ACIDS AND BASES - 1. - Problem Sheet

1. Write ionic equations and give observations for the following reactions:
   a) dilute hydrochloric acid is added to calcium carbonate

   b) a solution of sodium sulfide is added to a solution of nitric acid

   c) small pieces of magnesium are added to a solution of hydrochloric acid

   d) dilute sulfuric acid is added to copper hydroxide

2. Write ionic equations and give observations for the following reactions:
   a) an excess of sodium hydroxide solution is added to zinc hydroxide

   b) a solution of potassium hydroxide is added to aluminium and the mixture is heated.

   c) a solution of potassium hydroxide is added to a solution of copper sulfate

   d) a solution of sodium hydroxide is added to a solution of aluminium nitrate

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3. Identify each of the reactants in the following reactions as a Bronsted-Lowry acid or base.
   a) $HCl(aq) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$

   b) $NH_3(aq) + H_2O(l) \rightarrow NH_4^+(aq) + OH^-(aq)$

   c) $HSO_4^-(aq) + OH^-(aq) \rightarrow SO_4^{2-}(aq) + H_2O(l)$

   d) $2 H_2(g) + O_2(g) \rightarrow 2H_2O(l)$

   e) $HCO_3^-(aq) + H_2O(l) \rightarrow H_2CO_3(aq) + OH^-(aq)$

   f) $HF(aq) + HNO_3(aq) \rightarrow F^-(aq) + H_2NO_3^+(aq)$

4. a) Write an equation showing nitric acid (HNO_3) acting as an acid according to the Arrhenius theory.

   b) Write an equation showing calcium hydroxide acting as a base according to the Arrhenius theory.

   c) Write an equation to show nitric acid acting as an acid according to the Bronsted-Lowry theory

4. d) Write an equation to show ammonia, NH_3, acting as a base according to the Bronsted-Lowry theory

5. a) Give the conjugate acids of the following species -

Br^- HCO_3^- HF

b) Give the conjugate bases of the following species

OH^- NH_4^+ $H_2PO_4^-$

6. For the reactions below, list the conjugate pairs involved in each reaction, and state for each pair, which is the acid and which is the base:

a) $HCl(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + Cl^-(aq)$

b) $NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$

c) $HSO_4^-(aq) + OH^-(aq) \rightleftharpoons SO_4^{2-}(aq) + H_2O(l)$

7. 0.100 mole of hydrogen chloride is dissolved in 1.00 litre of solution. Calculate the concentrations, in moles per litre, of H^+ ions and OH^- ions in the solution.

8. Calculate the concentrations, in moles per litre, of Ca^{2+}, OH^- and H^+ in a 0.0300 mol L^{-1} $Ca(OH)_2$ solution.

9. 25.0 mL of 0.467 mol L^{-1} H_2SO_4 is added to 14.0 mL of 0. 600 mol L^{-1} NaOH. Calculate the concentrations, in mole per litre, of hydrogen ions and hydroxide ions in the resulting solution.

10. Calculate the pH of the following solutions

a) a solution of nitric acid in which $[H^+]$ is 1.00 x 10^{-3}.

b) 0.0100 mol L^{-1} HCl solution

c) a solution of potassium hydroxide in which $[OH^-]$ is 1.00 x 10^{-2}.

d) 0.0500 mol L^{-1} $Ca(OH)_2$ solution

11. Calculate the hydrogen ion and hydroxide ion concentrations in a solution with a pH of 9.00.

12. a) Calculate the pH of the solutions with the following concentrations of H^+:

i) 3.76 x 10^{-3} mol L^{-1}

ii) 0.000592 mol L^{-1}

b) Calculate the concentration of H^+ in solutions that have the following pH values:

i) pH of 2.31

ii) pH of 0.843

13. Calculate the hydrogen ion and the hydroxide ion concentrations and the pH of the solutions which form when the following solutions are mixed:

a) 0.500 L of 0.200 mol L^{-1} HCl and 0.500 L of 0.200 mol L^{-1} NaOH.

b) 1.00 L of 0.400 mol L^{-1} HCl and 1.00 L of 0.200 mol L^{-1} NaOH.

c) 1.00 L of 0.0200 mol L^{-1} HCl and 1.00 L of 0.0200 mol L^{-1} $Ca(OH)_2$.

14. Calculate the pH of the following solutions:

a) a solution in which the concentration of hydroxide ions is 3.25 x 10^{-2} mol L^{-1}.

b) 20.0 mL of 0.00482 mol L^{-1} HCl solution

c) 1.58 mol L^{-1} KOH solution

d) a solution that has been prepared by dissolving 0.589 g of HCl in 2.50 L of solution.

e) a solution formed by reacting 32.0 mL of 2.89 mol L^{-1} HNO_3 with 0.560 g of NaOH.

15. Identify each of the following as a strong acid, weak acid, strong base or weak base, and give an equation to support your answer.

a) KOH

b) HNO_2

c) NH_3

d) MgO

e) HNO_3

f) CH_3CH_2COOH

g) CO_3^{2-}

h) HBr

i) HCO_3^-

j) NH_4^+

k) HSO_4^-

16. Summarise the acid/base properties of substances by placing the following substances/labels in the correct columns:

most acids	negative ions of strong acids
NH_4^+	HSO_4^-, $H_2PO_4^-$
positive ions of Groups 1 and 2	HCl, HNO_3, H_2SO_4, $HClO_4$
transition metal ions and +3 metal ions	metal hydroxides and oxides
negative ions of weak acids	NH_3

Strong Acids	Weak Acids	Strong Bases	Weak Bases	Neutral

17. Place the following in the correct column:

CH_3COOH	HCl	$NaOH$	HNO_2	$HClO$
$HClO_4$	HSO_4^-	CO_3^{2-}	CaO	NH_3
NH_4^+ KOH	PO_4^{3-}	SO_3^{2-}	HCO_3^-	
HNO_3	HBr	Al^{3+}	$HCOOH$	Na^+
Cl^-	NO_3^-	SO_4^{2-}		

STRONG ACIDS	WEAK ACIDS	STRONG BASES	WEAK BASES	NEUTRAL

18.

0.03 mol L^{-1} HNO_3 solution	14 mol L^{-1} CH_3COOH solution
0.001 mol L^{-1} $Ca(OH)_2$ solution	16 mol L^{-1} H_2SO_4 solution
0.1 mol L^{-1} H_2SO_3 solution	0.01 mol L^{-1} NH_3 solution

From the above list choose

a) a dilute solution of a weak acid
b) a concentrated solution of a strong acid
c) a dilute solution of a strong acid
d) a dilute solution of a weak base
e) a concentrated solution of a weak acid
f) a dilute solution of a strong base.

19. Name the salt formed in each of the following reactions:

a) sodium hydroxide + nitric acid
b) magnesium hydroxide + hydrochloric acid
c) potassium hydroxide + ethanoic acid
d) ammonia + hydrobromic acid
e) sodium carbonate + sulfuric acid

20. For each of the following salts, decide whether they would form acidic, basic or neutral solutions, giving equations to support your answers.

$NaCl$

KF

Li_2CO_3

$Mg(HSO_4)_2$

NH_4Br

21. Describe the difference between "dissociation" and "hydrolysis".

22. a) Which is the stronger base: $Cl^-(aq)$ or $NH_3(aq)$?

b) Which is the weaker acid: $HF(aq)$ or $HCl(aq)$?

c) Which is the weaker base: $F^-(aq)$ or $Cl^-(aq)$?

23. H_2O is a weaker acid than HCO_3^-. Would you expect the reactants or the products to be favoured in the following equilibrium system?

$$CO_3^{2-}(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + OH^-(aq)$$

Which base would be the stronger?

ANSWERS: ACIDS AND BASES - 1. - Problem Sheet.

1. a) $2H^+(aq) + CaCO_3(s) \rightarrow CO_2(g) + H_2O(l) + Ca^{2+}(aq)$
   White solid dissolves to form colourless gas and colourless solution
   b) $2H^+(aq) + S^{2-}(aq) \rightarrow H_2S(g)$
   Colourless solution and a "rotten" smelling colourless gas form.
   c) $2H^+(aq) + Mg(s) \rightarrow H_2(g) + Mg^{2+}(aq)$
   Grey solid dissolves to form colourless solution and of colourless gas
   d) $2H^+(aq) + Cu(OH)_2(s) \rightarrow 2H_2O(l) + Cu^{2+}(aq)$
   Green solid dissolves to form blue solution

2. a) $Zn(OH)_2(s) + 2OH^-(aq) \rightarrow Zn(OH)_4^{2-}(aq)$
   White solid dissolves to form colourless solution
   b) $2Al(s) + 2OH^-(aq) + 6H_2O(l) \rightarrow 3H_2(g) + 2Al(OH)_4^-(aq)$
   Silver metal dissolves to form colourless solution and colourless gas
   c) $Cu^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(s)$
   A blue precipitate forms
   d) $Al^{3+}(aq) + 4OH^-$ (aq $\rightarrow Al(OH)_4^-(aq)$
   A white precipitate first forms. It then dissolves to form a colourless solution

3. a) $HCl(aq)$ - acid $H_2O(l)$ - base b) $NH_3(aq)$ - base $H_2O(l)$ - acid
   c) $HSO_4^-(aq)$ - acid $OH^-(aq)$ - base d) not an acid/base reaction
   e) $HCO_3^-(aq)$ - base $H_2O(l)$ - acid f) $HF(aq)$ - acid $HNO_3(aq)$ - base

4. a) $HNO_3 \rightarrow H^+ + NO_3^-$ b) $Ca(OH)_2 \rightarrow Ca^{2+} + 2OH^-$
   c) $HNO_3 + H_2O \rightarrow H_3O^+ + NO_3^-$ d) $NH_3 + H_2O \rightarrow NH_4^+ + OH^-$

5. a) Br^- - $\mathbf{HBr}$ HCO_3^- - $\mathbf{H_2CO_3}$ HF - $\mathbf{H_2F^+}$
   b) OH^- - $\mathbf{O^{2-}}$ NH_4^+ - $\mathbf{NH_3}$ $H_2PO_4^-$ - $\mathbf{HPO_4^{2-}}$

6. a) HCl (A) / Cl^- (B) H_2O (B) / H_3O^+ (A) b) NH_3 (B) / NH_4^+ (A) OH^-(B) / H_2O(A)
   c) HSO_4^-(A) / SO_4^{2-}(B) H_2O(A) / OH^-(B)

7. $HCl \rightarrow H^+ + Cl^-$ moles of H^+ formed = 0.100 i.e. conc of H^+ = **0.100 mol L^{-1}**
   $[OH^-]$ = = **1 x 10^{-13} mol L^{-1}**

8. $Ca(OH)_2 \rightarrow Ca^{2+} + 2OH^-$ conc of Ca^{2+} = **0.0300 mol L^{-1}**
   conc of OH^- = 2 x 0.0300 = **0.0600 mol L^{-1}** conc of H^+ = = **1.67 x 10^{-13} mol L^{-1}**

9. moles H_2SO_4 = 0.467 x 0.025 = 0.01167 i.e. moles of H^+ = 2 x 0.01167 = 0.02335
   moles NaOH = 0.600 x 0.0140 = 0.0084 = moles of OH^-
   $H^+ + OH^- \rightarrow H_2O$ OH^- is the limiting reagent
   i.e. 0.0084 moles of OH^- will react with 0.0084 moles of H^+
   moles of H^+ left after the reaction = 0.02335 - 0.0084 = 0.01495 vol of new solution = 39.0 mL
   conc of H^+ in new solution = = **0.383 mol L^{-1}**
   conc of OH^- = = **2.61 x 10^{-14} mol L^{-1}**

10. a) pH = **3** b) $[H^+]$ = 0.0100 mol L^{-1} i.e. pH = **2**
    c) $[H^+]$ = = 1 x 10^{-12} mol L^{-1} i.e. pH = **12**
    d) $[OH^-]$ = 2 x 0.0500 = 0.100 mol L^{-1} $[H^+]$ = = 1 x 10^{-13} mol L^{-1} i.e. pH = **13**

11. $[H^+]$ = **1 x 10^{-9} mol L^{-1}** $[OH^-]$ = **1 x 10^{-5} mol L^{-1}**

12. a) i) pH = -log 3.76 x 10^{-3} = **2.42** ii) pH = -log 0.000592 = **3.23**
    b) i) $[H^+]$ = **0.00490 mol L^{-1}** ii) $[H^+]$ = **0.144 mol L^{-1}**

13. a) moles HCl = 0.500 x 0.200 = 0.100 = moles of H^+
moles NaOH = 0.500 x 0.200 = 0.100 = moles of OH^-
$H^+ + OH^- \rightarrow H_2O$ 0.100 moles of H^+ will react with 0.100 moles of OH^-
i.e. there will be no H^+ or OH^- remaining from this reaction
But there will be H^+ and OH^- from the self-ionisation of water
i.e. $[H^+] = [OH^-] =$ **1×10^{-7} mol L^{-1}** (i.e. it is a neutral solution)
pH = -log [H] = -log 1×10^{-7} = **7**

b) moles HCl = 0.400 x 1.00 = 0.400 = moles of H^+
moles NaOH = 0.200 x 1.00 = 0.200 = moles of OH^-
$H^+ + OH^- \rightarrow H_2O$ OH^- is the limiting reagent
i.e. 0.200 moles of OH^- will react with 0.200 moles of H^+
After the reaction there will be 0.400 - 0.200 = 0.200 moles of H^+ remaining vol of new solution = 2.00 L
$[H^+]$ in new solution = = **0.100 mol L^{-1}** $[OH^-]$ = = **1.00×10^{-13} mol L^{-1}**
pH = -log $[H^+]$ = **1**

c) moles HCl = 0.0200 x 1.00 = 0.0200 = moles of H^+
moles $Ca(OH)_2$ = 0.0200 x 1.00 = 0.0200 moles of OH^- = 2 x 0.0200 = 0.0400
$H^+ + OH^- \rightarrow H_2O$ H^+ is the limiting reagent
0.0200 moles of H^+ will react with 0.0200 moles of OH^-
i.e. will be left with 0.0400 - 0.0200 = 0.0200 moles of OH^- new volume = 2.00 L
new $[OH^-]$ = = **0.0100 mol L^{-1}**
$[H^+]$ = = **1×10^{-12} mol L^{-1}** pH = -log [H] = **12**

14. a) $[H^+]$ = = 3.077×10^{-13} mol L^{-1} pH = - log (3.077×10^{-13}) = **12.5**
b) $[H^+]$ = 0.00482 mol L^{-1} pH = -log 0.00482 = **2.32**
c) $[OH^-]$ = 1.58 mol L^{-1} $[H^+]$ = = 6.329×10^{-15} mol L^{-1} pH = **14.2**
d) moles of HCl = = 0.01615 = moles of H^+
conc of H^+ = = 0.006462 mol L^{-1} pH = **2.19**

e) moles of HNO_3 = 2.89 x 0.032 = 0.09248 = moles of H^+
moles of NaOH = = 0.0140 = moles of OH^-
$H^+ + OH^- \rightarrow H_2O$ OH^- is the limiting reagent
0.0140 moles of OH^- will react with 0.0140 moles of H^+
i.e. will be left with 0.09248 - 0.0140 = 0.07848 moles of H^+ volume = 32.0 mL
$[H^+]$ = = 2.452 mol L^{-1} pH = **-0.390**

15. a) KOH - strong base $KOH \rightarrow K^+ + OH^-$
b) HNO_2 - weak acid $HNO_2 \rightleftharpoons NO_2^- + H^+$
c) NH_3 - weak base $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$
d) MgO - strong base $MgO + H_2O \rightarrow Mg^{2+} + 2\,OH^-$
e) HNO_3 - strong acid $HNO_3 \rightarrow H^+ + NO_3^-$
f) CH_3CH_2COOH - weak acid $CH_3CH_2COOH \rightleftharpoons CH_3CH_2COO^- + H^+$
g) CO_3^{2-} - weak base $CO_3^{2-} + H_2O \rightleftharpoons HCO_3^- + OH^-$
h) HBr - strong acid $HBr \rightarrow H^+ + Br^-$
i) HCO_3^- - weak base $HCO_3^- + H_2O \rightleftharpoons H_2CO_3 + OH^-$
j) NH_4^+ - weak acid $NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$
k) HSO_4^- - weak acid $HSO_4^- + H_2O \rightleftharpoons SO_4^{2-} + H_3O^+$

16.

Strong Acids	Weak Acids	Strong Bases	Weak Bases	Neutral
HCl, HNO_3, H_2SO_4, $HClO_4$	most acids NH_4^+ HSO_4^-, $H_2PO_4^-$ transition metal ions and +3 metal ions	metal hydroxides and oxides	negative ions of weak acids NH_3	negative ions of strong acids positive ions of Groups 1 and 2

17.

STRONG ACIDS	WEAK ACIDS	STRONG BASES	WEAK BASES	NEUTRAL
HCl $HClO_4$ HNO_3 HBr	CH_3COOH HNO_2 HClO HSO_4^- NH_4^+ Al^{3+} HCOOH	NaOH CaO KOH	CO_3^{2-} NH_3 PO_4^{3-} SO_3^{2-} HCO_3^-	Na^+ Cl^- NO_3^- SO_4^{2-}

18. a) 0.1 mol L^{-1} H_2SO_3 solution b) 16 mol L^{-1} H_2SO_4 solution
c) 0.03 mol L^{-1} HNO_3 solution d) 0.01 mol L^{-1} NH_3 solution
e) 14 mol L^{-1} CH_3COOH solution f) 0.001 mol L^{-1} $Ca(OH)_2$ solution

19 a) sodium nitrate b) magnesium chloride c) potassium ethanoate
d) ammonium bromide e) sodium sulfate

20. NaCl - neutral
KF - weak base $F^- + H_2O \rightleftharpoons HF + OH^-$
Li_2CO_3 - weak base $CO_3^{2-} + H_2O \rightleftharpoons HCO_3^- + OH^-$
$Mg(HSO_4)_2$ - weak acid $HSO_4^- + H_2O \rightleftharpoons SO_4^{2-} + H_3O^+$
NH_4Br - weak acid $NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$

21. Dissociation - the breaking up of an ionic lattice that occurs when an ionic substance is dissolved in water e.g. $NaCl(s) \rightarrow Na^+(aq) + Cl^-(aq)$
Hydrolysis - the reaction of a substance with water e.g. $HCO_3^- + H_2O \rightleftharpoons H_2CO_3 + OH^-$

22. a) $NH_3(aq)$ b) HF (aq) c) $Cl^-(aq)$

23. reactants OH^-