Revision Problems - ACIDS & BASES - 1. (Chapter 15)

Reactions of acids & bases

1. Write balanced equations for the following reactions. Use ionic equations where appropriate. Also, describe what you would expect to see happening i.e. the observations, in each case. If no reaction occurs, then write 'no reaction'.
   a) Dilute nitric acid is added to a piece of magnesium.
   b) A solution of sodium hydroxide is added to a piece of magnesium
   c) Dilute hydrochloric acid is added to solid calcium carbonate.
   d) A solution of sodium carbonate is added to dilute sulfuric acid.
   e) Aluminium hydroxide is added to dilute hydrochloric acid
   f) Aluminium hydroxide is added to a solution of sodium hydroxide
   g) Copper hydroxide is added to dilute sulfuric acid
   h) Copper hydroxide is added to a solution of sodium hydroxide.
   i) Zinc is added to dilute hydrochloric acid
   j) Zinc is added to a solution of potassium hydroxide.
   k) Black copper oxide is added to dilute nitric acid
2. Describe how you could use a solution of sodium hydroxide to distinguish between a lump of iron and a lump of aluminium. Give equations to support your answer.
3. Both magnesium hydroxide and zinc hydroxide are white solids. Describe an experiment you could carry out to distinguish between the two hydroxides. Give equations to support you answer.
4. Both calcium oxide and calcium carbonate are white solids. Describe an experiment you could carry out to distinguish between the two solids. Give equations to support you answer.

Bronsted-Lowry acid-base theory

5. In each of the following reactions state whether the first reactant is acting as an acid or a base.
   a) $SO_3^{2-} + H_2O \rightleftharpoons HSO_3^- + OH^-$.
   b) $PH_3 + HI \rightleftharpoons PH_4^+ + I^-$.
   c) $HPO_4^{2-} + H_2O \rightleftharpoons OH^- + H_2PO_4^-$.
   d) $CH_3COOH + HBr \rightleftharpoons CH_3COOH_2^+ + Br^-$.
   e) $CH_3NH_2 + CH_3CH_2OH \rightleftharpoons CH_3CH_2O^- + CH_3NH_3^+$.
6. For each of the equations given in question 5., give the two conjugate acid-base pairs involved in each reaction. For each pair, write the formula of the conjugate acid first.
7. Give the formula of the conjugate acid for each of the following bases:
   NO_3^-, SO_3^{2-}, HF, ClO_3^-, NH_3
8. Give the formula of the conjugate base for each of the following acids:
   HBr, HSO_3^-, H_3PO_4, H_3Se^+, H_2O, OH^-
9. Give an equation showing: a) HBr acting as an acid; b) HCO_3^- acting as a base.

pH

10. 0.400 mole of HNO_3 is dissolved in 2.00 L of solution. Calculate the concentration, in mol L^{-1}, of H^+ ions and OH^- ions in the solution

11. 4.00 g of NaOH is dissolved in 1.00 L of solution. Calculate the concentration of hydronium ions and hydroxide ions in the solution.

12. Calculate the concentration of H^+ and OH^- in the following solutions:
    a) 0.200 mol L^{-1} HNO_3 solution
    b) 0.00500 mol L^{-1} $Ca(OH)_2$ solution.
    c) 20.0 mL of 0.3 mol L^{-1} HCl solution
    d) a solution formed when 50.0 mL of water is added to 50.0 mL of 0.200 mol L^{-1} KOH

13. Calculate the pH of the following solutions
    a) a solution of acetic acid in which the concentration of hydrogen ions is 0.00100 mol L^{-1}
    b) 0.000100 mol L^{-1} HNO_3 solution
    c) 100 mL of 0.100 mol L^{-1} hydrobromic acid solution.
    d) a solution of ammonia in which the concentration of hydroxide ions is 0.000100 mol L^{-1}
    e) 5.00×10^{-3} mol L^{-1} $Ba(OH)_2$ solution
    f) the solution formed when 50.0 mL of 0.200 mol L^{-1} of HCl is added to 50.0 mL of 0.400 mol L^{-1} NaOH solution (assume that NaCl does not affect the pH)

14. a) Calculate the concentration of hydrogen ions and hydroxide ions in a solution with a pH of 8.
    b) How many moles of HCl must be added to 2.00 L of water to form a solution with a pH of 1?
    c) What mass of KOH must be added to 500 mL of water to form a solution with a pH of 14?

Strong & weak acids & bases

15. a) List 4 strong acids. b) List 3 weak acids. c) List 4 strong bases d) List 3 weak bases.

16. Identify the following as true or false:

    Comparing 1 L of 0.1 mol L^{-1} acetic acid and 1 L of 0.1 mol L^{-1} hydrochloric acid:
    a) both solutions would have the same pH
    b) the acetic acid solution would contain fewer hydrogen ions than the hydrochloric acid solution
    c) both solutions could be prepared by dissolving 0.1 moles of the respective acid in 1 L of solution.
    d) the pH of the acetic acid solution would be greater than 7 and the pH of the hydrochloric acid solution would be less than 7
    e) the equilibrium constant for the hydrolysis reaction for the acetic acid solution would be smaller than that for the hydrochloric acid solution.
    f) both solutions contain the same mass of acid
    g) both solutions would require the same volume of 0.1 mol L^{-1} sodium hydroxide for complete reaction

17. Identify the following as true or false:

    Comparing 100 mL of 0.1 mol L^{-1} NaOH and 100 mL of 0.1 mol L^{-1} ammonia solution:
    a) both solutions would have the same pH
    b) the NaOH solution would contain fewer hydroxide ions in solution than the ammonia solution
    c) the NaOH solution would contain fewer hydrogen ions in solution than the ammonia solution
    d) the pH of the NaOH solution would be greater than the pH of the ammonia solution
    e) both solutions would require the same volume of 0.1 mol L^{-1} hydrochloric acid for titration to the equivalence point i.e. for a complete reaction.

18. Identify the following statements as being true or false.

HBr is a stronger acid than H_2S, so it can be concluded that

a) HBr will have a larger equilibrium constant for the hydrolysis reaction than H_2S

b) a solution of HBr will always have a smaller pH than a solution of H_2S

c) Br^- will be a stronger base than HS^-.

d) the reaction $HBr + H_2O \rightleftharpoons Br^- + H_3O^+$ will occur to a greater extent than the reaction $H_2S + H_2O \rightleftharpoons HS^- + H_3O^+$

e) the reaction $HBr + HS^- \rightleftharpoons Br^- + H_2S$ will occur to a large extent.

f) when 1 mole of H_2S is bubbled through a solution containing 1 mole of NaBr, a large amount of HBr and HS^- will be formed i.e. the reaction will be essentially complete.

19. A chemist has 0.010 mol L^{-1} solutions of four acids, L, M, N and P, and measures the pH of each. The values are 2, 6.1, 2.0 and 2.7 respectively.

a) Arrange the four acids , L, M, N, P, in order of increasing acid strength (weakest first, strongest last).

b) Are any of these acids completely ionised? Justify your answer.

Acid/base nature of salts

20. The oxide ion, O^{2-}, in soluble metallic oxides such as Na_2O and CaO, reacts with water to form hydroxide ions.

a) Write the equation for this hydrolysis reaction, and identify the conjugate pairs.

b) Is O^{2-} a weaker or stronger base than the hydroxide ion? Give your reason.

21. a) Give the dissociation constant (K_a) expression for each of the following
i) HF ii) H_2SO_4 iii) $H_2PO_4^-$.

b) For which one of the above acids would you expect the value of K_a to be the largest?

22. When some potassium bromide was dissolved in water, a solution with a pH of 7 was obtained, but when some potassium hydrogensulfate was dissolved in water, a solution with a pH of 5.5 was obtained and when some potassium hydrogencarbonate was dissolved in water, a solution with a pH of 8.5 was obtained.

Explain these results in terms of the hydrolysis reactions that occur when the three salts are added to water.

23. For each of the following substances, give the dissociation equation and the hydrolysis equation that occur when it is added to water. Then state whether the solution formed would be neutral, acidic or basic.

a) $MgCl_2$ b) NH_4NO_3 c) K_2O d) Na_2SO_4

e) Na_2S f) LiCN g) $BaBr_2$ h) NaH_2PO_4

i) K_3PO_4

Miscellaneous multiple-choice problems

24 Which of the following aqueous solutions would be neutral i.e. have a pH equal to 7 at 25°C?

a) 0.1 mol L^{-1} CH_3COOH b) 0.1 mol L^{-1} CH_3COONa c) 0.1 mol L^{-1} NH_4Cl
d) 0.1 mol L^{-1} NaCl e) 0.1 mol L^{-1} NaOH

A a), b), c) and d) B b), c) and d) C b), d) and e)
D c) and d) E d) only

25. Sulfuric acid is said to be a stronger acid than acetic acid because

A sulfuric acid has two ionisable hydrogen atoms and acetic acid has only one ionisable hydrogen atom
B sulfuric acid ionises more completely than acetic acid in aqueous solution
C aqueous sulfuric acid conducts electricity but aqueous acetic acid does not.
D sulfuric acid is more soluble in water than acetic acid
E the pH of a sulfuric acid solution is greater than that of an acetic acid solution of the same concentration.

26. Aluminium hydroxide, $Al(OH)_3$, is said to be amphoteric for which one of the following reasons?

A The pH of a saturated solution of $Al(OH)_3$ is close to 7.
B $Al(OH)_3$ is a stronger acid than it is a base.
C $Al(OH)_3$ is a stronger base than it is an acid.
D $Al(OH)_3$ can act as an acid or a base.
E $Al(OH)_3$ when heated, can be dehydrated to form Al_2O_3.

27. Which one of the following statements about aqueous solutions is false?

A The pH of a 0.1 mol L^{-1} solution of NaCl is equal to 7.
B The pH of a 0.1 mol L^{-1} solution of $NaCH_3COO$ is greater than 7.
C The pH of a 0.1 mol L^{-1} solution of Na_2CO_3 is less than 7.
D The pH of a 0.1 mol L^{-1} solution of H_2SO_4 is less than the pH of a 0.1 mol L^{-1} solution of HCl .
E The pH of a 0.1 mol L^{-1} solution of NaOH is greater than the pH of a 0.1 mol L^{-1} solution of NH_3 .

28. Which one of the following solutions would show the greatest electrical conductivity?

A 10 mL of 0.2 mol L^{-1} HCl
B 30 mL of 0.1 mol L^{-1} HCl
C 10 mL of 0.4 mol L^{-1} CH_3COOH
D 30 mL of 0.2 mol L^{-1} CH_3COOH
E 10 mL of 0.1 mol L^{-1} CH_3COOH

29. The pH of a 0.01 mol L^{-1} aqueous sodium hydroxide solution is

A equal to 1 B equal to 2 C equal to 7 D between 7 and 11 E equal to 12

30. The measured pH value for 0.1 mol L^{-1} aqueous solutions of lithium nitrate, sodium acetate and ammonium chloride would fall into what regions?

	$LiNO_3$	CH_3COONa	NH_4Cl
A	acidic	neutral	basic
B	basic	neutral	acidic
C	neutral	neutral	basic
D	neutral	basic	basic
E	neutral	basic	acidic

31. Given that hydrofluoric acid is a weak acid and perchloric acid is a strong acid, which one of the following statements is true?

A The $[H^+]$ of a 0.1 mol L^{-1} hydrofluoric acid solution is greater than the $[H^+]$ of 0.1 mol L^{-1} perchloric acid solution.
B The pH of a sodium fluoride solution is 7.
C The pH of a sodium perchlorate solution is 7.
D The pH of a 0.1 mol L^{-1} perchloric acid solution is greater than 1 but less than 7.
E The pH of a 0.1 mol L^{-1} hydrofluoric acid solution is 1.

32. The pH of 0.001 mol L^{-1} sodium hydroxide solution is

A 2 B 3 C 7 D 11 E 14

33. Which one of the following compounds is a triprotic acid (i.e. can release three hydrogen ions into aqueous solution for each molecule of acid)?

A sulfuric acid B propanoic acid C nitric acid D phosphoric acid E ammonia

34. Ammonium chloride solution is

A acidic because chloride ion reacts with water to give HCl
B basic because ammonium ion reacts with water to give OH^-
C basic because it contains ammonia which is a base
D neutral because it is the result of neutralisation of ammonia with hydrochloric acid
E acidic because of a reaction between ammonium ion and water

35. What is the pH of a 1 x 10^{-3} mol L^{-1} calcium hydroxide solution?

A 0.001 B 0.002 C 3 D 11.3 E 14

36. In which of the following reactions is the hydrogencarbonate ion acting as an acid?

A $HCO_3^- + H_3O^+ \rightarrow CO_2 + 2H_2O$
B $HCO_3^- + H_2O \rightarrow H_2CO_3 + OH^-$
C $HCO_3^- + HSO_4^- \rightarrow H_2CO_3 + SO_4^{2-}$
D $HCO_3^- + PO_4^{3-} \rightarrow CO_3^{2-} + HPO_4^{2-}$
E $HCO_3^- + CH_3COOH \rightarrow CO_2 + H_2O + CH_3COO^-$

37. Which one of the following compounds, if dissolved in water, would form a solution with a pH less than 7?

A NH_4NO_3 B $CaCl_2$ C NaCl D $Ca(OH)_2$ E $NaCH_3COO$

38. An element X which occurs in the second short period has an outer electronic structure s^2p^2. What are the formula and the acid-base character of its principal oxide?

A XO, basic B XO, acidic C XO_2, acidic D XO_2, basic E X_2O_4, acidic

39. In the hydrolysis of the carbonate ion in aqueous solution, as understood by the Bronsted-Lowry theory, the conjugate acid formed is:

A H_3O^+ B Na^+ C CO_3^{2-} D HCO_3^- E H_2CO_3

40. 250.0 mL of 0.40 mol L^{-1} nitric acid is added 750.0 mL of 0.60 mol L^{-1} potassium hydroxide. What is the final hydroxide ion concentration?

A 0.35 mol L^{-1} B 0.45 mol L^{-1} C 0.50 mol L^{-1} D 0.55 mol L^{-1} E 10^{-7} mol L^{-1}

41. In which group would all three oxides be classified as basic oxides?

A CO_2, SiO_2, CuO B P_4O_{10}, SO_2, CO_2 C CaO, Na_2O, K_2O
D CO_2, SiO_2, Al_2O_3 E ZnO, SiO_2, Na_2O

42. In which one of the following reactions is dihydrogenphosphate acting as a base?

A $H_2PO_4^- + H_3O^+ \rightarrow HPO_4^{2-} + 2H_2O$ B $H_2PO_4^- + H_2O \rightarrow H_3PO_4 + OH^-$
C $H_2PO_4^- + CO_3^{2-} \rightarrow PO_4^{3-} + CO_2 + H_2O$ D $H_2PO_4^- + OH^- \rightarrow HPO_4^{2-} + H_2O$
E $H_2PO_4^- + NH_3 \rightarrow NH_4^+ + HPO_4^{2-}$

43. The pH of a solution is 9. If the pH is increased to 11, by what factor is the hydrogen ion concentration decreased?

A 0.01 B 2 C 10 D 100 E 1000

44. Which one of the following 1 mol L^{-1} solutions will contain the greatest number of ions?

A acetic acid B hydrochloric acid C ammonia solution
D magnesium acetate E phosphoric acid

45. 25.0 mL of 0.450 mol L^{-1} nitric acid is added to 80.0 mL of 0.0300 mol L^{-1} magnesium hydroxide. What is the final hydrogen ion concentration?

A 0.0614 mol L^{-1} B 0.00645 mol L^{-1} C 0.0645 mol L^{-1}
D 0.00885 mol L^{-1} E 0.0843 mol L^{-1}

46. Which one of the following groups consists ONLY of substances which give alkaline solutions (pH > 7) when added to water?

A sodium chloride, potassium hydrogensulfate and sodium carbonate
B potassium nitrate, sodium acetate and ammonium chloride
C potassium hydrogensulfate, ammonium chloride and sodium dihydrogenphosphate
D lithium fluoride, sodium hydrogencarbonate and potassium acetate

47. In which of the following reactions is water behaving as a base?

A $H_2O(g) + C(s) \rightarrow CO(g) + H_2(g)$ B $H_2O(l) + N_2H_4(aq) \rightarrow N_2H_5^+(aq) + OH^-(aq)$
C $H_2O(l) + HCO_3^-(aq) \rightarrow CO_3^{2-}(aq) + H_3O^+(aq)$ D $H_2O(l) + PO_4^{3-}(aq) \rightarrow HPO_4^{2-}(aq) + OH^-(aq)$
E $H_2O(l) + HSO_3^-(aq) \rightarrow H_2SO_3(aq) + OH^-(aq)$

48. Assuming that ionisation of water can be represented as $H_2O(l) \rightarrow H^+(aq) + OH^-(aq)$, what fraction of water molecules are ionised in pure water, at conditions of T = 25°C and P = 1 atm?

A 0 B 1 in 18 C 1 in 10^7 D 1 in 10^{-7} E 1 in 5.56×10^8

49. 40.0 mL of 0.500 mol L^{-1} HCl is added to 60.0 mL of 0.250 mol L^{-1} $Ba(OH)_2$. The pH of the resulting solution is:

A 1 B 2 C 3 D 12 E 13

50. Which of the following substances have a noticeable effect on the pH of water when dissolved in it?
a) potassium nitrate b) sodium acetate (acetate) c) iron (III) sulfate

A All B a) and b) only C b) and c) only D a) and c) only E b) only

51. In water one might expect the existence of
a) O^{2-} b) H_3O^+ c) H_2O d) OH^- e) H_4O^{2+}
Which of these cannot function as an acid?

A c) and d) B d) only C a) only D None of them E a) and e)

52. The pH of a solution is 5. If the pH of this solution is decreased by 2, by what factor is the concentration of hydrogen ion increased?

A 2.5 B 3 C 10 D 100 E 1000

53. f the pH of an aqueous solution is zero, what is the hydroxide ion concentration?

A 0 mol L^{-1} B 1 mol L^{-1} C 10 mol L^{-1} D 10^{-7} mol L^{-1} E 10^{-14} mol L^{-1}

54. Which base is strong, but can never be produced as a concentrated solution?

A magnesium hydroxide B sodium hydroxide C ammonia D water

55. The aqueous solution of one of the following salts is acidic. Which one?

A $NaHCO_3$ B Na_2CO_3 C NaCl D NH_4Cl E Na_2SO_4

56. When 50.0 mL of 1 mol L^{-1} NaOH is added to 49.9 mL of 1 mol L^{-1} HCl solution, the resulting solution has a pH of approximately:

A 2 B 3 C 8 D 10 E 11

57. Pure distilled water is virtually a non-conductor of electricity. This is because:

A The concentration of H^+ equals the concentration of OH^-.
B The concentration of ions is very low.
C The pH equals 7.
D The H_2O molecule is polar.
E Water can behave as both an acid and a base.

58. Sodium oxide (Na_2O) is soluble in water. As well as Na^+ ions, you obtain in aqueous solution:

A O^{2-} ions B H^+ ions C OH^- ions D H^- ions

59. A compound was dissolved in both potassium hydroxide solution and hydrochloric acid solution. In both cases, a clear colourless mixture was produced. Of the following, the compound could be:

A $Mg(OH)_2$ B Cr_2O_3 C $Al(OH)_3$ D $BaCO_3$

60. Which of the following solutions are weak acids?
$[Al(H_2O)_6]^{3+}(aq)$, HF(aq), HBr(aq), $HSO_4^-(aq)$, $H_2PO_4^-(aq)$

A All
B All except $[Al(H_2O)_6]^{3+}(aq)$
C All except $H_2PO_4^-(aq)$
D All except $HSO_4^-(aq)$ and HF(aq)
E All except HBr(aq)

61. Which of the following salts, when dissolved in water, would give a basic solution (pH > 7)?
a) NaF b) NH_4NO_3 c) $Ca(NO_2)_2$

A a) and b) only
B b) and c) only
C a) and c) only
D All of them
E None of them.

62. In which of the following reactions is water acting as an acid?

A $H_3O^+(aq) + HPO_4^{2-} \rightarrow H_2O(l) + H_2PO_4^-(aq)$
B $H_2O(l) + HCO_3^-(aq) \rightarrow H_3O^+(aq) + CO_3^{2-}(aq)$
C $H_2O(l) + NH_3(g) \rightarrow NH_4^+(aq) + OH^-(aq)$
D $H_3O^+(aq) + HS^-(aq) \rightarrow H_2S(aq) + H_2O(l)$

63. Which of the following species is amphiprotic (amphoteric) in water?

A NH_4^+ B Cl^- C $CH_3CO_2^-$ D HPO_4^{2-}

64. Hydrochloric acid is a strong acid which completely dissociates in aqueous solution. 1.0 mL of 10 mol L^{-1} hydrochloric acid is diluted to 1 litre using distilled water.
The pH of the final solution is closest to:

A 0 B 2 C 3 D 7

65. Which one of the following is a conjugate acid-base pair?

A HNO_3 and NO_3^- B H_3O^+ and OH^- C HNO_3 and H_2O D NH_3 and OH^-

66. Which one of the following lists contains only oxides which are acidic?

A CO_2, P_4O_{10}, SO_3 B MgO, CaO, Na_2O C NO_2, SO_2, Li_2O D CO_2, SO_3, CaO

67. 50 mL of NaOH(aq) with a pH of 13 is mixed with 100 mL of HCl(aq) with a pH of 1. In the resulting solution, the hydrogen ion concentration is:

A 0.033 mol L^{-1} B 0.05 mol L^{-1} C 0.10 mol L^{-1} D 0.20 mol L^{-1}

68. A basic solution would result from the hydrolysis of one of the ions in this compound. The compound is

A $NaNO_3$ B NH_4Cl C LiCN D $CaCl_2$

69. A water solution of which compound will turn litmus from blue to red?

A K_2CO_3 B $FeCl_3$ C NaOH D NaCl

<u>Miscellaneous short answer problems</u>

70 Give the conjugate base for each of the following acids: a) H_2S b) $CH_3NH_3^+$

71. Write <u>ionic equations</u> for the reactions which occur in the following experiments. In each case indicate what you would <u>observe</u> (e.g. solution changes from colourless to brown, white precipitate forms, brown gas evolved etc).

a) A solution of dilute sulfuric acid is added to sodium sulfite and gently heated

b) Dilute hydrochloric acid is added to a solid copper(II) carbonate.

c) A piece of aluminium is added to sodium hydroxide solution.

d) A solution of acetic acid is added to a sodium hydrogencarbonate solution.

e) Dilute nitric acid is added to solid cobalt (II) carbonate.

f) 1 mole hydrochloric acid solution is added to a solution containing 1 mole sodium aluminate, NaAl(OH)

g) The reaction of excess ammonia solution with a solution of copper(II) sulfate

h) Zinc metal is dropped into a potassium hydroxide solution.

i) Some dilute sulfuric acid is poured onto a piece of magnesium ribbon.

j) Dried-out encrustations of rust (assume it is Fe_2O_3) are cleaned out of a ceramic vessel by using spirit of salts (impure hydrochloric acid).

72. For each of the following, describe briefly a test and observation by which you could distinguish between the substances listed. (No equations are necessary)

a) Solid magnesium hydroxide and solid zinc hydroxide

b) Lead and zinc

c) Solid magnesium hydroxide and solid lead (II) sulfate

d) Solid aluminium oxide and solid calcium oxide.

73. A dilute hydrochloric acid solution has a pH of 3. What are the concentrations, in moles per litre, of

a) hydrogen ion b) hydroxide ion c) chloride ion

74. Acetic acid and ammonia solutions each have a relatively low conductivity though a greater conductivity than water. If the two solutions are mixed, however, the conductivity increases sharply. Explain with the aid of chemical equations:

a) why acetic acid is a poor conductor, though more conductive than water

b) why ammonia solution is a poor conductor, though more conductive than water.

c) why the conductivity increases when the two poorly conducting solutions are mixed.

75. A dilute solution of ammonia has a pH of 9. What are the concentrations, in mole per litre, of

(a) hydrogen ions (b) hydroxide ions

76. Explain the following observations giving ionic equations where possible.

a) A 0.01 mol L^{-1} solution of propanoic acid has a higher pH than a 0.01 mol L^{-1} solution of hydrochloric acid.

b) A 0.001 mol L^{-1} solution of sodium hydrogensulphate is acidic.

77. a) Write complete balanced equations for reactions in which water acts as:
i) a base ii) an acid

b) Classify distilled water as a strong, weak or non-electrolyte

c) Explain your answer to part (b) by reference to the ionisation constant of water, K_w.

78. In terms of the Bronsted-Lowry theory of acids and bases, write an ionisation reaction equation for each of the following:

a) $Ti(H_2O)_6^{4+}$ acting as an acid. b) CN^- acting as a base

79. a) Is an aqueous solution of $NaHSO_4$ acidic, basic or neutral?

b) What reaction occurs when $NaHSO_4(s)$ is dissolved in water?

c) If solid Na_2CO_3 is added to a solution of $NaHSO_4$, write an equation for the reaction that can occur between the CO_3^{2-} and HSO_4^- ions.

80. Calculate the $[OH^-]$, $[H^+]$ and pH of a 0.0002 mol L^{-1} barium hydroxide solution

81. Match each of the following descriptions with one of the reactions below:
i) Represents the ionisation of a weak acid in water
ii) Represents the hydrolysis of the conjugate base of a weak acid.
iii) Represents a neutralisation reaction between a strong base and a weak acid
iv) Represents a reaction in which there is a high yield of weak acid molecules formed.

a) $CN^-(aq) + H^+(aq) \rightarrow HCN(aq)$ b) $HCN(aq) + OH^-(aq) \rightarrow H_2O(aq) + CN^-(aq)$

c) $HCN(aq) + H_2O(l) \rightarrow H_3O^+(aq) + CN^-(aq)$ d) $CN^-(aq) + H_2O(l) \rightarrow HCN(aq) + OH^-(aq)$

82. The pH of household ammonia solution is about 12.

a) Write an equation and an equilibrium constant expression for ammonia acting as a base

b) Calculate the value of $[OH^-]$ for the ammonia solution.

c) What is $[NH_4^+]$ in household ammonia?

83. Predict whether the following salts, when dissolved in water, produce acidic, basic or neutral solutions:

a) $CoBr_3$ b) NH_4Br c) $NaHCO_3$ d) LiCN

TEE Questions

84. Which one of the following best describes what happens when magnesium chloride solution is added to dilute nitric acid?

A $MgCl_2 + 2HNO_3 \rightarrow Mg(NO_3)_2 + 2HCl$
B $Mg^{2+} + 2\ NO_3^- \rightarrow Mg(NO_3)_2$
C $H^+ + Cl^- \rightarrow 2\ HCl$
D $Cl^- + HNO_3 \rightarrow HCl + NO_3^-$
E There is no reaction

85. Which one of the following oxides dissolves in water to give a strongly basic solution?

A sodium oxide B magnesium oxide
C aluminium oxide D sulfur dioxide
E sulfur trioxide

86. Solid sodium carbonate is added to deionised water at pH 7.00. Which one of the following statements is correct?

A The pH decreases because of the reaction of CO_3^{2-} with water
B The pH decreases because of the reaction of Na^+ with water
C The pH increases because of the loss of carbon dioxide
D The pH increases because of the reaction of CO_3^{2-} with water
E The pH increases because of the reaction of Na^+ with water

87. Which one of the following species acts as an acid when ammonia gas is passed into a water solution of sodium chloride?

A Cl^- B H_2O C Na^+
D NH_3 E None of these species, since no acid/base reaction occurs.

88. A 0.100 mol L^{-1} acetic acid (acetic acid) solution is 1.34% ionised. What is the pH of this solution?

A 0.34 B 0.87 C 1.00 D 1.34 E 2.87

89. Write equations for any reactions that occur in the following procedures. If no reaction occurs write 'no reaction'. In each case describe **in full** what you would observe, including any

- colours
- odours
- precipitates (give colour)
- gases evolved (give the colour or describe as colourless).

If a reaction occurs but the change is not visible, you should state this.

a) Dilute hydrochloric acid is added to silver nitrate solution.
Equation:
Observation:

b) Dilute sulfuric acid is added to nickel carbonate.
Equation:
Observation:

c) Iron (II) sulfate solution is added to potassium hydroxide solution.
Equation:
Observation:

d) Dilute hydrochloric acid is added to sodium acetate (sodium acetate).
Equation:
Observation:

e) Lead nitrate solution is added to iron (II) sulfate solution.
Equation:
Observation:

f) Barium hydroxide solution is added to dilute hydrochloric acid.
Equation:
Observation:

g) Zinc oxide is warmed with dilute sulfuric acid.
Equation:
Observation:

90. Which of the following oxides will dissolve in water to give a basic solution?

I K_2O II Fe_2O_3 III Al_2O_3 IV SO_3

A I only B I, II and III only
C I and III only D II, III and IV only
E IV only

91. Some solid barium carbonate is added to dilute nitric acid. Which of the following equations best represents the reaction that takes place?
A $Ba_2CO_3 + 2HNO_3 \rightarrow 2BaNO_3 + H_2O + CO_2$
B $BaCO_3 + HNO_3 \rightarrow Ba(NO_3)_2 + H_2O + CO_2$
C $BaCO_3 + 2H^+ \rightarrow Ba^{2+} + H_2O + CO_2$
D $Ba^{2+} + 2NO_3^- \rightarrow Ba(NO_3)_2$
E $CO_3^{2-} + 2H^+ \rightarrow H_2O + CO_2$

92. For each of the following pairs of compounds, describe a chemical test to distinguish between them. Give all steps, but equations are not required.

	Your chemical test. Describe fully	What would you observe in each case
$Cu(NO_3)_2$ and $CuSO_4$		with $Cu(NO_3)_2$ –
		with $CuSO_4$
$MgCl_2$ and $ZnCl_2$		with $MgCl_2$
		with $ZnCl_2$

93. Which of the following best describes 10 mol L^{-1} ammonia?
A a dilute solution of a weak base B a concentrated solution of a weak base
C a dilute solution of a strong base D a concentrated solution of a strong base
E a strong solution of a weak base

94. Which of the following are Bronsted-Lowry acid-base reactions?
I $Mg + 2H^+ \rightarrow Mg^{2+} + H_2$
II $NH_4^+ + OH^- \rightarrow NH_3 + H_2O$
III $3Cu + 8H^+ + 2NO_3^- \rightarrow 3Cu^{2+} + 2NO + H_2O$
IV $NH_2^- + H_2O \rightarrow NH_3 + OH^-$

A I, II and III only B I and III only C II, III and IV only
D II and IV only E IV only.

95. Which of the following solutions has a pH less than 7?
A 0.01 mol L^{-1} ammonium chloride B 0.01 mol L^{-1} calcium hydroxide
C 0.01 mol L^{-1} potassium nitrate D 0.01 mol L^{-1} sodium acetate (sodium acetate)
E 0.01 mol L^{-1} sodium phosphate

96. Which one of the following describes the concentration of hydrogen ions in 1.00 mol L^{-1} sulfuric acid?
A less than 1.00 mol L^{-1} B exactly 1.00 mol L^{-1}
C between 1.00 and 2.00 mol L^{-1} D exactly 2.00 mol L^{-1}
E greater than 2.00 mol L^{-1}.

97. When a chemist does her annual stocktake she finds that the labels have fallen off six bottles, each of which contains white crystals. The labels read

BARIUM SULFATE POTASSIUM CHLORIDE
SILVER NITRATE SODIUM PHOSPHATE
ZINC NITRATE ZINC SULFATE

She is a knowledgable chemist, and so she uses some of her remaining labelled reagents to carry out a series of tests to identify the contents of the bottles. Her report sheet is reproduced below, except that her 'conclusion' column has been left blank.
Complete the report sheet by writing in each case the formula of the substance identified.

Test	Observation	Formula of substance identified
A little of each substance was shaken with water	One only of the substances did not dissolve. This substance was	
A little of each of the remaining five substances was dissolved in water to prepare a test solution. A little of each of the test solutions was treated with copper nitrate solution.	Only one of the test solutions gave a blue precipitate. The substance identified was	
A little of each of the remaining four test solutions was treated with sodium chloride solution.	One only of the test solutions gave a white precipitate (which darkened on standing in light). The substance identified was	
A little of the remaining three test solutions was treated with barium chloride solution.	One only of the test solutions gave a white precipitate. The substance identified was	
A little of each of the remaining two test solutions was treated with sodium hydroxide.	One only of the test solutions gave a white gelatinous precipitate which dissolved when excess sodium hydroxide solution was added. The substance identified was	
	The remaining substance (whose test solution gave no positive reaction in any experiment) was	

98 . Calculate the pH of 0.0250 mol L^{-1} rubidium hydroxide, RbOH.

99. a) When nickel nitrate solution is added to sodium phosphate solution, a green precipitate forms which settles below a colourless solution. Write the equation for the reaction that has occurred.

b) When cobalt sulfate solution is added to lanthanum chloride ($LaCl_2$) solution (which is colourless), a white precipitate forms which settles below a red solution. Write the equation for the reaction that has occurred.

100. Which one of the following solutions has a pH greater than 7?

A 0.1 mol L^{-1} ammonium sulfate
B 0.1 mol L^{-1} iron(II) chloride
C 0.1 mol L^{-1} magnesium nitrate
D 0.1 mol L^{-1} potassium acetate (potassium acetate)
E 0.1 mol L^{-1} sodium nitrate.

101. As ammonium chloride dissolves in water the temperature of the solution decreases. Which one of the following statements about the reaction is false?

A ΔH for $NH_4Cl(s) \rightarrow NH_4^+(aq) + Cl^-(aq)$ is negative
B When NH_4Cl dissolves, the NH_4^+ reacts to a small extent with water to give an acidic solution.
C When NH_4Cl dissolves, the conductivity of the solution increases.
D NH_4Cl dissolves more rapidly as the temperature is raised.
E More energy is needed to separate the ions from each other than is released when water molecules surround the ions.

102. The labels have fallen off four identical bottles, each of which contain white crystals. The labels read

Aluminium chloride
Aluminium nitrate
Aluminium sulfate, and
Magnesium chloride

Briefly describe chemical tests which could be used in turn to identify the contents of the four bottles. For these tests you may use any reagent of your choice. The identification has been commenced. No equations are required.
In each case describe the test and the relevant observation, and write the formula of the substance identified.

102 (cont)

Test	Observation	Formula of substance identified
A little of each substance is dissolved in water to prepare a test solution. A little of each of the test solutions is treated with barium nitrate solution.	One of the test solutions gives a white precipitate. The substance identified is	$Al_2(SO_4)_3$
A little of each of the remaining three.....		

103. Both perchloric acid, $HClO_4$, and barium hydroxide, $Ba(OH)_2$, are fully dissociated when in water-solution.

a) Calculate the pH of 0.0500 mol L^{-1} perchloric acid.

b) Calculate the pH of 0.0500 mol L^{-1} barium hydroxide.

104. Which of the following oxides dissolves in water to give an acidic solution?

I Na_2O II Al_2O_3 III P_4O_{10} IV SO_2

A I and II only B II and III only C II, III and IV only
D III and IV only E IV only

105. In which of the following processes is water acting as a base?

A $NH_3 + H_2O \rightarrow NH_4^+ + OH^-$ B $CH_3CO_2^- + H_2O \rightarrow CH_3COOH + OH^-$
C $O_2CCO_2^{2-} + H_2O \rightarrow HOOCCO_2^- + OH^-$ D $O^{2-} + H_2O \rightarrow 2\ OH^-$
E $HS^- + H_2O \rightarrow S^{2-} + H_3O^+$

106. Calcium hydroxide is a strong electrolyte. What is the pH of 0.0100 mol L^{-1} $Ca(OH)_2$?

A 1.7 B 2.0 C 7.0 D 12.0 E 12.3

107. a) The pH of a 0.1 mol L^{-1} $NaHCO_3$ solution is 8.3. With the help of one or more suitable chemical equations explain why the pH is greater than 7.

b) The pH of 0.1 mol l^{-1} $NaHSO_4$ solution is 1.2. With the help of one or more suitable chemical equations explain why the pH is less than 7.

ANSWERS - Acids & Bases - 1

1. a) $2H^+(aq) + Mg(s) \rightarrow H_2(g) + Mg^{2+}(aq)$
   - the grey solid will dissolve to form a colourless solution and a colourless, odourless gas.

   b) no reaction (only the metals Al, Zn and Cr react with OH^-)

   c) $2H^+(aq) + CaCO_3(s) \rightarrow CO_2(g) + H_2O(l) + Ca^{2+}(aq)$
   - the solid will dissolve to form a colourless solution and a colourless, odourless gas

   d) $2H^+(aq) + CO_3^{2-}(aq) \rightarrow CO_2(g) + H_2O(l)$
   - the solution will remain colourless, but a colourless, odourless gas will form

   e) $Al(OH)_3(s) + 3H^+(aq) \rightarrow Al^{3+}(aq) + 3H_2O(l)$
   - the solid will dissolve to form a colourless solution

   f) $Al(OH)_3(s) + OH^-(aq) \rightarrow [Al(OH)_4]^-(aq)$
   - the solid will dissolve to form a colourless solution

   g) $Cu(OH)_2(s) + 2H^+(aq) \rightarrow Cu^{2+}(aq) + 2H_2O(l)$
   - the solid dissolves to form a blue solution

   h) no reaction

   i) $2H^+(aq) + Zn(s) \rightarrow H_2(g) + Zn^{2+}(aq)$
   - the grey solid will dissolve to form a colourless solution and a colourless, odourless gas.

   j) $Zn(s) + 2\,OH^-(aq) + 2H_2O(l) \rightarrow H_2(g) + [Zn(OH)_4]^{2-}(aq)$
   - the grey solid will dissolve to form a colourless solution and a colourless, odourless gas

   k) $CuO(s) + 2H^+(aq) \rightarrow Cu^{2+}(aq) + H_2O(l)$
   - the black solid will dissolve to form a blue solution.

2. No reaction will occur when NaOH is added to iron. However, aluminium will react with NaOH to form a colourless gas.
   $2Al(s) + 2\,OH^-(aq) + 6H_2O(l) \rightarrow 3H_2(g) + 2\,[Al(OH)_4]^-(aq)$

3. If added to a solution of NaOH to each solid, only the zinc hydroxide would dissolve to give a colourless solution. The magnesium hydroxide would not dissolve. $Zn(OH)_2(s) + 2\,OH^-(aq) \rightarrow [Zn(OH)_4]^{2-}(aq)$

4. If you added an acid, such as hydrochloric acid, both solids would react and form a colourless solution, but the calcium carbonate would "fizz" whilst reacting i.e. it would form a colourless gas (carbon dioxide)
   $CaCO_3(s) + 2H^+(aq) \rightarrow Ca^{2+}(aq) + CO_2(g) + H_2O(l)$ $MgO(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2O(l)$

5. a) base b) base c) base d) base e) base

6. a) H_2O / OH^- and HSO_3^- / SO_3^{2-} b) PH_4^+ / PH_3 and HI / I^-.

   c) $H_2PO_4^-$ / HPO_4^{2-} and H_2O / OH^- d) $CH_3COOH_2^+$ / CH_3COOH and HBr / Br^-.

   e) $CH_3NH_3^+$ / CH_3NH_2 and CH_3CH_2OH / $CH_3CH_2O^-$

7. HNO_3 HSO_3^-, H_2F^+, $HClO_3$ NH_4^+

8. Br^-, SO_3^{2-}, $H_2PO_4^-$, H_2Se, OH^-, O^{2-}

9. The equations must show HBr losing H^+ and HCO_3^- gaining H^+
   e.g. $HBr + H_2O \rightarrow Br^- + H_3O^+$ $HCO_3^- + H_2O \rightarrow H_2CO_3 + OH^-$

10. $[H^+] = 0.200$ mol L^{-1}, $[OH^-] = 5.00 \times 10^{-14}$ mol L^{-1}

11. $[H^+] = 1.00 \times 10^{-13}$ mol L^{-1}, $[OH^-] = 0.100$ mol L^{-1}

12. a) $[H^+] = 0.200$ mol L^{-1}, $[OH^-] = 5.00 \times 10^{-14}$ mol L^{-1}

    b) $[H^+] = 1.00 \times 10^{-12}$ mol L^{-1}, $[OH^-] = 0.0100$ mol L^{-1},

    c) $[H^+] = 0.300$ mol L^{-1}, $[OH^-] = 3.33 \times 10^{-14}$ mol L^{-1},

    d) $[H^+] = 1.00 \times 10^{-13}$ mol L^{-1}, $[OH^-] = 0.100$ mol L^{-1}

13. a) 3 b) 4 c) 1 d) 10 e) 12 f) 13

14. a) $[H^+] = 1 \times 10^{-8}$ mol L^{-1}, $[OH^-] = 1.0 \times 10^{-6}$ mol L^{-1}, b) 0.2 mol c) 28.1 g

15. a) HCl, HNO_3, H_2SO_4, HBr, $HClO_4$, HI

    b) Any acid except the six listed in a), NH_4^+, any transition metal or group 3 ion, HSO_4^-, $H_2PO_4^-$

    c)Any metal hydroxide or metal oxide e.g. NaOH, MgO

    d) Any base except those listed in c) e.g. NH_3, CO_3^{2-}, HCO_3^-, any conjugate base of a weak acid

16. a)false b) true c) true d) false
    e)true f) false g) true

17. a)false b) false c) true d) true e) true

18. a)true b) false c) false d) true e) true f) false

19. a)M, L, P, N

b) If 0.01 mol L^{-1} acid is completely dissociated, then the $[H^+]$ will be 0.01 mol L^{-1}, and the pH will be 2. Thus, acid N is completely dissociated.

20. a) $O^{2-}(aq) + H_2O(l) \rightarrow OH^-(aq) + OH^-(aq)$ OH^- / O^{2-} and H_2O / OH^-

b) O^{2-} is a stronger base than OH^- because metal oxides are strong bases, and thus the equilibrium position for the reaction given in a) greatly favours the products. This means that the base O^{2-} must be stronger than the base OH^-.

21. a) i) ii) iii) b) ii)

22. Potassium bromide: $KBr \rightarrow K^+ + Br^-$ Neither the K^+ or Br^- ions react significantly with water i.e. they do not undergo hydrolysis. Thus, the $[H^+]$ is due just to the self-ionisation of water, and so the pH is 7.

Potassium hydrogensulfate: $KHSO_4 \rightarrow K^+ + HSO_4^-$. The K^+ ions formed in this dissociation reaction do not undergo significant hydrolysis. However, the HSO_4^- ion does undergo hydrolysis : $HSO_4^- + H_2O \rightarrow SO_4^{2-} + H_3O^+$. This reaction results in an increase in the $[H^+]$ in the aqueous solution, and so the solution will have a pH less than 7 i.e. it is an acidic solution.

Potassium hydrogencarbonate: $KHCO_3 \rightarrow K^+ + HCO_3^-$. The K^+ ions formed in this dissociation reaction do not undergo significant hydrolysis. However, the HCO_3^- ion does undergo hydrolysis : $HCO_3^- + H_2O \rightarrow H_2CO_3 + OH^-$. This reaction results in an increase in the $[OH^-]$ in the aqueous solution, and so the solution will have a pH greater than 7 i.e. it is a basic solution.

23. a) $MgCl_2 \rightarrow Mg^{2+} + 2Cl^-$. Neither of these ions hydrolyse further. Thus the solution will be neutral

b) $NH_4NO_3 \rightarrow NH_4^+ + NO_3^-$. Only the NH_4^+ ion hydrolyses: $NH_4^+ + H_2O \rightarrow NH_3 + H_3O^+$. Because H_3O^+ is formed, the solution will be acidic.

c) $K_2O \rightarrow 2K^+ + O^{2-}$ then $O^{2-} + H_2O \rightarrow 2OH^-$ Because OH^- is formed, the solution will be basic.

d) $Na_2SO_4 \rightarrow 2Na^+ + SO_4^{2-}$. Neither ions hydrolyse, thus solution will be neutral.

e) $Na_2S \rightarrow 2Na^+ + S^{2-}$ S^{2-} hydrolyses: $S^{2-} + H_2O \rightarrow HS^- + OH^-$
Because OH^- is formed, the solution will be basic.

f) $LiCN \rightarrow Li^+ + CN^-$ CN^- hydrolyses: $CN^- + H_2O \rightarrow HCN + OH^-$
Because OH^- is formed, the solution will be basic.

g) $BaBr_2 \rightarrow Ba^{2+} + 2Br^-$ Neither ions hydrolyse, thus solution will be neutral.

h) $NaH_2PO_4 \rightarrow Na^+ + H_2PO_4^-$ $H_2PO_4^-$ hydrolyses: $H_2PO_4^- + H_2O \rightarrow HPO_4^{2-} + H_3O^+$
Because H_3O^+ is formed, the solution will be acidic.

i) $K_3PO_4 \rightarrow 3K^+ + PO_4^{3-}$ PO_4^{3-} hydrolyses: $PO_4^{3-} + H_2O \rightarrow HPO_4^{2-} + OH^-$
Because OH^- is formed, the solution will be basic.

24. E	25. B	26. D	27. C	28. A
29. E	30. E	31. C	32. D	33. D
34. E	35. D	36. D	37. A	38. C
39. D	40. A	41. C	42. B	43. D
44. D	45. A	46. D	47. C	48. D
49. E	50. C	51. C	52. D	53. E
54. A	55. D	56. E	57. B	58. C
59. C	60. E	61. C	62. C	63. D
64. B	65. A	66. A	67. A	68. C
69. B				

70. a) HS^- b) CH_3NH_2.

71. a) $2H^+(aq) + Na_2SO_3(s) \rightarrow SO_2(g) + H_2O(l) + 2Na^+(aq)$
Pungent, colourless gas formed, solid dissolves to form colourless solution.

b) $2H^+(aq) + CuCO_3(s) \rightarrow CO_2(g) + H_2O(l) + Cu^{2+}(aq)$
Odourless, colourless gas formed, solid dissolves to form blue solution.

c) $2Al(s) + 2\,OH^-(aq) + 6\,H_2O(l) \rightarrow 2\,[Al(OH)_4]^-(aq) + 3H_2(g)$
Grey solid dissolves to form colourless solution, colourless, odourless gas formed.

71. d) $CH_3COOH(aq) + HCO_3^-(aq) \rightarrow CH_3COO^-(aq) + CO_2(g) + H_2O(l)$
Colourless, odourless gas forms, vinegar-smell disappears

e) $2H^+(aq) + CoCO_3(s) \rightarrow CO_2(g) + H_2O(l) + Co^{2+}(aq)$
Colourless, odourless gas formed, solid dissolves to form pink solution

f) $H^+(aq) + [Al(OH)_4]^-(aq) \rightarrow Al(OH)_3(s) + H_2O(l)$ White solid forms.

g) $Cu^{2+}(aq) + 4NH_3(aq) \rightarrow [Cu(NH_3)_4]^{2+}(aq)$ Blue precipitate forms which dissolves to form a darker blue solution.

h) $Zn(s) + 2\,OH^-(aq) + 2\,H_2O(l) \rightarrow [Zn(OH)_4]^{2-}(aq) + H_2(g)$
Grey solid dissolves to form colourless solution, colourless, odourless gas formed.

i) $2H^+(aq) + Mg(s) \rightarrow H_2(g) + Mg^{2+}(aq)$ Grey solid dissolves to form colourless solution and colourless, odourless gas

j) $Fe_2O_3(s) + 6H^+(aq) \rightarrow 2Fe^{3+}(aq) + 3H_2O(l)$ Solid dissolves to form orange solution

72. a) Add a solution of sodium hydroxide to both solids, the zinc hydroxide will dissolve (it forms $[Zn(OH)_4]^{2-}$) but the magnesium hydroxide will not.

b) Add a solution of sodium hydroxide (and if necessary, heat). The zinc (an amphoteric metal) will dissolve and form hydrogen gas, but the lead will not react.

c) Add hydrochloric acid solution. The magnesium hydroxide will dissolve (to form water and salt solution), but the lead sulfate will remain insoluble.

d) Add a solution of sodium hydroxide. The amphoteric aluminium oxide will dissolve, but calcium oxide will form a white solid.

73. a) $[H^+] = 10^{-3}$ mol L^{-1} b) $[OH^-] = 10^{-11}$ mol L^{-1} c) $[Cl^-] = 10^{-3}$ mol L^{-1}.

74. a) Acetic acid is a weak acid and when it dissolves in water it only slightly ionises. $CH_3COOH \rightleftharpoons CH_3COO^- + H^+$
Thus, in aqueous solution there are only a few ions, and so the solution is a poor conductor of electricity.

b) Ammonia is a weak base and when it dissolves in water , it only partially reacts to form a few ions:
$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$ .Thus, in an aqueous solution of ammonia, there are only a few ions and so it is a poor conductor of electricity.

c) When acetic acid and ammonia are mixed, they react to form the ionic compound, ammonium chloride:
$NH_3 + CH_3COOH \rightarrow NH_4^+ + CH_3COO^-$
This ionic substance is soluble in water and dissociates completely. Thus, there are lots of ions present, and so the solution is a very good conductor of electricity.

75. a) $[H^+] = 10^{-9}$ mol L^{-1} b) $[OH^-] = 10^{-5}$ mol L^{-1}

76. a) Hydrochloric acid is a strong acid and will ionise completely in solution $HCl \rightarrow H^+ + Cl^-$.
That is, a 0.01 mol L^{-1} solution of HCl will have a $[H^+] = 10^{-2}$, and a pH of 2.

Propanoic acid is a weak acid and so only partially ionises in solution: $CH_3CH_2COOH \rightleftharpoons CH_3CH_2COO^- + H^+$.
That is, the concentration of H^+ in the propanoic acid solution will be less than 10^{-2}, and so the pH will be greater than 2.

b) When sodium hydrogensulfate dissolves in water, it forms sodium ions and hydrogensulfate ions. The hydrogensulfate ions react further with water to form sulfate ions and H_3O^+ ions.
$HSO_4^- + H_2O \rightleftharpoons SO_4^{2-} + H_3O^+$. The presence of extra H_3O^+ ions makes the solution acidic.

77. a) i) $NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$ ii) $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$.

b) weak electrolyte

c) Water ionises slightly: $H_2O + H_2O \rightleftharpoons H_3O^+ + OH^-$. The equilibrium constant for this reaction is the ionisation constant of water and has the value of 10^{-1} Thus, the reaction occurs, but only slightly. That is there will only be a few ions present in pure water. Thus it will conduct, but only slightly.

78. a) $Ti(H_2O)_6^{4+} + H_2O \rightarrow Ti(H_2O)_5(OH)^{3+} + H_3O^+$. b) $CN^- + H_2O \rightarrow HCN + OH^-$.

79. a) Acidic.

b) First $NaHSO_4 \rightarrow Na^+ + HSO_4^-$ then $HSO_4^- + H_2O \rightarrow SO_4^{2-} + H_3O^+$.

c) $CO_3^{2-} + HSO_4^- \rightarrow HCO_3^- + SO_4^{2-}$ (or $CO_3^{2-} + 2HSO_4^- \rightarrow CO_2 + H_2O + 2SO_4^{2-}$).

80. $Ba(OH)_2 \rightarrow Ba^{2+} + 2\,OH^-$. $[OH^-] = 0.0004$ mol L^{-1} $[H^+] = 2.5 \times 10^{-11}$ mol L^{-1} pH = 10.6

81. a) iv) b) iii) c) i) d) ii)

82. a) $NH_3 + H_2O \rightarrow NH_4^+ + OH^-$. K =
b) 1×10^{-2} mol L^{-1} c) 1×10^{-2} mol L^{-1}

83. a) acidic b) acidic c) basic d) basic

84. E 85. A 86. D 87. B 88. E

89. a) $Cl^-(aq) + Ag^+(aq) \rightarrow AgCl(s)$ White precipitate forms

b) $NiCO_3(s) + 2H^+(aq) \rightarrow CO_2(g) + H_2O(l) + Ni^{2+}(aq)$ - green solution and colourless, odourless gas form

c) $Fe^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s)$ - pale green precipitate forms

d) $H^+(aq) + CH_3COO^-(aq) \rightarrow CH_3COOH(aq)$ - no visible change, but solution smells like vinegar

e) $Pb^{2+}(aq) + SO_4^{2-}(aq) \rightarrow PbSO_4(s)$ - white precipitate forms

f) $H^+(aq) + OH^-(aq) \rightarrow H_2O(aq)$ - no visible change occurs

g) $ZnO(s) + 2H^+(aq) \rightarrow H_2O(l) + Zn^{2+}(aq)$ - white solid dissolves to form colourless solution

90. A 91. C

92

	Your chemical test. Describe fully	What would you observe in each case
$Cu(NO_3)_2$ and $CuSO_4$	Prepare a solution in water of each compound Add a solution of barium chloride to each solution	with $Cu(NO_3)_2$ - no reaction
		with $CuSO_4$ - white precipitate forms
$MgCl_2$ and $ZnCl_2$	Prepare a solution of each compound. Add an excess of sodium hydroxide solution to each	with $MgCl_2$ - white precipitate forms
		with $ZnCl_2$ - white precipitate forms which then dissolves in excess sodium hydroxide.

93. B 94. D 95 A 96. C

97. $BaSO_4$, Na_3PO_4, $AgNO_3$, $ZnSO_4$, $Zn(NO_3)_2$, KCl

98. $[OH^-] = 0.0250$ mol L^{-1} $[H^+] = = 00 \times 10^{-13}$ mol L^{-1} pH = **12.4**

99. a) $3Ni^{2+}(aq) + 2PO_4^{3-}(aq) \rightarrow Ni_3(PO_4)_2(s)$ b) $La^{2+}(aq) + SO_4^{2-}(aq) \rightarrow LaSO_4(s)$

100. D 101. A

102.

Test	Observation	Formula
A little of each substance is dissolved in water to prepare a test solution. A little of each of the test solutions is treated with barium nitrate solution.	One of the test solutions gives a white precipitate. The substance identified is	$Al_2(SO_4)_3$
A little of each of the remaining three is dissolved in water. A little of each of the test solutions is treated with silver nitrate solution.	Two of the test solutions will give a white precipitate, one test solution will not react. This substance is	$Al(NO_3)_3$
A little of each of the remaining two is dissolved in water. A little of each of the test solutions is treated with an excess of sodium hydroxide solution.	Both test solutions will initially give a white precipitate but one will dissolve when excess sodium hydroxide is added. This substance is	$AlCl_3$
The remaining substance is		$MgCl_2$

103. a) pH = -log (0.0500) = **1.30**

b) $Ba(OH)_2 \rightarrow Ba^{2+} + 2\ OH^-$ $[OH^-] = 2 \times 0.0500 = 0.100$ mol L^{-1}

$[H^+] = = 1.00 \times 10^{-13}$ mol L^{-1} pH = **13**

104. D 105 E 106. E

107. a) In the solution there are Na^+ ions and CO_3^{2-} ions. The Na^+ ions do not significantly hydrolyse, but the CO_3^{2-} ions do hydrolyse: $CO_3^{2-} + H_2O \rightleftharpoons HCO_3^- + OH^-$

Because OH^- ions are formed, the solution will be basic with the $[OH^-] > 1 \times 10^{-7}$ i.e. the pH will be greater than 7.

b) In the solution there are Na^+ ions and CO_3^{2-} ions. The Na^+ ions do not significantly hydrolyse, but the HSO_4^- ions do hydrolyse: $HSO_4^- + H_2O \rightleftharpoons SO_4^{2-} + H_3O^+$

Because H_3O^+ ions are formed, the solution will be acidic with the $[H_3O^+] > 1 \times 10^{-7}$ i.e. the pH will be less than 7.