

**Revision Problems - ACIDS & BASES - 1.** (Chapter 15)**Reactions of acids & bases**

- 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'.
  - Dilute nitric acid is added to a piece of magnesium.
  - A solution of sodium hydroxide is added to a piece of magnesium
  - Dilute hydrochloric acid is added to solid calcium carbonate.
  - A solution of sodium carbonate is added to dilute sulfuric acid.
  - Aluminium hydroxide is added to dilute hydrochloric acid
  - Aluminium hydroxide is added to a solution of sodium hydroxide
  - Copper hydroxide is added to dilute sulfuric acid
  - Copper hydroxide is added to a solution of sodium hydroxide.
  - Zinc is added to dilute hydrochloric acid
  - Zinc is added to a solution of potassium hydroxide.
  - Black copper oxide is added to dilute nitric acid
- 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.
- 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 your answer.
- 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 your answer.

**Bronsted-Lowry acid-base theory**

- In each of the following reactions state whether the first reactant is acting as an acid or a base.
  - $\text{SO}_3^{2-} + \text{H}_2\text{O} \rightleftharpoons \text{HSO}_3^- + \text{OH}^-$ .
  - $\text{PH}_3 + \text{HI} \rightleftharpoons \text{PH}_4^+ + \text{I}^-$ .
  - $\text{HPO}_4^{2-} + \text{H}_2\text{O} \rightleftharpoons \text{OH}^- + \text{H}_2\text{PO}_4^-$ .
  - $\text{CH}_3\text{COOH} + \text{HBr} \rightleftharpoons \text{CH}_3\text{COOH}_2^+ + \text{Br}^-$ .
  - $\text{CH}_3\text{NH}_2 + \text{CH}_3\text{CH}_2\text{OH} \rightleftharpoons \text{CH}_3\text{CH}_2\text{O}^- + \text{CH}_3\text{NH}_3^+$ .
- 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.
- Give the formula of the conjugate acid for each of the following bases:  
 $\text{NO}_3^-$ ,  $\text{SO}_3^{2-}$ ,  $\text{HF}$ ,  $\text{ClO}_3^-$ ,  $\text{NH}_3$
- Give the formula of the conjugate base for each of the following acids:  
 $\text{HBr}$ ,  $\text{HSO}_3^-$ ,  $\text{H}_3\text{PO}_4$ ,  $\text{H}_3\text{Se}^+$ ,  $\text{H}_2\text{O}$ ,  $\text{OH}^-$
- Give an equation showing:
  - $\text{HBr}$  acting as an acid;
  - $\text{HCO}_3^-$  acting as a base.

pH

10. 0.400 mole of  $\text{HNO}_3$  is dissolved in 2.00 L of solution. Calculate the concentration, in  $\text{mol L}^{-1}$ , of  $\text{H}^+$  ions and  $\text{OH}^-$  ions in the solution
11. 4.00 g of  $\text{NaOH}$  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  $\text{H}^+$  and  $\text{OH}^-$  in the following solutions:
  - a)  $0.200 \text{ mol L}^{-1} \text{HNO}_3$  solution
  - b)  $0.00500 \text{ mol L}^{-1} \text{Ca(OH)}_2$  solution.
  - c) 20.0 mL of  $0.3 \text{ mol L}^{-1} \text{HCl}$  solution
  - d) a solution formed when 50.0 mL of water is added to 50.0 mL of  $0.200 \text{ mol L}^{-1} \text{KOH}$
13. Calculate the pH of the following solutions
  - a) a solution of acetic acid in which the concentration of hydrogen ions is  $0.00100 \text{ mol L}^{-1}$
  - b)  $0.000100 \text{ mol L}^{-1} \text{HNO}_3$  solution
  - c) 100 mL of  $0.100 \text{ mol L}^{-1}$  hydrobromic acid solution.
  - d) a solution of ammonia in which the concentration of hydroxide ions is  $0.000100 \text{ mol L}^{-1}$
  - e)  $5.00 \times 10^{-3} \text{ mol L}^{-1} \text{Ba(OH)}_2$  solution
  - f) the solution formed when 50.0 mL of  $0.200 \text{ mol L}^{-1}$  of  $\text{HCl}$  is added to 50.0 mL of  $0.400 \text{ mol L}^{-1} \text{NaOH}$  solution (assume that  $\text{NaCl}$  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  $\text{HCl}$  must be added to 2.00 L of water to form a solution with a pH of 1?
  - c) What mass of  $\text{KOH}$  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  $0.1 \text{ mol L}^{-1}$  acetic acid and 1 L of  $0.1 \text{ mol L}^{-1}$  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  $0.1 \text{ mol L}^{-1}$  sodium hydroxide for complete reaction
17. Identify the following as true or false:  
Comparing 100 mL of  $0.1 \text{ mol L}^{-1} \text{NaOH}$  and 100 mL of  $0.1 \text{ mol L}^{-1}$  ammonia solution:
  - a) both solutions would have the same pH
  - b) the  $\text{NaOH}$  solution would contain fewer hydroxide ions in solution than the ammonia solution
  - c) the  $\text{NaOH}$  solution would contain fewer hydrogen ions in solution than the ammonia solution
  - d) the pH of the  $\text{NaOH}$  solution would be greater than the pH of the ammonia solution
  - e) both solutions would require the same volume of  $0.1 \text{ mol L}^{-1}$  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<sub>2</sub>S, so it can be concluded that

- HBr will have a larger equilibrium constant for the hydrolysis reaction than H<sub>2</sub>S
- a solution of HBr will always have a smaller pH than a solution of H<sub>2</sub>S
- Br<sup>-</sup> will be a stronger base than HS<sup>-</sup>.
- the reaction  $\text{HBr} + \text{H}_2\text{O} \rightleftharpoons \text{Br}^- + \text{H}_3\text{O}^+$  will occur to a greater extent than the reaction  $\text{H}_2\text{S} + \text{H}_2\text{O} \rightleftharpoons \text{HS}^- + \text{H}_3\text{O}^+$
- the reaction  $\text{HBr} + \text{HS}^- \rightleftharpoons \text{Br}^- + \text{H}_2\text{S}$  will occur to a large extent.
- when 1 mole of H<sub>2</sub>S is bubbled through a solution containing 1 mole of NaBr, a large amount of HBr and HS<sup>-</sup> will be formed i.e. the reaction will be essentially complete.

19. A chemist has 0.010 mol L<sup>-1</sup> 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.

- Arrange the four acids, L, M, N, P, in order of increasing acid strength (weakest first, strongest last).
- Are any of these acids completely ionised? Justify your answer.

### Acid/base nature of salts

20. The oxide ion, O<sup>2-</sup>, in soluble metallic oxides such as Na<sub>2</sub>O and CaO, reacts with water to form hydroxide ions.

- Write the equation for this hydrolysis reaction, and identify the conjugate pairs.
- Is O<sup>2-</sup> a weaker or stronger base than the hydroxide ion? Give your reason.

21. a) Give the dissociation constant (K<sub>a</sub>) expression for each of the following

- HF
- H<sub>2</sub>SO<sub>4</sub>
- H<sub>2</sub>PO<sub>4</sub><sup>-</sup>.

b) For which one of the above acids would you expect the value of K<sub>a</sub> 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 <sub>2</sub>              | b) NH <sub>4</sub> NO <sub>3</sub> | c) K <sub>2</sub> O  | d) Na <sub>2</sub> SO <sub>4</sub>  |
| e) Na <sub>2</sub> S              | f) LiCN                            | g) BaBr <sub>2</sub> | h) NaH <sub>2</sub> PO <sub>4</sub> |
| i) K <sub>3</sub> PO <sub>4</sub> |                                    |                      |                                     |

### 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 <sup>-1</sup> CH <sub>3</sub> COOH | b) 0.1 mol L <sup>-1</sup> CH <sub>3</sub> COONa | c) 0.1 mol L <sup>-1</sup> NH <sub>4</sub> Cl |
| d) 0.1 mol L <sup>-1</sup> NaCl                 | e) 0.1 mol L <sup>-1</sup> 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

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

26. Aluminium hydroxide,  $\text{Al}(\text{OH})_3$ , is said to be amphoteric for which one of the following reasons?
- A The pH of a saturated solution of  $\text{Al}(\text{OH})_3$  is close to 7.      B  $\text{Al}(\text{OH})_3$  is a stronger acid than it is a base.  
C  $\text{Al}(\text{OH})_3$  is a stronger base than it is an acid.      D  $\text{Al}(\text{OH})_3$  can act as an acid or a base.  
E  $\text{Al}(\text{OH})_3$  when heated, can be dehydrated to form  $\text{Al}_2\text{O}_3$ .
27. Which one of the following statements about aqueous solutions is false?
- A The pH of a 0.1 mol  $\text{L}^{-1}$  solution of  $\text{NaCl}$  is equal to 7.  
B The pH of a 0.1 mol  $\text{L}^{-1}$  solution of  $\text{NaCH}_3\text{COO}$  is greater than 7.  
C The pH of a 0.1 mol  $\text{L}^{-1}$  solution of  $\text{Na}_2\text{CO}_3$  is less than 7.  
D The pH of a 0.1 mol  $\text{L}^{-1}$  solution of  $\text{H}_2\text{SO}_4$  is less than the pH of a 0.1 mol  $\text{L}^{-1}$  solution of  $\text{HCl}$ .  
E The pH of a 0.1 mol  $\text{L}^{-1}$  solution of  $\text{NaOH}$  is greater than the pH of a 0.1 mol  $\text{L}^{-1}$  solution of  $\text{NH}_3$ .
28. Which one of the following solutions would show the greatest electrical conductivity?
- A 10 mL of 0.2 mol  $\text{L}^{-1}$   $\text{HCl}$       B 30 mL of 0.1 mol  $\text{L}^{-1}$   $\text{HCl}$   
C 10 mL of 0.4 mol  $\text{L}^{-1}$   $\text{CH}_3\text{COOH}$       D 30 mL of 0.2 mol  $\text{L}^{-1}$   $\text{CH}_3\text{COOH}$   
E 10 mL of 0.1 mol  $\text{L}^{-1}$   $\text{CH}_3\text{COOH}$
29. The pH of a 0.01 mol  $\text{L}^{-1}$  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  $\text{L}^{-1}$  aqueous solutions of lithium nitrate, sodium acetate and ammonium chloride would fall into what regions?
- |   | $\text{LiNO}_3$ | $\text{CH}_3\text{COONa}$ | $\text{NH}_4\text{Cl}$ |
|---|-----------------|---------------------------|------------------------|
| 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  $[\text{H}^+]$  of a 0.1 mol  $\text{L}^{-1}$  hydrofluoric acid solution is greater than the  $[\text{H}^+]$  of 0.1 mol  $\text{L}^{-1}$  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  $\text{L}^{-1}$  perchloric acid solution is greater than 1 but less than 7.  
E The pH of a 0.1 mol  $\text{L}^{-1}$  hydrofluoric acid solution is 1.
32. The pH of 0.001 mol  $\text{L}^{-1}$  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  $\text{HCl}$   
B basic because ammonium ion reacts with water to give  $\text{OH}^-$   
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  $1 \times 10^{-3}$  mol  $\text{L}^{-1}$  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  $\text{HCO}_3^- + \text{H}_3\text{O}^+ \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$   
 B  $\text{HCO}_3^- + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3 + \text{OH}^-$   
 C  $\text{HCO}_3^- + \text{HSO}_4^- \rightarrow \text{H}_2\text{CO}_3 + \text{SO}_4^{2-}$   
 D  $\text{HCO}_3^- + \text{PO}_4^{3-} \rightarrow \text{CO}_3^{2-} + \text{HPO}_4^{2-}$   
 E  $\text{HCO}_3^- + \text{CH}_3\text{COOH} \rightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{CH}_3\text{COO}^-$
37. Which one of the following compounds, if dissolved in water, would form a solution with a pH less than 7?
- A  $\text{NH}_4\text{NO}_3$                       B  $\text{CaCl}_2$                       C  $\text{NaCl}$                       D  $\text{Ca}(\text{OH})_2$                       E  $\text{NaCH}_3\text{COO}$
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  $\text{XO}$ , basic                      B  $\text{XO}$ , acidic                      C  $\text{XO}_2$ , acidic                      D  $\text{XO}_2$ , basic                      E  $\text{X}_2\text{O}_4$ , 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  $\text{H}_3\text{O}^+$                       B  $\text{Na}^+$                       C  $\text{CO}_3^{2-}$                       D  $\text{HCO}_3^-$                       E  $\text{H}_2\text{CO}_3$
40. 250.0 mL of 0.40 mol  $\text{L}^{-1}$  nitric acid is added 750.0 mL of 0.60 mol  $\text{L}^{-1}$  potassium hydroxide. What is the final hydroxide ion concentration?
- A 0.35 mol  $\text{L}^{-1}$                       B 0.45 mol  $\text{L}^{-1}$                       C 0.50 mol  $\text{L}^{-1}$                       D 0.55 mol  $\text{L}^{-1}$                       E  $10^{-7}$  mol  $\text{L}^{-1}$
41. In which group would all three oxides be classified as basic oxides?
- A  $\text{CO}_2$ ,  $\text{SiO}_2$ ,  $\text{CuO}$                       B  $\text{P}_4\text{O}_{10}$ ,  $\text{SO}_2$ ,  $\text{CO}_2$                       C  $\text{CaO}$ ,  $\text{Na}_2\text{O}$ ,  $\text{K}_2\text{O}$   
 D  $\text{CO}_2$ ,  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$                       E  $\text{ZnO}$ ,  $\text{SiO}_2$ ,  $\text{Na}_2\text{O}$
42. In which one of the following reactions is dihydrogenphosphate acting as a base?
- A  $\text{H}_2\text{PO}_4^- + \text{H}_3\text{O}^+ \rightarrow \text{HPO}_4^{2-} + 2\text{H}_2\text{O}$                       B  $\text{H}_2\text{PO}_4^- + \text{H}_2\text{O} \rightarrow \text{H}_3\text{PO}_4 + \text{OH}^-$   
 C  $\text{H}_2\text{PO}_4^- + \text{CO}_3^{2-} \rightarrow \text{PO}_4^{3-} + \text{CO}_2 + \text{H}_2\text{O}$                       D  $\text{H}_2\text{PO}_4^- + \text{OH}^- \rightarrow \text{HPO}_4^{2-} + \text{H}_2\text{O}$   
 E  $\text{H}_2\text{PO}_4^- + \text{NH}_3 \rightarrow \text{NH}_4^+ + \text{HPO}_4^{2-}$
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  $\text{L}^{-1}$  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  $\text{L}^{-1}$  nitric acid is added to 80.0 mL of 0.0300 mol  $\text{L}^{-1}$  magnesium hydroxide. What is the final hydrogen ion concentration?
- A 0.0614 mol  $\text{L}^{-1}$                       B 0.00645 mol  $\text{L}^{-1}$                       C 0.0645 mol  $\text{L}^{-1}$   
 D 0.00885 mol  $\text{L}^{-1}$                       E 0.0843 mol  $\text{L}^{-1}$
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  $\text{H}_2\text{O}(\text{g}) + \text{C}(\text{s}) \rightarrow \text{CO}(\text{g}) + \text{H}_2(\text{g})$                       B  $\text{H}_2\text{O}(\text{l}) + \text{N}_2\text{H}_4(\text{aq}) \rightarrow \text{N}_2\text{H}_5^+(\text{aq}) + \text{OH}^-(\text{aq})$   
 C  $\text{H}_2\text{O}(\text{l}) + \text{HCO}_3^-(\text{aq}) \rightarrow \text{CO}_3^{2-}(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$                       D  $\text{H}_2\text{O}(\text{l}) + \text{PO}_4^{3-}(\text{aq}) \rightarrow \text{HPO}_4^{2-}(\text{aq}) + \text{OH}^-(\text{aq})$   
 E  $\text{H}_2\text{O}(\text{l}) + \text{HSO}_3^-(\text{aq}) \rightarrow \text{H}_2\text{SO}_3(\text{aq}) + \text{OH}^-(\text{aq})$

48. Assuming that ionisation of water can be represented as  $\text{H}_2\text{O}(\text{l}) \rightarrow \text{H}^+(\text{aq}) + \text{OH}^-(\text{aq})$ , what fraction of water molecules are ionised in pure water, at conditions of  $T = 25^\circ\text{C}$  and  $P = 1 \text{ atm}$ ?
- A 0                      B 1 in 18                      C 1 in  $10^7$                       D 1 in  $10^{-7}$                       E 1 in  $5.56 \times 10^8$
49. 40.0 mL of  $0.500 \text{ mol L}^{-1} \text{ HCl}$  is added to 60.0 mL of  $0.250 \text{ mol L}^{-1} \text{ Ba}(\text{OH})_2$ . 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)  $\text{O}^{2-}$                       b)  $\text{H}_3\text{O}^+$                       c)  $\text{H}_2\text{O}$                       d)  $\text{OH}^-$                       e)  $\text{H}_4\text{O}^{2+}$
- 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. If the pH of an aqueous solution is zero, what is the hydroxide ion concentration?
- A  $0 \text{ mol L}^{-1}$                       B  $1 \text{ mol L}^{-1}$                       C  $10 \text{ mol L}^{-1}$                       D  $10^{-7} \text{ mol L}^{-1}$                       E  $10^{-14} \text{ mol L}^{-1}$
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  $\text{NaHCO}_3$                       B  $\text{Na}_2\text{CO}_3$                       C  $\text{NaCl}$                       D  $\text{NH}_4\text{Cl}$                       E  $\text{Na}_2\text{SO}_4$
56. When 50.0 mL of  $1 \text{ mol L}^{-1} \text{ NaOH}$  is added to 49.9 mL of  $1 \text{ mol L}^{-1} \text{ HCl}$  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  $\text{H}^+$  equals the concentration of  $\text{OH}^-$ .                      B The concentration of ions is very low.  
C The pH equals 7.                      D The  $\text{H}_2\text{O}$  molecule is polar.  
E Water can behave as both an acid and a base.
58. Sodium oxide ( $\text{Na}_2\text{O}$ ) is soluble in water. As well as  $\text{Na}^+$  ions, you obtain in aqueous solution:
- A  $\text{O}^{2-}$  ions                      B  $\text{H}^+$  ions                      C  $\text{OH}^-$  ions                      D  $\text{H}^-$  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  $\text{Mg}(\text{OH})_2$                       B  $\text{Cr}_2\text{O}_3$                       C  $\text{Al}(\text{OH})_3$                       D  $\text{BaCO}_3$
60. Which of the following solutions are weak acids?
- $[\text{Al}(\text{H}_2\text{O})_6]^{3+}(\text{aq})$ ,                       $\text{HF}(\text{aq})$ ,                       $\text{HBr}(\text{aq})$ ,                       $\text{HSO}_4^-(\text{aq})$ ,                       $\text{H}_2\text{PO}_4^-(\text{aq})$
- A All                      B All except  $[\text{Al}(\text{H}_2\text{O})_6]^{3+}(\text{aq})$   
C All except  $\text{H}_2\text{PO}_4^-(\text{aq})$                       D All except  $\text{HSO}_4^-(\text{aq})$  and  $\text{HF}(\text{aq})$   
E All except  $\text{HBr}(\text{aq})$
61. Which of the following salts, when dissolved in water, would give a basic solution ( $\text{pH} > 7$ )?
- a)  $\text{NaF}$                       b)  $\text{NH}_4\text{NO}_3$                       c)  $\text{Ca}(\text{NO}_2)_2$
- 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  $\text{H}_3\text{O}^+(\text{aq}) + \text{HPO}_4^{2-} \rightarrow \text{H}_2\text{O}(\text{l}) + \text{H}_2\text{PO}_4^-(\text{aq})$   
B  $\text{H}_2\text{O}(\text{l}) + \text{HCO}_3^-(\text{aq}) \rightarrow \text{H}_3\text{O}^+(\text{aq}) + \text{CO}_3^{2-}(\text{aq})$   
C  $\text{H}_2\text{O}(\text{l}) + \text{NH}_3(\text{g}) \rightarrow \text{NH}_4^+(\text{aq}) + \text{OH}^-(\text{aq})$   
D  $\text{H}_3\text{O}^+(\text{aq}) + \text{HS}^-(\text{aq}) \rightarrow \text{H}_2\text{S}(\text{aq}) + \text{H}_2\text{O}(\text{l})$
63. Which of the following species is amphiprotic (amphoteric) in water?
- A  $\text{NH}_4^+$                       B  $\text{Cl}^-$                       C  $\text{CH}_3\text{CO}_2^-$                       D  $\text{HPO}_4^{2-}$
64. Hydrochloric acid is a strong acid which completely dissociates in aqueous solution. 1.0 mL of 10 mol L<sup>-1</sup> 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  $\text{HNO}_3$  and  $\text{NO}_3^-$                       B  $\text{H}_3\text{O}^+$  and  $\text{OH}^-$                       C  $\text{HNO}_3$  and  $\text{H}_2\text{O}$                       D  $\text{NH}_3$  and  $\text{OH}^-$
66. Which one of the following lists contains only oxides which are acidic?
- A  $\text{CO}_2$ ,  $\text{P}_4\text{O}_{10}$ ,  $\text{SO}_3$                       B  $\text{MgO}$ ,  $\text{CaO}$ ,  $\text{Na}_2\text{O}$                       C  $\text{NO}_2$ ,  $\text{SO}_2$ ,  $\text{Li}_2\text{O}$                       D  $\text{CO}_2$ ,  $\text{SO}_3$ ,  $\text{CaO}$
67. 50 mL of  $\text{NaOH}(\text{aq})$  with a pH of 13 is mixed with 100 mL of  $\text{HCl}(\text{aq})$  with a pH of 1. In the resulting solution, the hydrogen ion concentration is:
- A 0.033 mol L<sup>-1</sup>                      B 0.05 mol L<sup>-1</sup>                      C 0.10 mol L<sup>-1</sup>                      D 0.20 mol L<sup>-1</sup>
68. A basic solution would result from the hydrolysis of one of the ions in this compound. The compound is
- A  $\text{NaNO}_3$                       B  $\text{NH}_4\text{Cl}$                       C  $\text{LiCN}$                       D  $\text{CaCl}_2$
69. A water solution of which compound will turn litmus from blue to red?
- A  $\text{K}_2\text{CO}_3$                       B  $\text{FeCl}_3$                       C  $\text{NaOH}$                       D  $\text{NaCl}$

### Miscellaneous short answer problems

70. Give the conjugate base for each of the following acids:                      a)  $\text{H}_2\text{S}$                                       b)  $\text{CH}_3\text{NH}_3^+$
71. Write ionic equations for the reactions which occur in the following experiments. In each case indicate what you would observe (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,  $\text{NaAl}(\text{OH})_4$
- 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  $\text{Fe}_2\text{O}_3$ ) 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)
- Solid magnesium hydroxide and solid zinc hydroxide
  - Lead and zinc
  - Solid magnesium hydroxide and solid lead (II) sulfate
  - 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
- hydrogen ion
  - hydroxide ion
  - 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:
- why acetic acid is a poor conductor, though more conductive than water
  - why ammonia solution is a poor conductor, though more conductive than water.
  - 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
- hydrogen ions
  - hydroxide ions
76. Explain the following observations giving ionic equations where possible.
- A  $0.01 \text{ mol L}^{-1}$  solution of propanoic acid has a higher pH than a  $0.01 \text{ mol L}^{-1}$  solution of hydrochloric acid.
  - A  $0.001 \text{ mol L}^{-1}$  solution of sodium hydrogensulphate is acidic.
77. a) Write complete balanced equations for reactions in which water acts as:
- a base
  - 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:
- $\text{Ti}(\text{H}_2\text{O})_6^{4+}$  acting as an acid.
  - $\text{CN}^-$  acting as a base
79. a) Is an aqueous solution of  $\text{NaHSO}_4$  acidic, basic or neutral?
- b) What reaction occurs when  $\text{NaHSO}_4(\text{s})$  is dissolved in water?
- c) If solid  $\text{Na}_2\text{CO}_3$  is added to a solution of  $\text{NaHSO}_4$ , write an equation for the reaction that can occur between the  $\text{CO}_3^{2-}$  and  $\text{HSO}_4^-$  ions.
80. Calculate the  $[\text{OH}^-]$ ,  $[\text{H}^+]$  and pH of a  $0.0002 \text{ mol L}^{-1}$  barium hydroxide solution
81. Match each of the following descriptions with one of the reactions below:
- Represents the ionisation of a weak acid in water
  - Represents the hydrolysis of the conjugate base of a weak acid.
  - Represents a neutralisation reaction between a strong base and a weak acid
  - Represents a reaction in which there is a high yield of weak acid molecules formed.
- a)  $\text{CN}^-(\text{aq}) + \text{H}^+(\text{aq}) \rightarrow \text{HCN}(\text{aq})$
- b)  $\text{HCN}(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{aq}) + \text{CN}^-(\text{aq})$
- c)  $\text{HCN}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{H}_3\text{O}^+(\text{aq}) + \text{CN}^-(\text{aq})$
- d)  $\text{CN}^-(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{HCN}(\text{aq}) + \text{OH}^-(\text{aq})$
82. The pH of household ammonia solution is about 12.
- Write an equation and an equilibrium constant expression for ammonia acting as a base
  - Calculate the value of  $[\text{OH}^-]$  for the ammonia solution.
  - What is  $[\text{NH}_4^+]$  in household ammonia?

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

- a)  $\text{CoBr}_3$                       b)  $\text{NH}_4\text{Br}$                       c)  $\text{NaHCO}_3$                       d)  $\text{LiCN}$

### TEE Questions

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

- A  $\text{MgCl}_2 + 2\text{HNO}_3 \rightarrow \text{Mg}(\text{NO}_3)_2 + 2\text{HCl}$   
B  $\text{Mg}^{2+} + 2\text{NO}_3^- \rightarrow \text{Mg}(\text{NO}_3)_2$   
C  $\text{H}^+ + \text{Cl}^- \rightarrow 2\text{HCl}$   
D  $\text{Cl}^- + \text{HNO}_3 \rightarrow \text{HCl} + \text{NO}_3^-$   
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  $\text{CO}_3^{2-}$  with water  
B The pH decreases because of the reaction of  $\text{Na}^+$  with water  
C The pH increases because of the loss of carbon dioxide  
D The pH increases because of the reaction of  $\text{CO}_3^{2-}$  with water  
E The pH increases because of the reaction of  $\text{Na}^+$  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  $\text{Cl}^-$     B  $\text{H}_2\text{O}$     C  $\text{Na}^+$   
D  $\text{NH}_3$     E None of these species, since no acid/base reaction occurs.

88. A  $0.100 \text{ mol L}^{-1}$  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

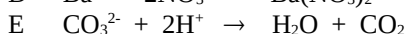
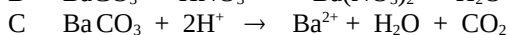
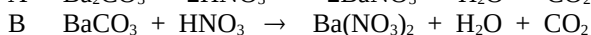
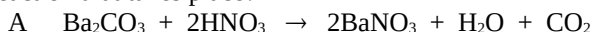
B I, II and III only

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?



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  $10 \text{ mol L}^{-1}$  ammonia?

A a dilute solution of a weak base

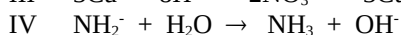
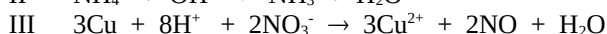
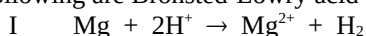
B a concentrated solution of a weak base

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?



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  $0.01 \text{ mol L}^{-1}$  ammonium chloride

B  $0.01 \text{ mol L}^{-1}$  calcium hydroxide

C  $0.01 \text{ mol L}^{-1}$  potassium nitrate

D  $0.01 \text{ mol L}^{-1}$  sodium acetate (sodium acetate)

E  $0.01 \text{ mol L}^{-1}$  sodium phosphate

96. Which one of the following describes the concentration of hydrogen ions in  $1.00 \text{ mol L}^{-1}$  sulfuric acid?

A less than  $1.00 \text{ mol L}^{-1}$

B exactly  $1.00 \text{ mol L}^{-1}$

C between  $1.00$  and  $2.00 \text{ mol L}^{-1}$

D exactly  $2.00 \text{ mol L}^{-1}$

E greater than  $2.00 \text{ mol L}^{-1}$ .

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 knowledgeable 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  $0.0250 \text{ mol L}^{-1}$  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 ( $\text{LaCl}_3$ ) 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  $0.1 \text{ mol L}^{-1}$  ammonium sulfateB  $0.1 \text{ mol L}^{-1}$  iron(II) chlorideC  $0.1 \text{ mol L}^{-1}$  magnesium nitrateD  $0.1 \text{ mol L}^{-1}$  potassium acetate (potassium acetate)E  $0.1 \text{ mol L}^{-1}$  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  $\Delta H$  for  $\text{NH}_4\text{Cl(s)} \rightarrow \text{NH}_4^+(\text{aq}) + \text{Cl}^-(\text{aq})$  is negativeB When  $\text{NH}_4\text{Cl}$  dissolves, the  $\text{NH}_4^+$  reacts to a small extent with water to give an acidic solution.C When  $\text{NH}_4\text{Cl}$  dissolves, the conductivity of the solution increases.D  $\text{NH}_4\text{Cl}$  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	$\text{Al}_2(\text{SO}_4)_3$
A little of each of the remaining three.....		

103. Both perchloric acid,  $\text{HClO}_4$ , and barium hydroxide,  $\text{Ba}(\text{OH})_2$ , are fully dissociated when in water-solution.

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

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

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

I  $\text{Na}_2\text{O}$

II  $\text{Al}_2\text{O}_3$

III  $\text{P}_4\text{O}_{10}$

IV  $\text{SO}_2$

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  $\text{NH}_3 + \text{H}_2\text{O} \rightarrow \text{NH}_4^+ + \text{OH}^-$

B  $\text{CH}_3\text{CO}_2^- + \text{H}_2\text{O} \rightarrow \text{CH}_3\text{COOH} + \text{OH}^-$

C  $\text{O}_2\text{CCO}_2^{2-} + \text{H}_2\text{O} \rightarrow \text{HOCCO}_2^- + \text{OH}^-$

D  $\text{O}^{2-} + \text{H}_2\text{O} \rightarrow 2 \text{OH}^-$

E  $\text{HS}^- + \text{H}_2\text{O} \rightarrow \text{S}^{2-} + \text{H}_3\text{O}^+$

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

A 1.7

B 2.0

C 7.0

D 12.0

E 12.3

107. a) The pH of a  $0.1 \text{ mol L}^{-1}$   $\text{NaHCO}_3$  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  $0.1 \text{ mol L}^{-1}$   $\text{NaHSO}_4$  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)  $2\text{H}^+(\text{aq}) + \text{Mg}(\text{s}) \rightarrow \text{H}_2(\text{g}) + \text{Mg}^{2+}(\text{aq})$   
- 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  $\text{OH}^-$ )
  - c)  $2\text{H}^+(\text{aq}) + \text{CaCO}_3(\text{s}) \rightarrow \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) + \text{Ca}^{2+}(\text{aq})$   
- the solid will dissolve to form a colourless solution and a colourless, odourless gas
  - d)  $2\text{H}^+(\text{aq}) + \text{CO}_3^{2-}(\text{aq}) \rightarrow \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$   
- the solution will remain colourless, but a colourless, odourless gas will form
  - e)  $\text{Al}(\text{OH})_3(\text{s}) + 3\text{H}^+(\text{aq}) \rightarrow \text{Al}^{3+}(\text{aq}) + 3\text{H}_2\text{O}(\text{l})$   
- the solid will dissolve to form a colourless solution
  - f)  $\text{Al}(\text{OH})_3(\text{s}) + \text{OH}^-(\text{aq}) \rightarrow [\text{Al}(\text{OH})_4]^{-}(\text{aq})$   
- the solid will dissolve to form a colourless solution
  - g)  $\text{Cu}(\text{OH})_2(\text{s}) + 2\text{H}^+(\text{aq}) \rightarrow \text{Cu}^{2+}(\text{aq}) + 2\text{H}_2\text{O}(\text{l})$   
- the solid dissolves to form a blue solution
  - h) no reaction
  - i)  $2\text{H}^+(\text{aq}) + \text{Zn}(\text{s}) \rightarrow \text{H}_2(\text{g}) + \text{Zn}^{2+}(\text{aq})$   
- the grey solid will dissolve to form a colourless solution and a colourless, odourless gas.
  - j)  $\text{Zn}(\text{s}) + 2\text{OH}^-(\text{aq}) + 2\text{H}_2\text{O}(\text{l}) \rightarrow \text{H}_2(\text{g}) + [\text{Zn}(\text{OH})_4]^{2-}(\text{aq})$   
- the grey solid will dissolve to form a colourless solution and a colourless, odourless gas
  - k)  $\text{CuO}(\text{s}) + 2\text{H}^+(\text{aq}) \rightarrow \text{Cu}^{2+}(\text{aq}) + \text{H}_2\text{O}(\text{l})$   
- 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.  
 $2\text{Al}(\text{s}) + 2\text{OH}^-(\text{aq}) + 6\text{H}_2\text{O}(\text{l}) \rightarrow 3\text{H}_2(\text{g}) + 2[\text{Al}(\text{OH})_4]^{-}(\text{aq})$
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.  $\text{Zn}(\text{OH})_2(\text{s}) + 2\text{OH}^-(\text{aq}) \rightarrow [\text{Zn}(\text{OH})_4]^{2-}(\text{aq})$
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)  
 $\text{CaCO}_3(\text{s}) + 2\text{H}^+(\text{aq}) \rightarrow \text{Ca}^{2+}(\text{aq}) + \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$        $\text{MgO}(\text{s}) + 2\text{H}^+(\text{aq}) \rightarrow \text{Mg}^{2+}(\text{aq}) + \text{H}_2\text{O}(\text{l})$
5. a) base                      b) base                      c) base                      d) base                      e) base
6. a)  $\text{H}_2\text{O} / \text{OH}^-$  and  $\text{HSO}_3^- / \text{SO}_3^{2-}$                       b)  $\text{PH}_4^+ / \text{PH}_3$  and  $\text{HI} / \text{I}^-$ .  
 c)  $\text{H}_2\text{PO}_4^- / \text{HPO}_4^{2-}$  and  $\text{H}_2\text{O} / \text{OH}^-$                       d)  $\text{CH}_3\text{COOH}_2^+ / \text{CH}_3\text{COOH}$  and  $\text{HBr} / \text{Br}^-$ .  
 e)  $\text{CH}_3\text{NH}_3^+ / \text{CH}_3\text{NH}_2$  and  $\text{CH}_3\text{CH}_2\text{OH} / \text{CH}_3\text{CH}_2\text{O}^-$
7.  $\text{HNO}_3$                        $\text{HSO}_3^-$ ,                       $\text{H}_2\text{F}^+$ ,                       $\text{HClO}_3$                        $\text{NH}_4^+$
8.  $\text{Br}^-$ ,                       $\text{SO}_3^{2-}$ ,                       $\text{H}_2\text{PO}_4^-$ ,                       $\text{H}_2\text{Se}$ ,                       $\text{OH}^-$ ,                       $\text{O}^{2-}$
9. The equations must show HBr losing  $\text{H}^+$  and  $\text{HCO}_3^-$  gaining  $\text{H}^+$   
 e.g.  $\text{HBr} + \text{H}_2\text{O} \rightarrow \text{Br}^- + \text{H}_3\text{O}^+$                        $\text{HCO}_3^- + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3 + \text{OH}^-$
10.  $[\text{H}^+] = 0.200 \text{ mol L}^{-1}$ ,                       $[\text{OH}^-] = 5.00 \times 10^{-14} \text{ mol L}^{-1}$
11.  $[\text{H}^+] = 1.00 \times 10^{-13} \text{ mol L}^{-1}$ ,                       $[\text{OH}^-] = 0.100 \text{ mol L}^{-1}$
12. a)  $[\text{H}^+] = 0.200 \text{ mol L}^{-1}$ ,                       $[\text{OH}^-] = 5.00 \times 10^{-14} \text{ mol L}^{-1}$   
 b)  $[\text{H}^+] = 1.00 \times 10^{-12} \text{ mol L}^{-1}$ ,                       $[\text{OH}^-] = 0.0100 \text{ mol L}^{-1}$ ,  
 c)  $[\text{H}^+] = 0.300 \text{ mol L}^{-1}$ ,                       $[\text{OH}^-] = 3.33 \times 10^{-14} \text{ mol L}^{-1}$ ,  
 d)  $[\text{H}^+] = 1.00 \times 10^{-13} \text{ mol L}^{-1}$ ,                       $[\text{OH}^-] = 0.100 \text{ mol L}^{-1}$
13. a) 3                      b) 4                      c) 1                      d) 10                      e) 12                      f) 13
14. a)  $[\text{H}^+] = 1 \times 10^{-8} \text{ mol L}^{-1}$ ,  $[\text{OH}^-] = 1.0 \times 10^{-6} \text{ mol L}^{-1}$ ,                      b) 0.2 mol                      c) 28.1 g
15. a) HCl,                       $\text{HNO}_3$ ,                       $\text{H}_2\text{SO}_4$ ,                      HBr,                       $\text{HClO}_4$ ,                      HI  
 b) Any acid except the six listed in a),  $\text{NH}_4^+$ , any transition metal or group 3 ion,  $\text{HSO}_4^-$ ,  $\text{H}_2\text{PO}_4^-$   
 c) Any metal hydroxide or metal oxide e.g. NaOH, MgO  
 d) Any base except those listed in c) e.g.  $\text{NH}_3$ ,  $\text{CO}_3^{2-}$ ,  $\text{HCO}_3^-$ , 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<sup>-1</sup> acid is completely dissociated, then the [H<sup>+</sup>] will be 0.01 mol L<sup>-1</sup>, and the pH will be 2. Thus, acid N is completely dissociated.
20. a)  $\text{O}^{2-}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{OH}^-(\text{aq}) + \text{OH}^-(\text{aq})$                        $\text{OH}^- / \text{O}^{2-}$  and  $\text{H}_2\text{O} / \text{OH}^-$
- b)  $\text{O}^{2-}$  is a stronger base than  $\text{OH}^-$  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  $\text{O}^{2-}$  must be stronger than the base  $\text{OH}^-$ .
21. a) i)                      ii)                      iii)                      b) ii)
22. **Potassium bromide:**  $\text{KBr} \rightarrow \text{K}^+ + \text{Br}^-$  Neither the  $\text{K}^+$  or  $\text{Br}^-$  ions react significantly with water i.e. they do not undergo hydrolysis. Thus, the [H<sup>+</sup>] is due just to the self-ionisation of water, and so the pH is 7.
- Potassium hydrogensulfate:**  $\text{KHSO}_4 \rightarrow \text{K}^+ + \text{HSO}_4^-$ . The  $\text{K}^+$  ions formed in this dissociation reaction do not undergo significant hydrolysis. However, the  $\text{HSO}_4^-$  ion does undergo hydrolysis:  $\text{HSO}_4^- + \text{H}_2\text{O} \rightarrow \text{SO}_4^{2-} + \text{H}_3\text{O}^+$ . This reaction results in an increase in the [H<sup>+</sup>] in the aqueous solution, and so the solution will have a pH less than 7 i.e. it is an acidic solution.
- Potassium hydrogencarbonate:**  $\text{KHCO}_3 \rightarrow \text{K}^+ + \text{HCO}_3^-$ . The  $\text{K}^+$  ions formed in this dissociation reaction do not undergo significant hydrolysis. However, the  $\text{HCO}_3^-$  ion does undergo hydrolysis:  $\text{HCO}_3^- + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3 + \text{OH}^-$ . This reaction results in an increase in the [OH<sup>-</sup>] in the aqueous solution, and so the solution will have a pH greater than 7 i.e. it is a basic solution.
23. a)  $\text{MgCl}_2 \rightarrow \text{Mg}^{2+} + 2\text{Cl}^-$ . Neither of these ions hydrolyse further. Thus the solution will be neutral
- b)  $\text{NH}_4\text{NO}_3 \rightarrow \text{NH}_4^+ + \text{NO}_3^-$ . Only the  $\text{NH}_4^+$  ion hydrolyses:  $\text{NH}_4^+ + \text{H}_2\text{O} \rightarrow \text{NH}_3 + \text{H}_3\text{O}^+$ . Because  $\text{H}_3\text{O}^+$  is formed, the solution will be acidic.
- c)  $\text{K}_2\text{O} \rightarrow 2\text{K}^+ + \text{O}^{2-}$  then  $\text{O}^{2-} + \text{H}_2\text{O} \rightarrow 2\text{OH}^-$  Because  $\text{OH}^-$  is formed, the solution will be basic.
- d)  $\text{Na}_2\text{SO}_4 \rightarrow 2\text{Na}^+ + \text{SO}_4^{2-}$ . Neither ions hydrolyse, thus solution will be neutral.
- e)  $\text{Na}_2\text{S} \rightarrow 2\text{Na}^+ + \text{S}^{2-}$   $\text{S}^{2-}$  hydrolyses:  $\text{S}^{2-} + \text{H}_2\text{O} \rightarrow \text{HS}^- + \text{OH}^-$  Because  $\text{OH}^-$  is formed, the solution will be basic.
- f)  $\text{LiCN} \rightarrow \text{Li}^+ + \text{CN}^-$   $\text{CN}^-$  hydrolyses:  $\text{CN}^- + \text{H}_2\text{O} \rightarrow \text{HCN} + \text{OH}^-$  Because  $\text{OH}^-$  is formed, the solution will be basic.
- g)  $\text{BaBr}_2 \rightarrow \text{Ba}^{2+} + 2\text{Br}^-$  Neither ions hydrolyse, thus solution will be neutral.
- h)  $\text{NaH}_2\text{PO}_4 \rightarrow \text{Na}^+ + \text{H}_2\text{PO}_4^-$   $\text{H}_2\text{PO}_4^-$  hydrolyses:  $\text{H}_2\text{PO}_4^- + \text{H}_2\text{O} \rightarrow \text{HPO}_4^{2-} + \text{H}_3\text{O}^+$  Because  $\text{H}_3\text{O}^+$  is formed, the solution will be acidic.
- i)  $\text{K}_3\text{PO}_4 \rightarrow 3\text{K}^+ + \text{PO}_4^{3-}$   $\text{PO}_4^{3-}$  hydrolyses:  $\text{PO}_4^{3-} + \text{H}_2\text{O} \rightarrow \text{HPO}_4^{2-} + \text{OH}^-$  Because  $\text{OH}^-$  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)  $\text{HS}^-$                       b)  $\text{CH}_3\text{NH}_2$ .
71. a)  $2\text{H}^+(\text{aq}) + \text{Na}_2\text{SO}_3(\text{s}) \rightarrow \text{SO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) + 2\text{Na}^+(\text{aq})$   
Pungent, colourless gas formed, solid dissolves to form colourless solution.
- b)  $2\text{H}^+(\text{aq}) + \text{CuCO}_3(\text{s}) \rightarrow \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) + \text{Cu}^{2+}(\text{aq})$   
Odourless, colourless gas formed, solid dissolves to form blue solution.
- c)  $2\text{Al}(\text{s}) + 2\text{OH}^-(\text{aq}) + 6\text{H}_2\text{O}(\text{l}) \rightarrow 2[\text{Al}(\text{OH})_4]^-(\text{aq}) + 3\text{H}_2(\text{g})$   
Grey solid dissolves to form colourless solution, colourless, odourless gas formed.

71. d)  $\text{CH}_3\text{COOH}(\text{aq}) + \text{HCO}_3^-(\text{aq}) \rightarrow \text{CH}_3\text{COO}^-(\text{aq}) + \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$   
Colourless, odourless gas forms, vinegar-smell disappears
- e)  $2\text{H}^+(\text{aq}) + \text{CoCO}_3(\text{s}) \rightarrow \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) + \text{Co}^{2+}(\text{aq})$   
Colourless, odourless gas formed, solid dissolves to form pink solution
- f)  $\text{H}^+(\text{aq}) + [\text{Al}(\text{OH})_4]^-(\text{aq}) \rightarrow \text{Al}(\text{OH})_3(\text{s}) + \text{H}_2\text{O}(\text{l})$  White solid forms.
- g)  $\text{Cu}^{2+}(\text{aq}) + 4\text{NH}_3(\text{aq}) \rightarrow [\text{Cu}(\text{NH}_3)_4]^{2+}(\text{aq})$  Blue precipitate forms which dissolves to form a darker blue solution.
- h)  $\text{Zn}(\text{s}) + 2\text{OH}^-(\text{aq}) + 2\text{H}_2\text{O}(\text{l}) \rightarrow [\text{Zn}(\text{OH})_4]^{2-}(\text{aq}) + \text{H}_2(\text{g})$   
Grey solid dissolves to form colourless solution, colourless, odourless gas formed.
- i)  $2\text{H}^+(\text{aq}) + \text{Mg}(\text{s}) \rightarrow \text{H}_2(\text{g}) + \text{Mg}^{2+}(\text{aq})$  Grey solid dissolves to form colourless solution and colourless, odourless gas
- j)  $\text{Fe}_2\text{O}_3(\text{s}) + 6\text{H}^+(\text{aq}) \rightarrow 2\text{Fe}^{3+}(\text{aq}) + 3\text{H}_2\text{O}(\text{l})$  Solid dissolves to form orange solution
72. a) Add a solution of sodium hydroxide to both solids, the zinc hydroxide will dissolve (it forms  $[\text{Zn}(\text{OH})_4]^{2-}$ ) 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)  $[\text{H}^+] = 10^{-3} \text{ mol L}^{-1}$       b)  $[\text{OH}^-] = 10^{-11} \text{ mol L}^{-1}$       c)  $[\text{Cl}^-] = 10^{-3} \text{ mol L}^{-1}$ .
74. a) Acetic acid is a weak acid and when it dissolves in water it only slightly ionises.  $\text{CH}_3\text{COOH} \rightleftharpoons \text{CH}_3\text{COO}^- + \text{H}^+$   
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:  
 $\text{NH}_3 + \text{H}_2\text{O} \rightleftharpoons \text{NH}_4^+ + \text{OH}^-$ . 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:  
 $\text{NH}_3 + \text{CH}_3\text{COOH} \rightarrow \text{NH}_4^+ + \text{CH}_3\text{COO}^-$   
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)  $[\text{H}^+] = 10^{-9} \text{ mol L}^{-1}$       b)  $[\text{OH}^-] = 10^{-5} \text{ mol L}^{-1}$
76. a) Hydrochloric acid is a strong acid and will ionise completely in solution  $\text{HCl} \rightarrow \text{H}^+ + \text{Cl}^-$ .  
That is, a  $0.01 \text{ mol L}^{-1}$  solution of HCl will have a  $[\text{H}^+] = 10^{-2}$ , and a pH of 2.
- Propanoic acid is a weak acid and so only partially ionises in solution:  $\text{CH}_3\text{CH}_2\text{COOH} \rightleftharpoons \text{CH}_3\text{CH}_2\text{COO}^- + \text{H}^+$ .  
That is, the concentration of  $\text{H}^+$  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  $\text{H}_3\text{O}^+$  ions.  
 $\text{HSO}_4^- + \text{H}_2\text{O} \rightleftharpoons \text{SO}_4^{2-} + \text{H}_3\text{O}^+$ . The presence of extra  $\text{H}_3\text{O}^+$  ions makes the solution acidic.
77. a) i)  $\text{NH}_4^+ + \text{H}_2\text{O} \rightleftharpoons \text{NH}_3 + \text{H}_3\text{O}^+$       ii)  $\text{NH}_3 + \text{H}_2\text{O} \rightleftharpoons \text{NH}_4^+ + \text{OH}^-$ .
- b) weak electrolyte
- c) Water ionises slightly:  $\text{H}_2\text{O} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{OH}^-$ . The equilibrium constant for this reaction is the ionisation constant of water and has the value of  $10^{-14}$ . 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)  $\text{Ti}(\text{H}_2\text{O})_6^{4+} + \text{H}_2\text{O} \rightarrow \text{Ti}(\text{H}_2\text{O})_5(\text{OH})^{3+} + \text{H}_3\text{O}^+$ .      b)  $\text{CN}^- + \text{H}_2\text{O} \rightarrow \text{HCN} + \text{OH}^-$ .
79. a) Acidic.
- b) First  $\text{NaHSO}_4 \rightarrow \text{Na}^+ + \text{HSO}_4^-$  then  $\text{HSO}_4^- + \text{H}_2\text{O} \rightarrow \text{SO}_4^{2-} + \text{H}_3\text{O}^+$ .
- c)  $\text{CO}_3^{2-} + \text{HSO}_4^- \rightarrow \text{HCO}_3^- + \text{SO}_4^{2-}$  (or  $\text{CO}_3^{2-} + 2\text{HSO}_4^- \rightarrow \text{CO}_2 + \text{H}_2\text{O} + 2\text{SO}_4^{2-}$ ).
80.  $\text{Ba}(\text{OH})_2 \rightarrow \text{Ba}^{2+} + 2\text{OH}^-$ .       $[\text{OH}^-] = 0.0004 \text{ mol L}^{-1}$        $[\text{H}^+] = 2.5 \times 10^{-11} \text{ mol L}^{-1}$       pH = 10.6
81. a) iv)      b) iii)      c) i)      d) ii)
82. a)  $\text{NH}_3 + \text{H}_2\text{O} \rightarrow \text{NH}_4^+ + \text{OH}^-$ .      K =
- b)  $1 \times 10^{-2} \text{ mol L}^{-1}$       c)  $1 \times 10^{-2} \text{ mol L}^{-1}$
83. a) acidic      b) acidic      c) basic      d) basic
84. E      85. A      86. D      87. B      88. E



89. a)  $\text{Cl}^-(\text{aq}) + \text{Ag}^+(\text{aq}) \rightarrow \text{AgCl}(\text{s})$  White precipitate forms  
 b)  $\text{NiCO}_3(\text{s}) + 2\text{H}^+(\text{aq}) \rightarrow \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) + \text{Ni}^{2+}(\text{aq})$  - green solution and colourless, odourless gas form  
 c)  $\text{Fe}^{2+}(\text{aq}) + 2\text{OH}^-(\text{aq}) \rightarrow \text{Fe}(\text{OH})_2(\text{s})$  - pale green precipitate forms  
 d)  $\text{H}^+(\text{aq}) + \text{CH}_3\text{COO}^-(\text{aq}) \rightarrow \text{CH}_3\text{COOH}(\text{aq})$  - no visible change, but solution smells like vinegar  
 e)  $\text{Pb}^{2+}(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) \rightarrow \text{PbSO}_4(\text{s})$  - white precipitate forms  
 f)  $\text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l})$  - no visible change occurs  
 g)  $\text{ZnO}(\text{s}) + 2\text{H}^+(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l}) + \text{Zn}^{2+}(\text{aq})$  - white solid dissolves to form colourless solution

90. A

91. C

92.

	Your chemical test. Describe fully	What would you observe in each case
$\text{Cu}(\text{NO}_3)_2$ and $\text{CuSO}_4$	Prepare a solution in water of each compound Add a solution of barium chloride to each solution	with $\text{Cu}(\text{NO}_3)_2$ - no reaction
		with $\text{CuSO}_4$ - white precipitate forms
$\text{MgCl}_2$ and $\text{ZnCl}_2$	Prepare a solution of each compound. Add an excess of sodium hydroxide solution to each	with $\text{MgCl}_2$ - white precipitate forms
		with $\text{ZnCl}_2$ - white precipitate forms which then dissolves in excess sodium hydroxide.

93. B

94. D

95. A

96. C

97.  $\text{BaSO}_4$ ,  $\text{Na}_3\text{PO}_4$ ,  $\text{AgNO}_3$ ,  $\text{ZnSO}_4$ ,  $\text{Zn}(\text{NO}_3)_2$ ,  $\text{KCl}$ 98.  $[\text{OH}^-] = 0.0250 \text{ mol L}^{-1}$   $[\text{H}^+] = 0.00 \times 10^{-13} \text{ mol L}^{-1}$  pH = **12.4**99. a)  $3\text{Ni}^{2+}(\text{aq}) + 2\text{PO}_4^{3-}(\text{aq}) \rightarrow \text{Ni}_3(\text{PO}_4)_2(\text{s})$  b)  $\text{La}^{2+}(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) \rightarrow \text{LaSO}_4(\text{s})$ 

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	$\text{Al}_2(\text{SO}_4)_3$
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	$\text{Al}(\text{NO}_3)_3$
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	$\text{AlCl}_3$
The remaining substance is		$\text{MgCl}_2$

103. a) pH =  $-\log(0.0500) = \mathbf{1.30}$ b)  $\text{Ba}(\text{OH})_2 \rightarrow \text{Ba}^{2+} + 2\text{OH}^-$   $[\text{OH}^-] = 2 \times 0.0500 = 0.100 \text{ mol L}^{-1}$   
 $[\text{H}^+] = 1.00 \times 10^{-13} \text{ mol L}^{-1}$  pH = **13**

104. D

105. E

106. E

107. a) In the solution there are  $\text{Na}^+$  ions and  $\text{CO}_3^{2-}$  ions. The  $\text{Na}^+$  ions do not significantly hydrolyse, but the  $\text{CO}_3^{2-}$  ions do hydrolyse:  $\text{CO}_3^{2-} + \text{H}_2\text{O} \rightleftharpoons \text{HCO}_3^- + \text{OH}^-$   
 Because  $\text{OH}^-$  ions are formed, the solution will be basic with the  $[\text{OH}^-] > 1 \times 10^{-7}$  i.e. the pH will be greater than 7.
- b) In the solution there are  $\text{Na}^+$  ions and  $\text{CO}_3^{2-}$  ions. The  $\text{Na}^+$  ions do not significantly hydrolyse, but the  $\text{HSO}_4^-$  ions do hydrolyse:  $\text{HSO}_4^- + \text{H}_2\text{O} \rightleftharpoons \text{SO}_4^{2-} + \text{H}_3\text{O}^+$   
 Because  $\text{H}_3\text{O}^+$  ions are formed, the solution will be acidic with the  $[\text{H}_3\text{O}^+] > 1 \times 10^{-7}$  i.e. the pH will be less than 7.