CO_3^{2-}$ Reaction A

$HCO_3^- + H_2O \rightleftharpoons OH^- + H_2CO_3$ Reaction B

(b)   When sodium bicarbonate, $NaHCO_3$, dissolves in water the solution is basic. Circle Reaction A or Reaction B to show which reaction predominates. Justify your answer. Reaction B circled. Formation of OH^- causes solution to be basic, and only reaction B produces this.

QUESTION (2007:2)

(a)   Give the pH of 0.125 mol L^{-1} HCl. pH = 0.903

(b)   Calculate the hydroxide ion concentration of NaOH solution at pH 10.2. $[OH^-]$ = 1.58 x 10^{-4} mol L^{-1}

(c)   Calculate the pH of 0.124 mol L^{-1} NaOH. pH = 13.1

QUESTION (2007:7)

Methyl orange can be used as an acid-base indicator. It is pink in solutions with a pH less than 3 and yellow in solutions with a pH greater than 4.

Four beakers are known to contain one each of:
- 0.1 mol L^{-1} HCl
- 0.01 mol L^{-1} HCl
- distilled water
- 0.1 mol L^{-1} NaOH

(a)   Complete the following table.

	pH	Colour of methyl orange
0.1 mol L^{-1} HCl	1	pink
0.01 mol L^{-1} HCl	2	pink
distilled water	7	yellow
0.1 mol L^{-1} NaOH	13	yellow

(b)   Using only the methyl orange indicator, additional water, test tubes and a measuring cylinder, discuss how a student could identify each of the four solutions. Both HCl solutions – add indicator and slowly add the same volume of water to each solution. The solution that turns the indicator from pink to yellow first is the more dilute acid, ie 0.01 mol L^{-1} HCl. Water / NaOH solution – take 1 mL samples of the 0.1 mol L^{-1} HCl solution and add indicator. Add the same volume of water and NaOH, eg 100 mL. The indicator will remain pink for the water sample, and the NaOH will cause the indicator to turn from pink to yellow.

Answers: Acids & bases and pH calculations:

QUESTION (2006:1)

(a) Complete the table below to show the conjugate acid-base pairs.

Conjugate acid	Conjugate base
NH_4^+	NH_3
$H_2PO_4^-$	HPO_4^{2-}
HCl	Cl^-
H_2SO_4	HSO_4^-

(b) Circle the ion that can act as both an acid and a base. CH_3COO^- HCO_3^-

Justify your choice. HCO_3^- can donate H^+, can accept H^+

QUESTION (2006:4)

The table below shows the pH of two acids, HA and HB, each with the same concentration. When these acids react with magnesium metal, hydrogen gas (H_2) is produced. Discuss the reactions of both acids, HA and HB, with magnesium metal when the same volume of each acid is used.

Acid	pH
HA	1.00
HB	4.00

In your answer include:

* species in solution
* rate of reaction
* total volume of gas produced.

HA has higher $[H_3O^+]$ / $[H^+]$. HA's: rate of reaction with Mg will be higher or converse statement for HB. Same amount acid is present and if same amount Mg then same volume of gas.

QUESTION (2006:7)

(a) Complete the table below to show the hydronium ion concentration, hydroxide ion concentration, and pH for the three solutions shown.

$$Kw = 1.00 \times 10^{-14}$$

Solution	$[H_3O^+]$ / mol L^{-1}	$[OH^-]$ / mol L^{-1}	pH
hydrochloric acid (HCl)	0.0720	1.39×10^{-13}	1.14
sodium hypochlorite (NaOCl)	3.98×10^{-12}	2.51×10^{-3}	11.4
hypochlorous acid (HOCl)	4.46×10^{-4}	2.24×10^{-11}	3.35

Answers: Acids & bases and pH calculations:

(b) Hypochlorous acid is a weak acid. Complete the equation below to show the reaction of hypochlorous acid with water.

$HOCl + H_2O \rightleftharpoons$ _____ + _____ $OCl^- + H_3O^+$
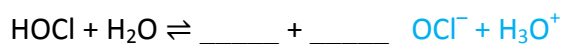
(c) A solution of sodium hypochlorite, NaOCl, is basic. Discuss the above statement, including appropriate chemical equation(s) in your answer. OCl⁻ is basic or reacts with water or reacts to accept H⁺ from water; $OCl^- + H_2O \rightleftharpoons HOCl + OH^-$; $[OH^-] > [H_3O^+]$ or $[OH^-]$ now increased.

QUESTION (2005:6)

The concentration and pH of three acids, HA, HB and HC, are shown in the table below.

acid	concentration (mol L^{-1})	pH
HA	0.100	1.00
HB	0.100	2.50
HC	0.00100	3.00

(a) A small piece of magnesium is added to a 20 mL sample of each of the acids. Circle the acid that would be expected to react most rapidly with the magnesium. acid HA   acid HB   acid HC

Explain why this acid will react the fastest. HA is circled. Reaction rate of acid depends on concentration of hydrogen / hydronium ions - the higher the faster the reaction. Acid HA has the lowest pH therefore highest hydrogen / hydronium ion concentration.

(b) Circle the weakest acid.   acid HA   (acid HB)   acid HC

Explain why this acid is the weakest.

Acid strength is indicated by the ability to donate H⁺ ions - the weakest acid is the poorest H⁺ donor. Acid HA has fully donated H+ ions since a pH of 1.00 indicates [H+] of 0.100 mol L^{-1}, which is the concentration of the acid. Similarly acid HC has fully donated H⁺ ions since a pH of 3.00 indicates $[H^+]$ of 0.00100 mol L^{-1}, which is the concentration of the acid. These are both strong acids.

Acid HB has only donated some of the H⁺ ions since a pH of 2.50 is $[H^+]$ of about 3×10^{-3} mol L^{-1} and the acid concentration is 0.100 mol L^{-1}, thus it is only partly dissociated and therefore the weakest acid.

QUESTION (2005:7)

Complete the following table showing hydronium ion concentration, hydroxide ion concentration and pH for some solutions. $K_w = 1.00 \times 10^{-14}$

Solution	$[H_3O^+]$	$[OH^-]$	pH
1	0.0350	2.86×10^{-13}	1.46
2	1.58×10^{-11}	6.31×10^{-4}	10.8
3	1.77×10^{-9}	5.66×10^{-6}	8.75

QUESTION (2005:8)

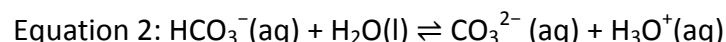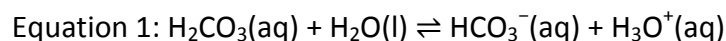A solution of sodium ethanoate ($NaCH_3COO$) is tested and found to have a pH of 8.50.

Discuss why the pH of the solution is greater than 7. Include appropriate equation(s) in your answer.

Sodium ethanoate solution contains both $Na^+(aq)$ and $CH_3COO^-(aq)$ ions. Ethanoate ions react with water to accept H^+ since ethanoic acid is a weak acid. / ethanoate ions are weakly basic.

$CH_3COO^-(aq) + H_2O \rightleftharpoons CH_3COOH(aq) + OH^-(aq)$. So $[OH^-]$ has increased. The increase in $[OH^-]$ means there is a decrease in $[H_3O^+]$ (or $[H^+]$), which makes the solution basic so the pH is greater than 7.

QUESTION ONE (2004:1)

Chickens make egg shell, $CaCO_3$, using carbon dioxide gas from the air. The carbon dioxide forms carbonic acid (H_2CO_3), which then reacts to form the carbonate ions (CO_3^{2-}) needed to make egg shell. Two equations showing part of this process are given below.

$$\text{Equation 1: } H_2CO_3(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + H_3O^+(aq)$$

$$\text{Equation 2: } HCO_3^-(aq) + H_2O(l) \rightleftharpoons CO_3^{2-}(aq) + H_3O^+(aq)$$

(a)   Identify three conjugate acid-base pairs in the equations above.

H_2CO_3 / HCO_3^- H_3O^+ / H_2O HCO_3^- / CO_3^{2-}

(b) HCO_3^- can act as both an acid and a base. Specify which equation above (1 or 2) shows HCO_3^- acting as an acid. Give a reason for your answer. Equation 2: HCO_3^- is donating a proton / H^+

QUESTION (2004:3)

Two acids of the same concentration, hydrochloric acid (HCl) and propanoic acid (CH_3CH_2COOH), have properties as shown below:

Property	Hydrochloric acid (0.100 mol L^{-1})	Propanoic acid (0.100 mol L^{-1})
Relative conductivity of solution	High	Low
pH of solution	1.00	2.93

(a)   Complete the following equations to show the reaction of both hydrochloric acid and propanoic acid with water.

Answers: Acids & bases and pH calculations:

$$HCl + H_2O \rightarrow H_3O^+ + Cl^-$$

$$CH_3CH_2COOH + H_2O \rightleftharpoons H_3O^+ + CH_3CH_2COO^-$$
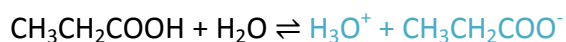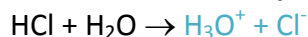
(b) Consider the properties described in the table above. Explain the differences in the conductivity and pH of the two acids. In your explanation include reference to the species present in each solution.
Propanoic acid is a weak acid which only partially dissociates in water. Therefore, it will have a relatively low concentration of H_3O^+, resulting in a higher pH, and low concentration of ions overall, resulting in a low conductivity. Hydrochloric acid is a strong acid that fully dissociates in water. Therefore, it will have a high concentration of H_3O^+ and a lower pH, and a high concentration of ions overall, resulting in a high conductivity.

QUESTION (2004:6)

(a) The table below shows four different solutions. Each solution contains both hydronium ions (H_3O^+) and hydroxide ions (OH^-). Complete the table, showing the relative concentrations of these two ions in solution, by placing H_3O^+ ions and OH^- ions in the appropriate box. The first one has been done for you.

Solution	Concentration of H_3O^+ and OH^- in solution	
	Greater than 1×10^{-7} mol L^{-1}	Less than 1×10^{-7} mol L^{-1}
Na_2CO_3 0.100 mol L^{-1}	OH^-	H_3O^+
HNO_3 0.100 mol L^{-1}	H_3O^+	OH^-
NaOH 0.100 mol L^{-1}	OH^-	H_3O^+
NH_4Cl 0.100 mol L^{-1}	H_3O^+	OH^-

(b) Calculate the pH of a solution with a hydronium ion concentration, $[H_3O^+]$, of 0.0350 mol L^{-1}. State your answer to 3 significant figures. pH = $-$log 0.035 = 1.46

(c) If a solution of sodium hydrogen carbonate has a pH of 9.20, calculate the concentration of hydroxide ions, $[OH^-]$, present in the solution. State your answer to 3 significant figures.

$K_w = 1.00 \times 10^{-14}$ $[OH^-] = 1.58 \times 10^{-5}$ mol L^{-1}