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Chemistry Module 6

Acid-Base Reactions

WORKSHEETS

Worksheet 1 Acids, Bases & Indicators

Part 1 Fill in the blank spaces

Student Name...

Acids and bases are chemical a)................................ If you add one to the other, they b)............................. each other.

Acidity is measured by the c)............. scale. On this scale, a neutral substance has a value of d)....... Values above this indicate e)................................. substances, while values below indicate f)....................................... substances.

Indicators are chemicals which g)............................. .... according to the h)........................ of the solution they are in. The original indicators were extracts from i)..

The colour changes for the following indicators need to be learnt.

Indicator	Acid	Neutral	Base
Litmus	j)............	purple	k).............
Phenolphthalein	l)...........	....	....
Methyl orange	m)............	....	....
Bromothymol blue	n).............	green/blue	o)............

In everyday situations, indicators are used for purposes such as p).. for farming and gardening, q)..................................... for pools and aquariums, and for monitoring r).............................. from industries.

Part 2 Practice Questions

1.
Each solution listed below has been tested with one or more indicators, and the colour is given. For each, state if it is acidic, neutral or basic.

Solution A: Phenolphthalein is clear.
Methyl orange is red.

Solution B: Phenolphthalein is pink.
Methyl orange is yellow.

Solution C: Phenolphthalein is clear.
Methyl orange is yellow.

Solution D: Bromothymol blue is blue.
Methyl orange is yellow.

Solution E: Phenolphthalein is clear.
Litmus is pink.

2.
A household substance most likely to be strongly basic is
A. vinegar.
B. soap.
C. sugar.
D. milk.

3.
a) What is meant by an “acid-base indicator”?

b) Identify an everyday use of an indicator.

c) Describe how you could prepare a simple indicator from a named natural substance.

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Worksheet 2 Practice Questions

Acid-Base Reactions

Student Name..

1. Acid-Alkali Reactions

a) Name the salt formed in a reaction between:
i) hydrochloric acid & calcium hydroxide

ii) sulfuric acid & magnesium hydroxide

iii) nitric acid & barium hydroxide

b) Write a balanced equation for the reaction of:
i) hydrochloric acid and lithium hydroxide

ii) sulfuric acid and sodium hydroxide

iii) nitric acid and magnesium hydroxide

2. Reactions of Basic Oxides

Write a balanced equation for the reaction of:

a) sulfuric acid & iron(II) oxide

b) hydrochloric acid & magnesium oxide

c) nitric acid & copper(II) oxide

3. Reactions of Acidic Oxides

a) carbon dioxide reacts with calcium hydroxide to form water and calcium carbonate. (This is the "limewater" reaction) Write a balanced equation for the reaction.

b) P_2O_5 is an acidic oxide. It reacts with water to form phosphoric acid, H_3PO_4. Write the balanced equation.

c) Sulfur trioxide reacts with water to form a strong acid. Write a balanced equation, and name the acid.

4. Acid-Metal Reactions

Write a balanced ionic equation (including states) for each reaction.

a) Nitric acid reacting with zinc metal.

b) Calcium metal plus sulfuric acid

c) Hydrochloric acid plus magnesium metal.

d) Lead metal plus nitric acid.

e) (Revision)
Assuming all the acids above have the same concentration, all metals the same surface area, all reactions at the same temperture, etc., which of the reactions above is likely to proceed most vigorously, and why?

5. Acid-Carbonate Reactions

Write a balanced "molecular-style" equation (including states) for each reaction.

a) nitric acid + copper(II) carbonate

b) sulfuric acid + potassium carbonate

c) sodium carbonate + hydrochloric acid

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Worksheet 3 Practice Problems
Reaction of Acids & Bases With Water

Student Name..

For each substance below, write an equation describing its monoprotic reaction with water, according to Bronsted-Lowry Theory. (In brackets is a description of how the substance behaves in each case)

For each equation, identify the conjugate acid/base of the named species.

a) methanoic acid, HCOOH (acid)

b) ammonia, NH_3 (base)

c) hydrogen phosphate ion, HPO_4^{2-}, (acid)

d) hydrogen phosphate ion, HPO_4^{2-}, (base)

e) sulfide ion, S^{2-} (base)

f) cyanide ion, CN^- (base)

g) hydrogen sulfide, H_2S (acid)

h) nitrite ion, NO_2^- (base)

i) ammonium ion, NH_4^+ (acid)

j) hydrogen sulfite ion, HSO_3^- (acid)

Worksheet 4 Practice Questions
Acid Ionisation & pH

Student Name..

1. Write a balanced equation for the reaction of each acid with water. (Assume complete ionisation in each case, even though some may be weak acids)

Monoprotic acids

a) HCl

b) HBr (hydrobromic)

c) HCOOH (methanoic)

d) HCN (hydrocyanic)

Diprotic acids

e) H_2SO_4

f) H_2CO_3 (carbonic)

Triprotic acids

g) H_3PO_4 (phosphoric)

h) $C_6H_8O_7$ (citric)

2. Calculating pH from $[H_3O^+]$

Each of the following values is the hydronium ion concentration of a solution, in $molL^{-1}$. For each, calculate the pH, and state if the solution is acidic or basic.

a) 0.0675
b) 0.000840
c) 2.50
d) $2.50x10^{-12}$
e) 3.5×10^{-3}
f) 1.50×10^{-8}

3. Calculating pH from Acid Concentration

Calculate the pH of each solution, taking into account that some acids may be diprotic or triprotic. (assume total ionisation)

a) 0.250 $molL^{-1}$ HCl
b) 0.0750 $molL^{-1}$ H_2SO_4.
c) $7.50x10^{-4}$ $molL^{-1}$ H_2SO_4.
d) $4.50x10^{-3}$ $molL^{-1}$ H_3PO_4.
e) 6.00 $molL^{-1}$ H_2SO_4.

4. Calculating $[H_3O^+]$ from pH.

Find the $[H_3O^+]$ in each solution.

a) pH = 5.30
b) pH = 11.5
c) pH = -0.40
d) pH = 4.85
e) pH = 8.50
f) pH = 0

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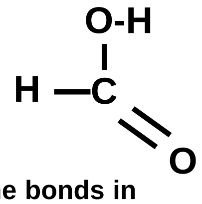
Worksheet 5 **Test-Style Questions**

Student Name...

Multiple Choice

1.
The diagram shows a molecule of the weak acid, methanoic acid.

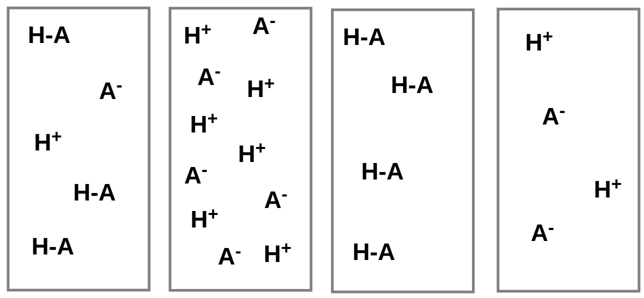


When dissolved in water, one of the bonds in the molecule may ionise, resulting in acid behaviour.

The bond most likely to ionise is the
A. H-C bond **B. C=O bond**
C. O-H bond **D. C-O bond**

2.
If an undissociated molecule of an acid is represented by "H-A", and the ionised acid by separate "H^+" and "A^-" symbols, which diagram could show a <u>dilute solution of a strong acid</u>?

A. **B.** **C.** **D.**



3.
In a solution of pH=10, the concentration of hydronium ions is:

A. 10 $molL^{-1}$. **B. 10^{10} $molL^{-1}$.**
C. 10^{-10} $molL^{-1}$. **D. 1 $molL^{-1}$.**

4.
If you had 4 solutions of different acids
Hydrochloric **Nitric**
Ethanoic **Sulfuric**
all with exactly the same molar concentration of acid, which <u>two only</u> would you expect to have the same pH?

A. sulfuric and ethanoic
B. hydrochloric and nitric
C. nitric and sulfuric
D. ethanoic and hydrochloric

5.
In the following equation...

$$NO_2^-{}_{(aq)} + H_2O_{(l)} \rightleftharpoons HNO_{2(aq)} + OH^-{}_{(aq)}$$

...it is true to say that:
A. H_2O is a B-L acid.
B. the conjugate base of NO_2^- is HNO_2
C. the species NO_2^- is amphiprotic
D. HNO_2 is a diprotic acid.

Longer Response Questions

Answer on reverse if insufficient space.

6.
A certain diprotic acid can be represented by the formula "H_2A". ("A" is not the correct symbol)

a) Write a balanced equation for the complete ionisation of H_2A when added to water.
Label each species in the equation as acid or base.

b) If H_2A is a strong acid, calculate the pH of a solution with concentration $[H_2A] = 0.0250$ $molL^{-1}$.

c) In fact, when this exact concentration solution was tested, it was found to have a pH = 2.50.
What do you conclude from this?

7.
A certain solution has a pH = 9.5

a) What is the value of the pOH?

b) Find the concentration of:
i) hydronium ions.

ii) hydroxide ions

c) The solution contains a single, pure compound dissolved in water at a concentration of 0.002$molL^{-1}$.
A student describes this solution as "a weak solution of a strong base". The student has made at least 2 errors in this description.
Give a more accurate description.
<u>Justify</u> three parts of your description.

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Worksheet 6 Amphiprotic Ions, Acidic & Basic Salts
Practice Problems

Student Name..............................

1. Amphiprotic Substances

Each of the substances below is amphiprotic.
For each, write TWO equations to show its reaction
i) with H_3O^+
ii) with OH^-

a) dihydrogen phosphate ion, $H_2PO_4^-$

b) hydrogen carbonate ion, HCO_3^-

c) hydrogen sulfide ion HS^-

2. Acidic and Basic Salts

Each of the following salts dissolves in water, and reacts (as shown in brackets) to form an acidic or basic solution.

Write a net ionic equation (leave out spectators) to show the reaction with water.

a) potassium ethanoate, CH_3COOK (basic)

b) ammonium nitrate, NH_4NO_3 (acidic)

c) sodium nitrite, $NaNO_2$ (basic)

d) potassium hydrogen oxalate, KHC_2O_4 (acidic)

e) lithium cyanide, LiCN (basic)

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Worksheet 7 Practice Problems
Titration

Student Name...

1.
25.00mL of an "unknown" NaOH solution was titrated against standardised HCl, of concentration = 0.09255 $molL^{-1}$. The titration was carried out 4 times, with the end-point titres being 22.50mL, 22.45mL, 23.10mL and 22.50mL.

Average these results appropriately, then write an equation, and calculate the concentration of the NaOH solution.

2.
Using a 0.05025$molL^{-1}$ standardised solution of NH_4OH (ammonia solution), 25.00mL samples of an unknown H_2SO_4 solution were titrated. The average titre was 28.32mL

i) Write a balanced equation for the neutralisation.

ii) Find the concentration of the acid.

iii) For this titration there were 3 indicators available:

Indicator	pH of Colour Change
J	≅ 8.7
K	≅ 6.8
L	≅ 4.2

Which indicator is most appropriate for this titration? Explain your answer.

3.
A student wants to make 500mL of a 0.02500$molL^{-1}$ solution of oxalic acid (COOHCOOH), from the solid chemical.

i) What are the characteristics that qualify this chemical as a "primary standard"?

ii) What mass needs to be accurately weighed out?

iii) Summarise the main steps involved in preparing the solution.

4.
The solution, when prepared, was used to determine the concentration of a KOH solution. 25.00mL aliquots of KOH required an average titre of 31.45mL. Find the concentration of the KOH. (hint: oxalic acid is diprotic)

5.
To find the concentration of an ammonia solution (NH_4OH), a student has 2 choices of standardised solutions she could use:
- **0.7438 $molL^{-1}$ HNO_3 solution**

or
- **0.8863 $molL^{-1}$ CH_3COOH solution**

i) Which solution should she use in the titration? Explain.

ii) Using 10.00mL samples of the ammonia unknown, and titrating with the appropriate acid, the average titre was found to be 12.76mL. Calculate the concentration of the ammonia solution.

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Worksheet 8 Dissociation Constants & pK_a

Practice Exercises

Student Name....................................

1.
A certain <u>weak</u> acid can be represented by the symbols "HZ", where H is for hydrogen, but "Z" is not the correct symbol for the other part of the molecule.

a) Write an equilibrium equation describing how this weak acid reacts with water. States may be omitted.

b) Write an expression for its acid dissociation constant "K_a".

c) Explain why part of the "formal" equilibrium expression seems to be "missing" from K_a.

d) At 25°C, a 0.040 $molL^{-1}$ solution of HZ is found to have a pH = 3.8

Calculate the value of K_a and pK_a for this acid.

2. Calculate the pH of a solution of nitric acid (strong acid) if its concentration is c = 2.50 $molL^{-1}$.

3.
Benzoic acid (C_6H_5COOH) is a weak, monoprotic acid with pKa = 4.20 (at 25°C)

a) Write an equilibrium equation for its reaction with water.

b) What is the pH of a 0.00258 $molL^{-1}$ solution of benzoic acid at 25°C?

4.
Hypochlorous acid (HOCl) has a pKa = 7.53.

a) Write an equilibrium equation for its reaction with water.

b) If the pH of a solution is 4.75, what is the concentration of the HOCl solution?

5.
Calculate the pK_a of a weak monoprotic acid if a 1.50 $molL^{-1}$ solution has a pH = 2.9 at 25°C.

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Worksheet 9
Acid-Base Theory & Titration

Fill in the blank spaces Student Name.......................................

Lavoisier concluded that acids must contain a)................................. Later, Davy described acids as all containing b)...................................., and being able to react with c)...

The first attempt at a complete acid-base theory was made by d)................................. in 1885. According to this theory, all acids produce e)....................................... in solution. Bases were defined as compounds containing f)......................... or .... ions. This theory was successful at explaining some acid-base behaviour, but failed to take into account the important role of g)................................

The h)....................-...................... (B-L) Theory is much more useful for explaining things. It defines an acid as a i)................ ...., and a base as a j)......................... ...., and all acid-base reactions involve the k)........................... of one or more l)............................

When an acid loses a proton it forms the "m)........................... base", and when a base gains a proton it forms the n)................................

Water can acts as either o)....................... or ...., depending on the chemical environment. The word for this is "p)......................................."

Many salts dissolve in water to form acidic or basic solutions, because of their interaction with q)........................
An example of an acidic salt is r).. An example of a basic salt is s)......................................
An example of a neutral salt is t)....................................

The "rules" governing this are:
• Neutral salts form from the neutralisation of u).................... acids by v)........................ bases.
• Acidic salts form from the neutralisation of w)............................ acids by x).......................... bases.
• Basic salts form from the neutralisation of y).................... acids by z).......................... bases.

All neutralisation reactions (in aqueous solution) involve the reaction of aa)......................... and .... ions to form ab)........................... The reaction is always ac).............-thermic.

ad).................................. is a technique used for chemical analysis. A measured ae)..................... of "unknown" solution is reacted with a "af)...................... solution" until the "ag)........................... point" is reached. The main piece of equipment involved is a ah)............................. It is important to choose the ai)....................... which will change aj).................... at the pH of the end-point, depending on the nature of the salt formed.

If the ak)..................... is measured during titration and graphed, the graphs generally show an "S" shaped curve. The end-point is located in the middle of the al)........................ part of the curve.

Buffers are solutions containing an equilibrium mixture of a am).................... .... and its ....
If either acid or base is added, the equilibrium an)..................... (according to ao)..................................... Principle) so that the change in ap)............ is minimized.
Buffers are important in all aq)......................... things, by helping to maintain ar)............... ....
A specific example is as)..........................., where the pH is maintained by a mixture of at)........................ and .... ions.

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Worksheet 10 Test-Style Questions

Student Name..

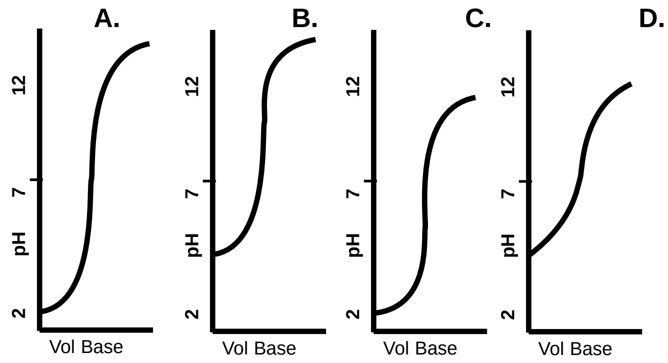
Multiple Choice

1.
The hydrogen phosphate ion, HPO_4^{2-} is an amphiprotic species. If it were to act as a base, then its conjugate acid would be:
A. $H_2PO_4^-$ B. H_3PO_4 C. PO_4^{3-} D. HPO_3^{3-}

2.
An ionic "salt" is found to be acidic in water solution. It is likely that this salt is the product of the reaction between:
A. a strong acid and a strong base.
B. a weak acid and a weak base.
C. a weak acid and a strong base.
D. a strong acid and a weak base.

3.
The salt mentioned in Q2 was formed during a titration. The most appropriate indicator for the titration would be:
A. bromothymol blue.
B. methyl orange.
C. phenolphthalein.
D. universal indicator.

4. Which of the following graphs might be the "titration curve" for the titration described in Q2?



5.
An appropriate material to use in case of an acid spill is:
A. an amphiprotic substance, e.g. sodium bicarbonate.
B. a strong base, like sodium hydroxide.
C. a buffer solution, like methanoic/methanoate mixture.
D. a weak base, like ammonia.

6.
In the reaction $HBr + NH_3 \longrightarrow NH_4^+ + Br^-$
it is true to say that:

A. NH_3 is the base, because it has accepted a proton.
B. HBr is the acid, because it has accepted a proton.
C. NH_4^+ is the conjugate acid of HBr.
D. Br^- is the conjugate acid of HBr.

Longer Response Questions

Mark values shown are suggestions only, and are to give you an idea of how detailed an answer is appropriate. Answer on reverse if insufficient space.

7. (7 marks)
a) Give the definition of an acid according to the Arrhenius Theory.

b) Write an equation which Arrhenius might have used to explain why hydrogen chloride gas is an acid when dissolved in water.

c) Give the definitions for acid and base according to the Bronsted-Lowry Theory.

d) Write an equation to show why hydrogen chloride gas in water is an acid according to the B-L Theory.

8. (7 marks)
a) A solution containing carbonate ions (CO_3^{2-}) is found to be quite strongly basic.

Write an equation to explain why, and state the role of the water molecule in this reaction.

b) Write TWO different equations to show the amphiprotic nature of the hydrogen carbonate ion, HCO_3^-.

9. (8 marks)
A diluted vinegar sample (CH_3COOH solution) was analysed by titration with a standardised solution of KOH with concentration of 0.008263 $molL^{-1}$.

9.00mL samples of the vinegar solution were used. The titration was done 4 times, giving burette titres of 27.35, 26.70, 26.75 and 26.65mL of KOH.

a) What is an appropriate indicator for this titration? Justify your choice.

b) Write a balanced symbol equation for the reaction.

c) Explain how the titration measurements should be used.

d) Calculate the concentration of the diluted vinegar solution.

10. (4 marks)
a) What are the characteristics of a "buffer solution"?

b) In general terms, what are the usual ingredients of a buffer solution? Give a specific example.

c) Give an example of a natural buffer system.

Answer Section

Worksheet 1

<u>Part 1</u>

a) opposites
b) neutralise
c) pH
d) 7
e) basic
f) acidic
g) change colour
h) pH (acidity)
i) plants / lichens
j) pink
k) blue
l) clear, clear, pink/red
m) red, yellow, yellow
n) yellow
o) blue
p) soil testing
q) water testing
r) effluents

<u>Part 2</u>

1. A = acid. B = base. C = neutral. D = base. E = acid.
2. B
3.
a) A chemical which changes colour depending on the pH of the solution it is in.
b) Soil testing, to help gardening or agriculture.
c) Put <u>Hydrangea</u> flowers through a blender with a small amount of water and ethanol. Filter the mixture. The liquid will act as an acid-base indicator.

Worksheet 2

1.
a) i) calcium chloride
ii) magnesium sulfate
iii) barium nitrate

b) i) $HCl + LiOH \longrightarrow H_2O + LiCl$

ii) $H_2SO_4 + 2NaOH \longrightarrow 2H_2O + Na_2SO_4$

iii) $2HNO_3 + Mg(OH)_2 \longrightarrow 2H_2O + Mg(NO_3)_2$

2.
a) $H_2SO_4 + FeO \longrightarrow H_2O + FeSO_4$

b) $2HCl + MgO \longrightarrow H_2O + MgCl_2$

c) $2HNO_3 + CuO \longrightarrow 2H_2O + Cu(NO_3)_2$

3.
a) $CO_2 + Ca(OH)_2 \longrightarrow H_2O + CaCO_3$

b) $P_2O_5 + 3H_2O \longrightarrow 2H_3PO_4$

c) $SO_3 + H_2O \longrightarrow H_2SO_4$ (sulfuric acid)

4.
a) $2H^+_{(aq)} + 2NO_3{}^-_{(aq)} + Zn_{(s)} \longrightarrow H_{2(g)} + Zn^{2+}_{(aq)} + 2NO_3{}^-_{(aq)}$

b) $2H^+_{(aq)} + SO_4{}^{2-}_{(aq)} + Ca_{(s)} \longrightarrow H_{2(g)} + Ca^{2+}_{(aq)} + SO_4{}^{2-}_{(aq)}$

c) $2H^+_{(aq)} + 2Cl^-_{(aq)} + Mg_{(s)} \longrightarrow H_{2(g)} + Mg^{2+}_{(aq)} + 2Cl^-_{(aq)}$

d) $2H^+_{(aq)} + 2NO_3{}^-_{(aq)} + Pb_{(s)} \longrightarrow H_{2(g)} + Pb^{2+}_{(aq)} + 2NO_3{}^-_{(aq)}$

e) Reaction (b) because of these metals, calcium is the most active in the "Activity Series".

5.
a) $2HNO_{3(aq)} + CuCO_{3(s)} \longrightarrow CO_{2(g)} + H_2O_{(l)} + Cu(NO_3)_{2(aq)}$

b) $H_2SO_{4(aq)} + K_2CO_{3(s)} \longrightarrow CO_{2(g)} + H_2O_{(l)} + K_2SO_{4(aq)}$

c) $2HCl_{(aq)} + Na_2CO_{3(s)} \longrightarrow CO_{2(g)} + H_2O_{(l)} + 2NaCl_{(aq)}$

Worksheet 3

In each case the conjugate is underlined.

a) $CH_3COOH_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + \underline{CH_3COO^-}_{(aq)}$

b) $NH_{3(aq)} + H_2O_{(l)} \rightleftharpoons \underline{NH_4{}^+_{(aq)}} + OH^-_{(aq)}$

c) $HPO_4{}^{2-}_{(aq)} + H_2O_{(l)} \rightleftharpoons \underline{PO_4{}^{3-}_{(aq)}} + H_3O^+_{(aq)}$

d) $HPO_4{}^{2-}_{(aq)} + H_2O_{(l)} \rightleftharpoons \underline{H_2PO_4{}^-_{(aq)}} + OH^-_{(aq)}$

e) $S^{2-}_{(aq)} + H_2O_{(l)} \rightleftharpoons \underline{HS^-_{(aq)}} + OH^-_{(aq)}$

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

g) $H_2S_{(aq)} + H_2O_{(l)} \rightleftharpoons \underline{HS^-_{(aq)}} + H_3O^+_{(aq)}$

h) $NO_2{}^-_{(aq)} + H_2O_{(l)} \rightleftharpoons \underline{HNO_{2(aq)}} + OH^-_{(aq)}$

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

j) $HSO_3{}^-_{(aq)} + H_2O_{(l)} \rightleftharpoons \underline{SO_3{}^{2-}_{(aq)}} + H_3O^+_{(aq)}$

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Answer Section

Worksheet 4

1. Acid Ionisation in Water

a) $HCl_{(g)} + H_2O_{(l)} \longrightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$

b) $HBr_{(g)} + H_2O_{(l)} \longrightarrow H_3O^+_{(aq)} + Br^-_{(aq)}$

c) $HCOOH_{(l)} + H_2O_{(l)} \longrightarrow H_3O^+_{(aq)} + HCOO^-_{(aq)}$

d) $HCN_{(g)} + H_2O_{(l)} \longrightarrow H_3O^+_{(aq)} + CN^-_{(aq)}$

e) $H_2SO_{4(l)} + 2H_2O_{(l)} \longrightarrow 2H_3O^+_{(aq)} + SO_4^{2-}{}_{(aq)}$

f) $H_2CO_{3(l)} + 2H_2O_{(l)} \longrightarrow 2H_3O^+_{(aq)} + CO_3^{2-}{}_{(aq)}$

g) $H_3PO_{4(l)} + 3H_2O_{(l)} \longrightarrow 3H_3O^+_{(aq)} + PO_4^{3-}{}_{(aq)}$

h) $C_6H_8O_{7(s)} + 3H_2O_{(l)} \longrightarrow 3H_3O^+_{(aq)} + C_6H_5O_7^{3-}{}_{(aq)}$

2. pH from $[H_3O^+]$

use pH = $-\log[H_3O^+]$ in each case

a) 1.17 (acidic) b) 3.08 (acidic)
c) -0.398 (acidic) d) 11.6 (basic)
e) 2.46 (acidic) f) 7.82 (just barely basic)

3. pH from Acid Concentration

a) $[H_3O^+]$ = 0.250, so pH = 0.602
b) $[H_3O^+]$ = 0.0750 x 2, so pH = 0.824
c) $[H_3O^+] = 7.50\times10^{-4}$ x 2, so pH = 2.82
d) $[H_3O^+] = 4.5\times10^{-3}$ x 3, so pH = 1.87
e) $[H_3O^+]$ = 6.00 x 2, so pH = -1.08

4. $[H_3O^+]$ from pH

use inverse (or 2nd function) log (-pH) on calculator

a) 5.01×10^{-6} $molL^{-1}$. b) 3.16×10^{-12} $molL^{-1}$.
c) 2.51 $molL^{-1}$. d) 1.41×10^{-5} $molL^{-1}$.
e) 3.16×10^{-9} $molL^{-1}$. f) 1.00 $molL^{-1}$.

Worksheet 5

1. C 2. D 3. C 4. B 5. A

6.

a) $H_2A + 2H_2O_{(l)} \longrightarrow 2H_3O^+_{(aq)} + A^{2-}{}_{(aq)}$
acid base conj.acid conj.base

b) if $[H_2A]$ = 0.0250, then $[H_3O^+]$= 0.0500 moL^{-1}
pH = $-\log_{10}[H_3O^+]$
= 1.30

c) H_2A must be a weak acid and has only partially ionised. The $[H_3O^+]$ is lower and pH higher than predicted.

7.

a) pH + pOH = 14. ∴ pOH = 14-9.5 = 4.5

b) i) pH = $-\log[H_3O^+]$
so $[H_3O^+]$ = antilog (-pH)
= 3.16×10^{-10} $molL^{-1}$.

ii) pOH = $-\log[OH^-]$
so $[OH^-]$ = antilog (-pOH)
= 3.16×10^{-5} $molL^{-1}$.

c) Correct Description: "This a <u>dilute</u> solution of a <u>weak</u> <u>base</u>". Justification of the underlined words:

<u>dilute</u>.
The concentration is quite low... "dilute". Do NOT use "weak" to describe concentrations.

<u>weak</u>
The [OH-] concentration (in (b) (ii) above) is well below the concentration of the solution itself.
Therefore, ionisation is partial.
Therefore, "weak" is the appropriate word.

<u>base</u>.
The pH is above 7, so the dissolved substance has reacted as a B-L base with water.

Worksheet 6

1. Amphiprotic Substances

a) $H_2PO_4^-{}_{(aq)} + H_3O^+_{(aq)} \longrightarrow H_3PO_{4(aq)} + H_2O_{(l)}$

$H_2PO_4^-{}_{(aq)} + OH^-_{(aq)} \longrightarrow HPO_4^{2-}{}_{(aq)} + H_2O_{(l)}$

b) $HCO_3^-{}_{(aq)} + H_3O^+_{(aq)} \longrightarrow H_2CO_{3(aq)} + H_2O_{(l)}$

$HCO_3^-{}_{(aq)} + OH^-_{(aq)} \longrightarrow CO_3^{2-}{}_{(aq)} + H_2O_{(l)}$

c) $HS^-_{(aq)} + H_3O^+_{(aq)} \longrightarrow H_2S_{(aq)} + H_2O_{(l)}$

$HS^-_{(aq)} + OH^-_{(aq)} \longrightarrow S^{2-}{}_{(aq)} + H_2O_{(l)}$

2. Acidic & Basic Salts

a) $CH_3COO^-_{(aq)} + H_2O_{(l)} \longrightarrow OH^-_{(aq)} + CH_3COOH_{(aq)}$

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

c) $NO_2^-{}_{(aq)} + H_2O_{(l)} \longrightarrow HNO_{2(aq)} + OH^-_{(aq)}$

d) $HC_2O_4^-{}_{(aq)} + H_2O_{(l)} \longrightarrow C_2O_4^{2-}{}_{(aq)} + H_3O^+_{(aq)}$

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

keep it simple science

Answer Section

Worksheet 7

1.

23.10 omitted

Average titre = (22.50+22.45+22.50)/3 = 22.48mL

$HCl_{(aq)} + NaOH_{(aq)} \longrightarrow H_2O_{(l)} + NaCl_{(aq)}$

$\frac{Ca \times Va}{a} = \frac{Cb \times Vb}{b}$

Cb = b x Ca x Va/(Vb x a)
= 1 x 0.09255 x 22.48/25.00 x1
= 0.08322

∴ c(NaOH) = 0.08322 $molL^{-1}$.

2.

i) $H_2SO_4 + 2NH_4OH \longrightarrow 2H_2O + (NH_4)_2SO_4$

ii) $\frac{Ca \times Va}{a} = \frac{Cb \times Vb}{b}$

Ca = a x Cb x Vb/(Va x b)
= 1 x 0.05025 x 28.32/(25.00 x 2)
= 0.02846

∴ $c(H_2SO_4)$ = 0.08322 $molL^{-1}$.

iii) L is best choice because stong acid-weak base titration has end-point at acidic pH.
L changes colour at 4.2.

3.

i) Can be obtained in a pure, dry state. Is stable and does not react with gases in air or absorb moisture.

ii) moles required:
n = C x V = 0.02500 x 0.5 = 0.01250 mol.
mass required: m = n x MM (MM= 90.04g)
= 0.01250 x 90.04
mass = 1.126g.

iii) Weigh out chemical into clean, dry beaker.
Add enough pure water, and stir, to dissolve it completely.
Transfer solution into 500mL volumetric flask.
Rinse beaker with small amounts of extra water and add washings to flask.
Fill flask to mark with pure water. Use a dropper at the end to fill exactly to the mark.
Insert stopper and invert repeatedly to mix solution thoroughly.

4.

$C_2H_2O_4 + 2KOH \longrightarrow 2H_2O + C_2O_4K_2$

(or)

$COOHCOOH + 2KOH \longrightarrow 2H_2O + COOKCOOK$

$\frac{Ca \times Va}{a} = \frac{Cb \times Vb}{b}$

Cb = b x Ca x Va/(Vb x a)
= 2 x 0.02500 x 31.45/25.00 x1
= 0.06290

∴ c(KOH) = 0.06290 $molL^{-1}$.

5.

i) use nitric acid because it is strong acid. Weak acid-weak base titrations have indistinct end-point... best avoided.

ii) $HNO_3 + NH_4OH \longrightarrow H_2O + NH_4NO_3$

Cb = b x Ca x Va/(Vb x a)
= 1 x 0.7438 x 12.76/10.00 x1
= 0.9491

∴ $c(NH_4OH)$ = 0.9491 $molL^{-1}$.

Worksheet 8

1.

a) $HZ + H_2O \rightleftharpoons H_3O^+ + Z^-$

b) $K_a = \frac{[H_3O^+][Z^-]}{[HZ]}$

c) $[H_2O]$ is "missing" because the concentration of the water in any aqueous solution is essentially the same. This constant value has been "absorbed" into the value of Ka.

d) Since pH = 3.8, then $[H_3O^+]$ = antilog(-3.8)
= 1.58 x 10^{-4} $molL^{-1}$.

∴ $[Z^-]$ = 1.58 x 10^{-4} and [HZ] ≅ 0.040

∴ $K_a = (1.58\times10^{-4})^2 / 0.040 = 6.24 \times 10^{-7}$
and pKa = 6.20

2.

Since HNO_3 is considered a strong acid, dissociation is 100%.
∴ $[H_3O^+]$ = 2.50 $molL^{-1}$.
So pH = -log(2.50) = -1.40

3.

a) $C_6H_5COOH + H_2O \rightleftharpoons H_3O^+ + C_6H_5COO^-$

b) Since pKa = 4.20, then K_a = antilog (-4.20)
∴ $K_a = 6.31 \times 10^{-5}$

let $[H_3O^+]$ = "x" at equilibrium.
So $[C_6H_5COO^-]$ = "x" also.

So, a good approximation is
$K_a = x^2 / 0.00258 = 6.31\times10^{-5}$

∴ $x = \sqrt{0.00258 \times 6.31\times10^{-5}}$
$[H_3O^+] = 4.03\times10^{-4}$ $molL^{-1}$.

$pH = -\log[H_3O^+] = 3.39$

Answer Section

Worksheet 8 (cont.)

4.

a) $HOCl + H_2O \rightleftharpoons H_3O^+ + OCl^-$

b) Since pKa = 7.53, then K_a = antilog (-7.53)

$$\therefore K_a = 2.95 \times 10^{-8} = \frac{[H_3O^+][OCl^-]}{[HOCl]}$$

pH = 4.75, so $[H_3O^+] = [OCl^-] = 1.78 \times 10^{-5}$ $molL^{-1}$.

Substituting into the Ka expression gives

$$K_a = 2.95 \times 10^{-8} = \frac{(1.78 \times 10^{-5})^2}{[HOCl]}$$

$$\therefore [HOCl] = (1.78 \times 10^{-5})^2 / 2.95 \times 10^{-8}$$
$$= 0.011\ molL^{-1}.$$

5.

In general terms, $HA + H_2O \rightleftharpoons H_3O^+ + A^-$

$$K_a = \frac{[H_3O^+][A^-]}{[HA]}$$

and since pH = 2.9, $[H_3O^+] = 1.26 \times 10^{-3}$

$K_a = (1.26 \times 10^{-3})^2 / 1.50 = 1.06 \times 10^{-6}$

$\therefore pK_a = 5.97$

Worksheet 9

a) oxygen	b) hydrogen
c) metals	d) Arrhenius
e) hydrogen ions	f) hydroxide or oxide
g) the solvent (water)	h) Bronsted-Lowry
i) proton donor	j) proton acceptor
k) transfer	l) protons
m) conjugate	n) conjugate acid
o) acid or base	p) amphiprotic
q) water	r) any ammonium salt
s) sodium carbonate	t) sodium chloride/sulfate
u) strong	v) strong
w) strong	x) weak
y) weak	z) strong
aa) hydronium & hydroxide	ab) water
ac) exo-	ad) Titration
ae) volume	af) standard
ag) equivalence (end)	ah) burette
ai) indicator	aj) colour
ak) pH	al) near-vertical
am) weak acid and its conjugate base	
an) shifts	ao) Le Chatelier's
ap) pH	aq) living
ar) constant chemical conditions	
as) in the blood	at) bicarbonate & carbonate

Worksheet 10

1. A **2.** D **3.** B **4.** C **5.** A **6.** A

7.

a) An acid produces hydrogen ions in solution.

b) $HCl_{(g)} \longrightarrow H^+_{(aq)} + Cl^-_{(aq)}$

c) Acids are proton donors. Bases are proton acceptors.

d) $HCl_{(g)} + H_2O_{(l)} \rightleftharpoons Cl^-_{(aq)} + H_3O^+_{(aq)}$

The HCl molecule has transferred a proton to the water molecule, therefore it is an acid.

8.

a) $CO_3^{2-}{}_{(aq)} + H_2O_{(l)} \rightleftharpoons HCO_3^-{}_{(aq)} + OH^-_{(aq)}$

Water acts as an acid and donates a proton to the carbonate ion. A hydroxide ion forms, which explains why the solution is basic.

b) If the environment is acidic, HCO_3^- acts as a base:

$H_3O^+_{(aq)} + HCO_3^-{}_{(aq)} \rightleftharpoons H_2CO_{3(aq)} + H_2O_{(aq)}$

If the environment is basic, HCO_3^- acts as an acid:

$OH^-_{(aq)} + HCO_3^-{}_{(aq)} \rightleftharpoons CO_3^{2-}{}_{(aq)} + H_2O_{(aq)}$

9.

a) A weak acid-strong base titration has an end point about pH = 8-10, so <u>phenolphthalein</u> is best.

b) $CH_3COOH + KOH \rightleftharpoons H_2O + CH_3COOK$

c) The first titre should be discarded because it does not agree closely with the others. The remaining 3 should be averaged.
Average = (26.70+26.75+26.65)/3 = 26.70mL

d) $$\frac{Ca \times Va}{a} = \frac{Cb \times Vb}{b}$$

$Ca = a \times Cb \times Vb/(Va \times b)$
$= 1 \times 0.008263 \times 26.70/(25.00 \times 1)$
$= 0.008825$

$\therefore c(CH_3COOH) = 0.08322\ molL^{-1}$.

10.

a) A buffer can maintain a constant pH despite addition of acid or base.

b) A (roughly equal) mixture of a weak acid and its conjugate base, such as ethanoic acid plus sodium ethanoate (which provides ethanoate ions).

c) Our blood is buffered by a mixture of bicarbonate ions and carbonate ions. The blood pH remains quite constant, despite constant changes occurring as gases dissolve, food is absorbed, etc.