ACID-BASE STUDY GUIDE- written questions

. **Written Section**: The questions below represent provincial exam questions(written) from Provincial Examinations in Chemistry dating back to Jan/94to April 2000. It is important to do as many question types as possible. Once you have familiarized yourself with a particular type of problem and are confident in your abilities to solve it, signify it by placing checkmark on your <u>INTENDED LEARNING OUTCOMES</u> handout for this section. Good Luck!

SUGGESTIONS FOR MAXIMIZING USE OF THIS GUIDE:

- **Do all of the questions in this guide!!!**
- **This guide contains all the questions from Provincial Exams dating back to Jan/94. Some sections are bigger than others in regards to questions asked….you should be intimately familiar with "repeat questions".**
- **Compare your fully worked out solutions against the key provided, paying attention to how marks are awarded for each type of question.**

PROPERTIES AND DEFINITIONS

1. State two tests that could be safely performed to determine whether an unknown solution is acidic. Predict the results if the solution is acidic. (**2 marks**)

    Test 1: _____

    Result: _____

    Test 2: _____

    Result: _____

2. a) Define the term *weak Brönsted-Lowry bas*e. (**2marks**)
    b) Give an example of a compound that acts as a weak base. (**1mark**)

3. Define the term *strong Brönsted-Lowry aci*d. (**2 marks**)

4. a) Write a definition for a conjugate acid-base pair. (**1 mark**)
    b) Give one example of a conjugate acid-base pair. (**1 mark**)

5. a) Write the Brönsted-Lowry acid-base equation for the reaction between $HCN_{(aq)}$ and $NH_3{}_{(aq)}$ (**1 mark**)
    b) Write a conjugate acid-base pair from the equation above. (**1 mark**)

STRONG/WEAK ACIDS AND BASES

6. A 1.0 M unknown solution was analyzed and the following was observed:
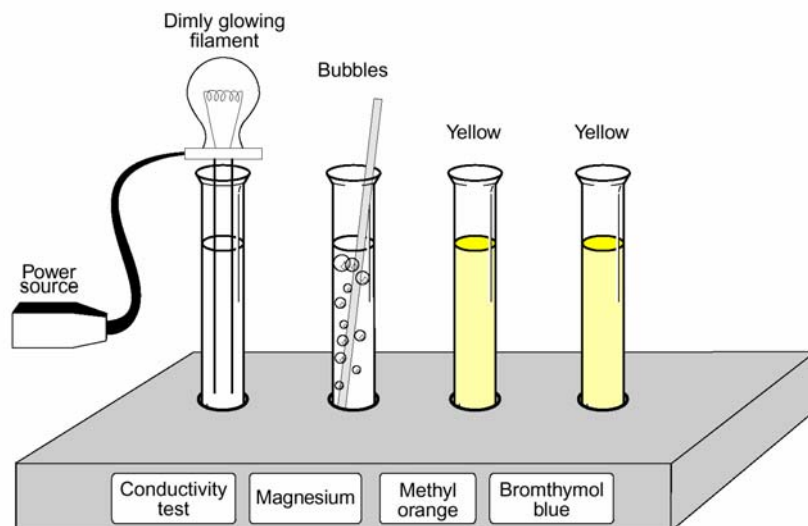
Classify the unknown as an acid or base indicating whether it is weak or strong. Justify your answer using the data provided. **(2marks)**

7. A sample of a weak acid was found to conduct an electric current better than a sample of a strong acid. Explain these results in terms of ion concentration. **(2marks)**

8.
a) Write the net ionic equation for the predominant reaction between $NaHSO_3$ and $NaHC_2O_4$. **(2 marks)**

b) Explain why the reactants are favoured in the above reaction. **(1 mark)**

9. a) Write the balanced equation representing the reaction of HF with H_2O. **(1 mark)**
b) Identify the Brönsted-Lowry bases in the above equation. **(1 mark)**

10.
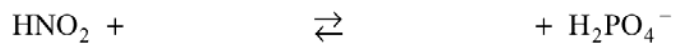A weak acid, $H_2C_6H_6O_6$, is dissolved in water. Write a chemical equation to represent this system. **(2 marks)**

11.

Consider a Brönsted-Lowry acid-base equation, where HNO_2 is a reactant and $H_2PO_4^-$ is a product.

a) Complete the following equation. **(1 mark)**

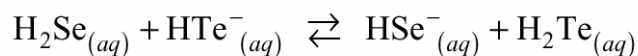$$HNO_2 \; + \; \underline{\hspace{2cm}} \; \rightleftarrows \; \underline{\hspace{2cm}} \; + \; H_2PO_4^-$$

b) Identify the weaker base in the equilibrium in part a). **(1 mark)**

12.

Consider the following equilibrium:

$$H_2Se_{(aq)} + HTe^-_{(aq)} \rightleftarrows HSe^-_{(aq)} + H_2Te_{(aq)}$$

The reactants are favoured in this equilibrium.

a) Identify the stronger acid. $\underline{\hspace{5cm}}$ **(1 mark)**

b) Identify the weaker base. $\underline{\hspace{5cm}}$ **(1 mark)**

13.

In an acid-base reaction, the **two Brönsted-Lowry acids** are hydrofluoric acid (HF) and the hydrogen sulphite ion $\left(HSO_3^-\right)$. Write the equation for this reaction.
(2 marks)

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14. In aqueous solutions, H_3O^+ is the strongest acid present. This phenomenon is called the levelling effect. Explain why this occurs. **(2 marks)**

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15. a) Define the term *amphiprotic*. **(1 mark)**
    b) Give an example of an amphiprotic anion. **(1 mark)**

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16. Define the term *amphiprotic*. Give an example of an ion which is amphiprotic.{2marks}
    Definition: $\underline{\hspace{8cm}}$
    Example: $\underline{\hspace{8cm}}$

17.

The ionization constant for water, K_w, is 9.6×10^{-14} at $60°C$.

a) Write an equation including the heat term representing the ionization of water.

(2 marks)

b) Calculate the pH for water at $60°C$. **(2 marks)**

18.

a) The ionization of water is an endothermic process. What happens to the value of K_W as water is heated? Explain. **(2 marks)**

b) What happens to the pH of pure water as the temperature increases? **(1 mark)**

c) As the temperature of pure water rises, will the water become more acidic, more basic, or remain neutral? **(1 mark)**

19.

Calculate the mass of NaOH needed to prepare $2.0\,L$ of a solution with a pH of 12.00.

(3 marks)

20.

What is the $\left[H_3O^+\right]$ in a solution formed by adding 60.0 mL of water to 40.0 mL of 0.040 M KOH? **(2 marks)**

21. Calculate the pH in 100.0 mL of 0.400 M H_3BO_3. **(4 marks)**

22. Four monoprotic acids of the same concentration are labelled as follows:

SOLUTION	LABEL
A	$\left[OH^-\right] = 5.0 \times 10^{-11}$ M
B	$\left[H^+\right] = 0.20$ M
C	pOH $= 11.30$ M
D	pH $= 1.20$ M

List the four solutions in order of decreasing acidity. Use calculations to support your answer. **(4marks)**

23. A chemist pipettes 25.00 mL of 0.15 M HCl into a 100.0 mL volumetric flask. Then she adds water to the mark. Calculate the pH of this solution. **(2 marks)**

24. Calculate the pH of a solution prepared by dissolving 0.050 mol of NaOH in enough water to make 500.0 mL of solution. **(2 marks)**

25.

Tomato juice has a pH of 4.20. Calculate the $\left[H_3O^+\right]$ and $\left[OH^-\right]$ in tomato juice. **(2 marks)**

K_a and K_b Problem Solving

26. Lactic acid, $HC_3H_5O_3$, is a compound that accumulates in muscle tissue during exertion. Write the equation and the K_a expression for the ionization of lactic acid in water. **(2marks)**

27. Write the equation for the hydrogen carbonate ion acting as a weak acid. **(1 mark)**

28. Consider the following amphiprotic anions reacting with each other:

$$HC_6H_5O_7{}^{2-} + HC_2O_4{}^- \rightleftarrows \quad ?$$

a) Complete the Brönsted-Lowry acid-base equilibrium for the predominant reaction. **(1 mark)**
b) Does the equilibrium above favour reactants or products? Explain. **(1 mark)**

29. Consider the following data:

CHEMICAL SPECIES	FORMULA	IONIZATION CONSTANT
barbituric acid	$HC_4H_3N_2O_3$	$K_a = 9.8 \times 10^{-5}$
sodium propanoate	$NaC_3H_5O_2$	$K_b = 7.5 \times 10^{-10}$
propanoic acid	$HC_3H_5O_2$	?

Which is the stronger acid, propanoic acid or barbituric acid? Explain, using appropriate calculations. **(2 marks)**

30. Calculate the pH of 0.50 M H_3BO_3. **(4 marks)**

31. Calculate the pH of a $1.5\,M\ H_2S$ solution. **(4 marks)**

32. Calculate the $\left[OH^-\right]$ of $0.10\,M\ NH_3$. **(4 marks)**

33. The salt Na_2CO_3 undergoes hydrolysis to produce a basic solution. Calculate the $\left[OH^-\right]$ in 0.100 M Na_2CO_3. **(4 marks)**

34. Nicotinic acid, $HC_6H_4NO_2$, is a weak acid found in vitamin B.
Calculate the pH of 0.010 M $HC_6H_4NO_2$ $\left(K_a = 1.4 \times 10^{-5}\right)$. **(4 marks)**

35. Calculate the $\left[H_3O^+\right]$ in $0.550\,M\ C_6H_5COOH$. **(3 marks)**

36. Calculate the pH of 2.0 M nitrous acid. **(4marks)**

37.	Calculate the pH of 0.30 M CH$_3$COOH. **(3marks)**
38.	Calculate the pH of 0.20 M CH$_3$COOH. **(3marks)**
39.	Calculate the pH of 0.50 M H$_2$S. **(4 marks)**
40.	What pH results when 0.75 mol of acetic acid is dissolved in enough water to make 3.0 litres of solution? **(4 marks)**
41.	Determine the pH of a 0.10 M solution of hydrogen cyanide. **(4 marks)**
42.	The salt NaCN dissolves in water and forms a slightly basic solution. a) Write the dissociation equation for NaCN in water. **(1 mark)** b) Write the net ionic equation for the hydrolysis reaction. **(1 mark)** c) Write the K$_b$ expression and calculate its value. **(2 marks)**
43.	An aqueous solution of Na$_2$CO$_3$ undergoes hydrolysis. a) Write the equation for the hydrolysis. **(1 mark)** b) Calculate K$_b$ for the hydrolysis in a). **(1 mark)**
44.	a) Write two equations showing the amphiprotic nature of water as it reacts with HCO$_3^-$ **(2 marks)** b) Calculate the K$_b$ for HCO$_3^-$ **(1 mark)**
45.	a) Write a chemical equation representing the hydrolysis of sodium acetate.**(1 mark)** b) Calculate the K$_b$ value for the hydrolysis in part (a) above. **(1 mark)**
46.	a) Write an equilibrium equation to represent the hydrolysis of ammonia in water.**(1mark)** b) Calculate the value of the equilibrium constant. **(1 mark)**
47.	A 1.00 M OCl$^-$ solution has an $\left[OH^-\right]$ of 5.75×10^{-4} M. a) Calculate K$_b$ for OCl$^-$. (3 marks) b) Calculate K$_a$ for HOCl. **(1 mark)**
48.	A 3.50×10^{-3} M sample of the unknown acid, HA, has a pH of 2.90. Calculate the value of K$_a$ and identify this acid. (4 marks)
49.	Lactic acid, C$_2$H$_5$OCOOH, is a weak acid produced by the body. At $25°$C, 0.0100 M C$_2$H$_5$OCOOH has a pH of 2.95. Calculate the value of K$_a$ for lactic acid. (4 marks)
50.	A solution of 0.0100 M lactic acid, HC$_3$H$_5$O$_3$, has a pH of 2.95. Calculate the K$_a$ value. (3 marks)
51.	A 0.0200 M solution of methylamine, CH$_3$NH$_2$, has a pH $= 11.40$. Calculate the K$_b$ for methylamine. (4 marks)
52.	A solution of 0.100 M HOCN has a pH of 2.24. Calculate the K$_a$ value for this acid. **(4 marks)**

53. An acid is known to be either iodic, nitrous, ethanoic (acetic) or benzoic. A 0.200 M solution of this acid is found to have a pH of 2.44. Using this data and appropriate calculations, identify this acid. **(4 marks)**

HYDROLYSIS OF SALTS

54. A chemist prepares a solution by dissolving the salt $NaIO_3$ in water.
   a) Write the equation for the dissociation reaction that occurs. **(1 mark)**
   b) Write the equation for the hydrolysis reaction that occurs. **(1 mark)**
   c) Calculate the value of the equilibrium constant for the hydrolysis in part b). **(1 mark)**

55. Sodium phosphate, Na_3PO_4, is commonly used as a cleaning agent. Write the net ionic equation for the hydrolysis reaction between Na_3PO_4 and water. **(2 marks)**

56. a) Write the formula of an amphiprotic anion that will act as an acid when added to water. **(1 mark)**
   b) Write a hydrolysis equation to represent the anion selected in part (a) above behaving as an acid. **(1 mark)**

57. **Consider the reaction between HCO_3^- and $HC_2O_4^-$**
   a) Write the equation for the predominant reaction. **(1mark)**
   b) Identify the Brönsted-Lowry acids in the reaction above. **(1mark)**
   c) Explain why products are favoured in the reaction above. **(1mark)**

58. a) Write two equations representing the acidic and basic hydrolysis of $NaHSO_{3\ (s)}$ **(2marks)**
   b) Use calculations to determine if the solution is acidic or basic. **(2 marks)**

59. The hydrogen carbonate ion can act as an acid or a base. Use calculations to determine if a solution containing 0.10 M hydrogen carbonate ion is acidic or basic. **(3marks)**

INDICATORS

60. **Consider the salt sodium oxalate, $Na_2C_2O_4$**
   a) Write the dissociation equation for sodium oxalate. **(1 mark)**
   b) A 1. 0 M solution of sodium oxalate turns pink when a few drops of the indicator phenolphthalein are added. Write a hydrolysis equation and explain why this salt causes the indicator to change colour. **(2 marks)**
   c) Calculate the equilibrium constant for the hydrolysis in b). **(1 mark)**

61. Neutral red, HInd , is an acid-base indicator.
   a) Write an equation to represent the equilibrium of this indicator in water. **(1 mark)**
   b) What colour would this indicator be in 0.1 M NaOH ? **(1 mark)**

62. A new indicator "B.C. red" is red when $\left[H_3O^+\right] > 6.3 \times 10^{-3}$ and blue when $\left[H_3O^+\right] < 2.5 \times 10^{-4}$. Calculate the pH value at the transition point for this indicator.

(2 marks)

63. A 25. 0mL sample of $Sr(OH)_2$ is titrated with a standardized solution of HCl to the equivalence point.
   a) Write the formula equation for the neutralization. **(1 mark)**
   b) Write the net ionic equation for the neutralization. **(1 mark)**
   c) What is meant by the term "standardized" solution? **(1 mark)**
   d) Define *equivalence point*. **(1 mark)**

64. A student titrated a 25.00 mL sample of a 0.20 M HX (unknown) acid with 0.20 M NaOH. The following data were collected.

Volume of base added (mL)	pH
0.00	2.72
10.00	4.57
24.90	7.14
24.99	8.14
25.00	8.88
25.01	9.60
26.00	11.59
35.00	12.52

   a) Describe the acid HX as strong or weak. Support your answer with two observations from the data table. **(3marks)**
   b) Select an appropriate indicator for this titration and identify the colour at the equivalence point. **(1mark)**

65. In a titration, 25.00 mL of 0.10 M HCl was neutralized by slowly adding 50.00 mL of 0.10 M NaOH.

a) Sketch the titration curve for the reaction and label:
– the initial pH of the HCl,
– the volume of NaOH required to neutralize the HCl, and
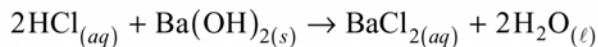– the pH at the equivalence point. **(4 marks)**

pH vs Volume of NaOH(mL)
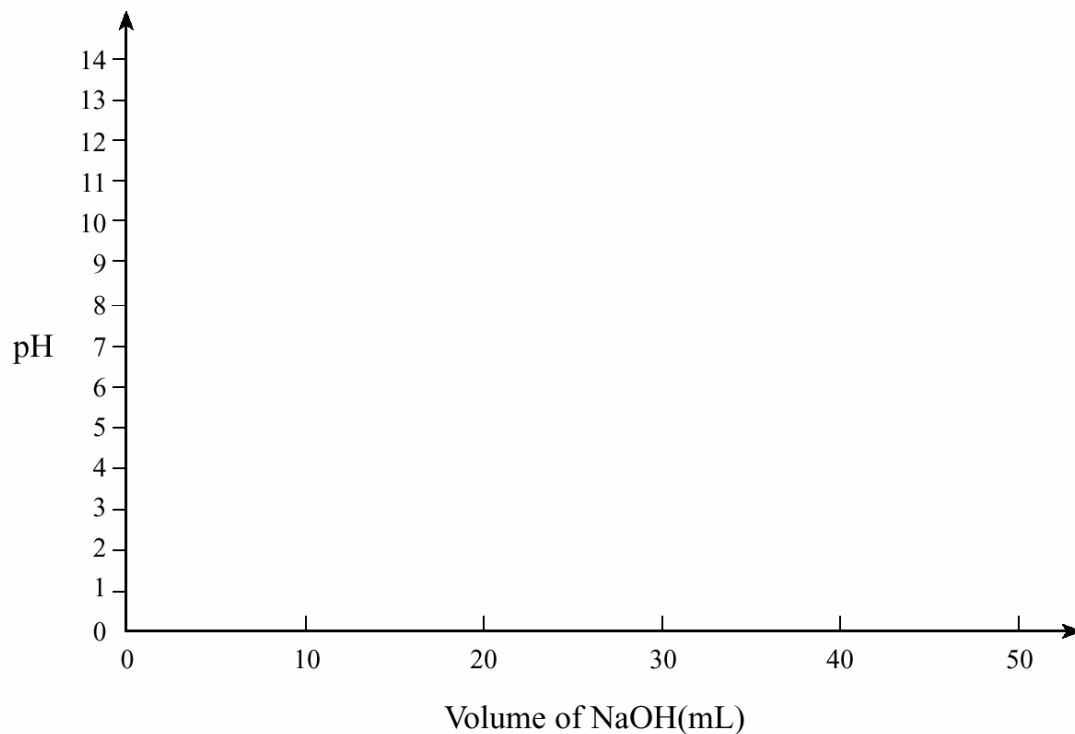
b) Select a suitable indicator for this titration. **(1 mark)**

66.

A titration was performed by adding $0.115\,M$ NaOH to a $25.00\,mL$ sample of H_2SO_4. Calculate the $[H_2SO_4]$ from the following data. **(3 marks)**

	Trial #1	Trial #2	Trial #3
Initial volume of NaOH(mL)	4.00	17.05	8.00
Final volume of NaOH(mL)	17.05	28.00	19.05

67.

Consider the following reaction:

$$2HCl_{(aq)} + Ba(OH)_{2(s)} \rightarrow BaCl_{2(aq)} + 2H_2O_{(\ell)}$$

When $3.16\,g$ samples of $Ba(OH)_2$ were titrated to the equivalence point with an HCl solution, the following data were recorded:

	Volume of HCl added
Trial 1	$37.80\,mL$
Trial 2	$35.49\,mL$
Trial 3	$35.51\,mL$

Using the data above, calculate the original $[HCl]$. **(4 marks)**

68.

A titration was performed by adding $0.175\,M$ $H_2C_2O_4$ to a $25.00\,mL$ sample of $NaOH$. The following data was collected:

	Trial #1	Trial #2	Trial #3
Final volume of $H_2C_2O_4$ (mL)	23.00	39.05	20.95
Initial volume of $H_2C_2O_4$ (mL)	4.85	23.00	5.00

a) Calculate the $[NaOH]$. **(3 marks)**

b) Explain why the pH at the equivalence point is greater than 7. **(1mark)**

69.

Calculate the mass of $NaOH$ which is required to neutralize 25.00 mL of 0.500 M H_2SO_4. **(3 marks)**

70.

Calculate the mass of solid $NaOH$ needed to neutralize 250.0 mL of 0.125 M $H_2C_2O_4$. **(3 marks)**

71. **A solution of NaOH is used to neutralize separate solutions of HF and HBr.**

a) Write the formula equation for the neutralization of HF. **(1 mark)**
b) Write the net ionic equation for the neutralization of HBr. **(1 mark)**
c) One of the neutralization reactions above produces a salt that undergoes hydrolysis. Identify the salt and write the net ionic equation for the hydrolysis reaction. **(2 marks)**

72.

Calculate the pH of a solution prepared by adding $15.0\,mL$ of $0.500\,M$ H_2SO_4 to $35.0\,mL$ of $0.750\,M$ $NaOH$. **(4 marks)**

73. Calculate the pH of a solution prepared by adding 40.0 mL of 0.440 M NaOH to 60.0 mL of 0.320 M HCl. **(3 marks)**

74. Calculate the pH of a 25.0 mL solution formed by mixing 0.0300 mol HNO_3 and 0.0280 mol NaOH. **(2 marks)**

75. Calculate the pH of the solution formed by mixing 20.0 mL of 0.500 M HCl with 30.0 mL 0.300 M NaOH. **(4 marks)**

76. Calculate the pH of a solution prepared by adding 60.0 mL of 0.150 M HCl to 140.0 mL of 0.100 M KOH. **(4 marks)**

BUFFERS

77. A 2.0 L solution contains one mole of the weak acid, H_3PO_4, in equilibrium with one mole of the salt, NaH_2PO_4.

   a) Write an equation that represents this equilibrium. **(2marks)**
   b) Explain why the pH of this solution does not change significantly when 10.0 mL of 1.0 M KOH is added. **(1mark)**

78. a) A student prepares a buffer by dissolving solid sodium acetate, $NaCHCOO_3$, in a solution of acetic acid, CH_3COOH. Write the **net** ionic equation for the buffer system. **(1 mark)**
   b) What happens to the concentrations of CH_3COOH and CH_3COO^- when a small amount of acid is added to this system? **(1 mark)** Explain the reason. **(1 mark)**
   c) What happens to the pH of the buffer when a small amount of acid is added? **(1 mark)**

ACID RAIN

79. Explain why 'normal' rain water is slightly acidic. Use an equation to support your answer. **(2marks)**

1.
Test: Use an indicator such as litmus.
Result: Turns red.

Test: Add magnesium metal.
Result: H_2 gas is given off.

← any test and result for 1 mark each

Test: pH meter.
Result: pH < 7

2. a) A weak Brönsted-Lowry base is a proton acceptor that reacts with water less than 100%. ← **2 marks**
b) An example of a compound that acts as a weak base is NH_3. ¬**1 mark**

3. A strong Brönsted-Lowry acid is a species that donates a proton **(1 mark)** 100% to a receptive base **(1 mark)**.

4. a) a pair or chemical species that differ only by one H^+ (or proton)
b) H_2CO_3/HCO_3^- (this is just one example…..)

5. a)

$$HCN_{(aq)} + NH_{3(aq)} \rightleftarrows NH_{4(aq)}^+ + CN_{(aq)}^-$$
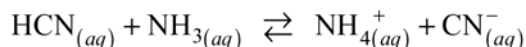
b)

HCN and CN^- or NH_4^+ and NH_3

6.
Unknown is an **acid** because it reacts with magnesium.

or

bromthymol blue is yellow ∴ pH < 6.0

← **1 mark**

Unknown is a **weak** acid because it has poor electrical conductivity.

or

indicators are both yellow which indicates a pH between 4.4 and 6.0

← **1 mark**

7.
The greater the conductivity, the higher the concentration of ions. Since the weaker acid conducts better, it must contain a higher concentration of ions.
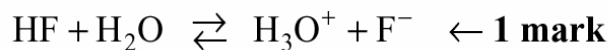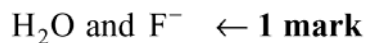
← **2 marks**

8. a)

$$HSO_3^- + HC_2O_4^- \rightleftarrows C_2O_4^{2-} + H_2SO_3$$
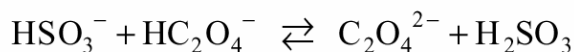
b) H_2SO_3 is a stronger acid than $HC_2O_4^-$ (1 mark)

9. a)

$$HF + H_2O \rightleftarrows H_3O^+ + F^- \quad \leftarrow \textbf{1 mark}$$

b)

$$H_2O \text{ and } F^- \quad \leftarrow \textbf{1 mark}$$

10.

$$H_2C_6H_6O_6 \rightleftarrows H^+ + HC_6H_6O_6^- \qquad \leftarrow \textbf{2 marks}$$

or

$$H_2C_6H_6O_6 + H_2O \rightleftarrows H_3O^+ + HC_6H_6O_6^- \qquad \leftarrow \textbf{2 marks}$$

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11. a)

$$HNO_2 + \underline{HPO_4{}^{2-}} \rightleftarrows \underline{NO_2{}^-} + H_2PO_4{}^- \quad \leftarrow \textbf{1 mark}$$

b)

$$NO_2{}^- \qquad \leftarrow \textbf{1 mark}$$

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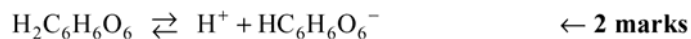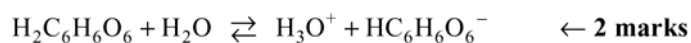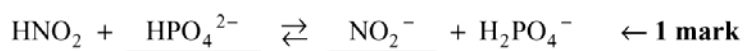
12. (a) the stronger acid is H_2Te (b) the weaker base is HTe^-

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13.

$$HF + SO_3{}^{2-} \rightleftarrows HSO_3{}^- + F^-$$
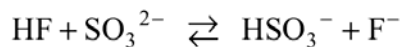
14.

A strong acid such as HCl donates all of its protons to water forming H_3O^+. Hence, the strongest acid is the hydronium ion. $\Big\} \leftarrow \textbf{2 marks}$

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15. a) The ability to act as both a proton donor or proton acceptor. **1 mark**
b) HCO_3^- (for example) **1 mark**

16.

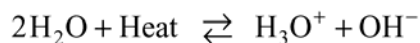**For Example:**

The ability to act as either an acid or a base. $\leftarrow \textbf{1 mark}$
For example $HPO_4{}^{2-}$. $\leftarrow \textbf{1 mark}$

17. a)

$$2H_2O + Heat \rightleftharpoons H_3O^+ + OH^-$$

b)

$$K_w = \left[H_3O^+\right]\left[OH^-\right] = 9.6 \times 10^{-14}$$

$$\left[H_3O^+\right] = \left[OH^-\right] = \sqrt{9.6 \times 10^{-14}}$$

$$\left[H_3O^+\right] = 3.10 \times 10^{-7}$$

$$pH = 6.51$$

$\leftarrow$ **2 marks**

18. a) Since $K_w = [OH^-][H_3O^+]$ is endothermic, more ions are produced according to Le Chatelier's principle. Therefore, the value of K_w should increase.
b) The pH will decrease as more H_3O^+ ions are formed
c) The water will remain neutral as OH^- ions increase in concentration to the same extent as H_3O^+ ions.

19. a)

	OCl^-	$+ H_2O \rightleftharpoons$	$HOCl$	$+$	OH^-
[I]	1.00		0		0
[C]	-5.75×10^{-4}		$+5.75 \times 10^{-4}$		$+5.75 \times 10^{-4}$
[E]	1.00		5.75×10^{-4}		5.75×10^{-4}

$\leftarrow 1\frac{1}{2}$ **marks**

$$K_b = \frac{\left[HOCl\right]\left[OH^-\right]}{\left[OCl^-\right]}$$

$$= \frac{\left(5.75 \times 10^{-4}\right)^2}{1.00}$$

$$= 3.31 \times 10^{-7}$$

$\leftarrow 1\frac{1}{2}$ **marks**

b)

$$K_a = \frac{K_w}{K_b}$$

$$= \frac{1.0 \times 10^{-14}}{3.31 \times 10^{-7}}$$

$$= 3.0 \times 10^{-8}$$

$\leftarrow$ **1 mark**

20.

$$\text{After dilution } [KOH] = 0.040\,M \times \frac{40.0\,mL}{100.0\,mL}$$

$\leftarrow \frac{1}{2}$ **mark**

$$\left[OH^-\right] = 0.016\,M$$

$\leftarrow \frac{1}{2}$ **mark**

$$\left[H_3O^+\right] = \frac{1.0 \times 10^{-14}}{0.016} = 6.2 \times 10^{-13}\,M$$

$\leftarrow$ **1 mark**

21.
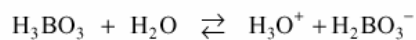
$$H_3BO_3 + H_2O \rightleftharpoons H_3O^+ + H_2BO_3^-$$

[I]	0.400	0	0
[C]	$-x$	$+x$	$+x$
[E]	$0.400 - x \approx 0.400$	x	x

$\leftarrow 1\frac{1}{2}$ marks

$$K_a = \frac{\left[H_3O^+\right]\left[H_2BO_3^-\right]}{\left[H_3BO_3\right]}$$

$$7.3 \times 10^{-10} = \frac{x^2}{0.400}$$

$$x = 1.7 \times 10^{-5}$$

$$\left[H_3O^+\right] = 1.7 \times 10^{-5}\,M$$

$\leftarrow 1\frac{1}{2}$ marks

$$pH = -\log\left(1.7 \times 10^{-5}\right) = 4.77 \qquad \leftarrow 1\text{ mark}$$

22.

Solution A: $\left[H_3O^+\right] = \dfrac{1.00 \times 10^{-14}}{5.0 \times 10^{-11}\,M} = 2.0 \times 10^{-4}$

Solution B: $\left[H_3O^+\right] = 0.20\,M = 2.0 \times 10^{-1}$

Solution C: $\qquad pH = 14.00 - 11.30 = 2.70$

$\qquad\qquad \left[H_3O^+\right] = -\text{antilog }2.70 = 2.0 \times 10^{-3}$

Solution D: $\left[H_3O^+\right] = -\text{antilog }1.20 = 6.3 \times 10^{-2}$

$\leftarrow 3$ marks

Decreasing acidity: $B > D > C > A$ $\qquad\qquad \leftarrow 1$ mark

23.

$$[HCl] = \frac{0.15\,M \times 25.00\,mL}{100.0\,mL}$$

$$\left[H_3O^+\right] = 0.0375\,M \qquad\qquad \leftarrow 1\text{ mark}$$

$$pH = -\log\left[H_3O^+\right]$$

$$= 1.43$$

$\leftarrow 1$ mark

$\left(\text{Subtract } \frac{1}{2} \text{ mark for incorrect significant figures.}\right)$

24.

$$\left[OH^-\right] = 0.050 \, mol \, / \, 0.500 \, L = 0.100 \, M \qquad \leftarrow \tfrac{1}{2} \textbf{ mark}$$

$$K_w = \left[H_3O^+\right]\left[OH^-\right] \qquad \leftarrow \tfrac{1}{2} \textbf{ mark}$$

$$(0.10M)\left[H_3O^+\right] = 1.0 \times 10^{-14}$$

$$\left.\begin{array}{c} \\ \left[H_3O^+\right] = 1.0 \times 10^{-13} \, M \end{array}\right\} \leftarrow \tfrac{1}{2} \textbf{ mark}$$

$$pH = 13.00 \qquad \leftarrow \tfrac{1}{2} \textbf{ mark}$$
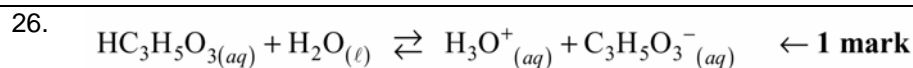
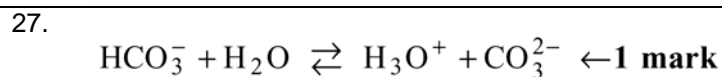**NOTE:** Deduct ½ point for incorrect significant figures.

25.

$$4.20 = -\log\left[H_3O^+\right] \qquad 6.3 \times 10^{-5} \, M = \left[H_3O^+\right] \qquad \leftarrow \textbf{1 mark}$$

$$1.0 \times 10^{-14} = \left[H_3O^+\right]\left[OH^-\right], \quad \left[OH^-\right] = 1.6 \times 10^{-10} \, M \quad \leftarrow \textbf{1 mark}$$

$(-\tfrac{1}{2} \textbf{ mark}$ for incorrect sig. figs.$)$

26.

$$HC_3H_5O_{3(aq)} + H_2O_{(\ell)} \rightleftarrows H_3O^+_{(aq)} + C_3H_5O_3^-_{(aq)} \qquad \leftarrow \textbf{1 mark}$$

$$K_a = \dfrac{\left[H_3O^+\right]\left[C_3H_5O_3^-\right]}{\left[HC_3H_5O_3\right]} \qquad \leftarrow \textbf{1 mark}$$

27.

$$HCO_3^- + H_2O \rightleftarrows H_3O^+ + CO_3^{2-} \quad \leftarrow \textbf{1 mark}$$

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28. a)

$$HC_6H_5O_7^{2-} + HC_2O_4^- \rightleftarrows C_2O_4^{2-} + H_2C_6H_5O_7^-$$
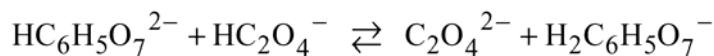
b) Products are favoured because reactants contain the stronger acid. **1 mark**

29.

For propanoic acid:
$$\left.\begin{array}{l} K_a = \dfrac{K_w}{K_b} \\ \\ = \dfrac{1.0 \times 10^{-14}}{7.5 \times 10^{-10}} \\ \\ = 1.3 \times 10^{-5} \end{array}\right\} \leftarrow \textbf{1 mark}$$

$$\left.\begin{array}{l} 9.8 \times 10^{-5} > 1.3 \times 10^{-5} \\ \\ \text{Therefore, barbituric acid is a stronger acid than propanoic acid.} \end{array}\right\} \leftarrow \textbf{1 mark}$$

30.

$$\begin{array}{c|ccc} & H_3BO_3 & + \ H_2O \ \rightleftharpoons & H_3O^+ & + \ H_2BO_3^- \\ \hline [I] & 0.50 & & 0 & 0 \\ [C] & -x & & +x & +x \\ \hline [E] & 0.50 - \cancel{x} & & x & x \end{array}$$ $\left.\rule{0pt}{60pt}\right\} \leftarrow 1\frac{1}{2}$ marks

neglect since $0.50\,M \gg x$

$$K_a = \frac{\left[H_3O^+\right]\left[H_2BO_3^-\right]}{\left[H_3BO_3\right]}$$

$$7.3 \times 10^{-10} = \frac{(x)(x)}{0.50 - \cancel{x}}$$

$$= \frac{(x)(x)}{0.50}$$

$$x = \left[H_3O^+\right] = 1.91 \times 10^{-5}\,M$$

$\left.\rule{0pt}{80pt}\right\} \leftarrow 1\frac{1}{2}$ marks

$$pH = -\log 1.91 \times 10^{-5} = 4.72$$ $\left.\rule{0pt}{12pt}\right\} \leftarrow 1$ mark

NOTE: $\left(\frac{1}{2}\,\text{mark}\right)$ is deducted for incorrect significant figures.

31.

$$\begin{array}{c|ccc} & H_2S & + \ H_2O \ \rightleftharpoons & H_3O^+ & + \ HS^- \\ \hline [I] & 1.5 & & 0 & 0 \\ [C] & -x & & +x & +x \\ \hline [E] & 1.5 - x & & x & x \end{array}$$ $\left.\rule{0pt}{60pt}\right\} \leftarrow 1\frac{1}{2}$ marks

$$K_a = \frac{\left[H_3O^+\right]\left[HS^-\right]}{\left[H_2S\right]}$$

$$= \frac{(x)(x)}{1.5 - x}$$

$$= \frac{(x)(x)}{1.5} \ (\text{assume } x \text{ is negligible})$$

$$= 9.1 \times 10^{-8}$$

$$x = \left[H_3O^+\right] = 3.69 \times 10^{-4}\,M$$

$\left.\rule{0pt}{80pt}\right\} \leftarrow 1\frac{1}{2}$ marks

$$pH = -\log 3.69 \times 10^{-4}\,M = 3.43$$ $\leftarrow 1$ mark

NOTE: $\left(\frac{1}{2}\,\text{mark}\right)$ is deducted for incorrect significant figures.

32.

	NH_3	$+$	H_2O	$\rightleftarrows$	$NH_4{}^+$	$+$	OH^-
[I]	0.10				0		0
[C]	$-x$				$+x$		$+x$
[E]	$0.10-x$				x		x

$\leftarrow 1\frac{1}{2}$ mark

$$K_b = \frac{1.0 \times 10^{-14}}{5.6 \times 10^{-10}} = 1.8 \times 10^{-5}$$

$\leftarrow 1$ mark

$$K_b = \frac{\left[NH_4{}^+\right]\left[OH^-\right]}{\left[NH_3\right]}$$

$$= \frac{(x)(x)}{(0.10-x)}$$

assume $x \, \acute{} \, 0.10$

$$1.8 \times 10^{-5} = \frac{x^2}{0.10}$$

$$x = \left[OH^-\right] = 1.3 \times 10^{-3} \, M$$

$\leftarrow 1\frac{1}{2}$ marks

33.
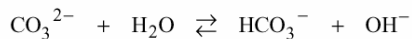
	$CO_3{}^{2-}$	$+$	H_2O	$\rightleftarrows$	$HCO_3{}^-$	$+$	OH^-
$[I]$	0.100				0		0
$[C]$	$-x$				$+x$		$+x$
$[E]$	$0.100-x$				x		x
	≈ 0.100						

$\leftarrow 1\frac{1}{2}$ marks

$$K_b = \frac{K_w}{K_a} = \frac{1.0 \times 10^{-14}}{5.6 \times 10^{-11}} = 1.8 \times 10^{-4}$$

$\leftarrow 1$ mark

$$K_b = \frac{\left[HCO_3{}^-\right]\left[OH^-\right]}{\left[CO_3{}^{2-}\right]}$$

$$1.8 \times 10^{-4} = \frac{(x)(x)}{(0.100)}$$

$$\left[OH^-\right] = x = 4.2 \times 10^{-3}$$

$\leftarrow 1\frac{1}{2}$ marks

NOTE: $\left(\frac{1}{2} \text{ mark}\right)$ is deducted for incorrect significant figures.

34.

$$HC_6H_4NO_2 + H_2O \ \rightleftarrows \ H_3O^+ + C_6H_4NO_2^-$$

$[\mathbf{I}]$	0.010	0	0
$[\mathbf{C}]$	$-x$	$+x$	$+x$
$[\mathbf{E}]$	$0.010 - x$	x	x
	≈ 0.010		

$\leftarrow 1\frac{1}{2}$ **marks**

$$K_a = \frac{\left[H_3O^+\right]\left[C_6H_4NO_2^-\right]}{\left[HC_6H_4NO_2\right]}$$

$$1.4\times10^{-5} = \frac{(x)(x)}{(0.010)}$$

$$x = \left[H_3O^+\right] = 3.74\times10^{-4}\,M$$

$\leftarrow 1\frac{1}{2}$ **marks**

$$pH = -\log\left(3.74\times10^{-4}\right) = 3.43 \qquad \leftarrow \textbf{1 mark}$$

$\left(\text{Deduct } \frac{1}{2} \textbf{ mark} \text{ for incorrect significant figures.}\right)$

35.

$$C_6H_5COOH_{(aq)} + H_2O \ \rightleftarrows \ H_3O^+{}_{(aq)} + C_6H_5COO^-{}_{(aq)}$$

$[\mathbf{I}]$	0.550	0	0
$[\mathbf{C}]$	$-x$	$+x$	$+x$
$[\mathbf{E}]$	$0.550 - x$	x	x

$\leftarrow 1\frac{1}{2}$ **marks**
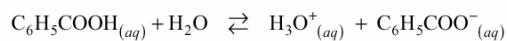
$$K_a = \frac{\left[H_3O^+\right]\left[C_6H_5COO^-\right]}{\left[C_6H_5COOH\right]}$$

$$\frac{x^2}{0.550 - x} = 6.5\times10^{-5}$$

assume $x \ll 0.550$

$$\frac{x^2}{0.550} = 6.5\times10^{-5}$$

$$x = 0.0060$$

$$\left[H_3O^+\right] = 6.0\times10^{-3}\,M$$

$\leftarrow 1\frac{1}{2}$ **marks**

Note: $\left(\frac{1}{2} \textbf{ mark deduction for incorrect significant figures.}\right)$

36.

$$HNO_2 + H_2O \rightleftharpoons H_3O^+ + NO_2^-$$

	HNO_2	H_3O^+	NO_2^-
[I]	2.0	0	0
[C]	$-x$	$+x$	$+x$
[E]	$2.0-x$	x	x
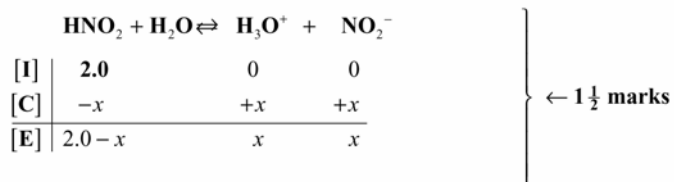
$\leftarrow 1\frac{1}{2}$ marks

$\approx 2.0 \leftarrow \frac{1}{2}$ **mark** assumption

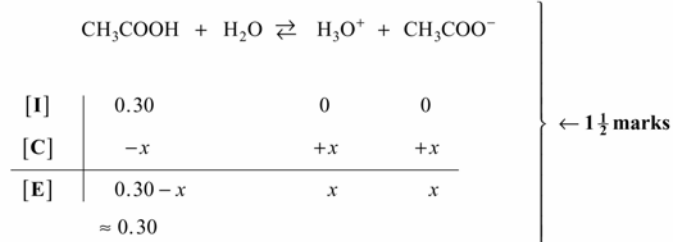$$K_a\ HNO_2 = 4.6\times10^{-4} = \frac{\left[H_3O^+\right]\left[NO_2^-\right]}{\left[HNO_2\right]}$$

$$4.6\times10^{-4} = \frac{x^2}{2.0}$$

$$3.0\times10^{-2} = x$$

$$\left[H_3O^+\right] = 3.0\times10^{-2}\ M$$

$$pH = -\log 3.0\times10^{-2} = 1.52$$

$\leftarrow$ **2 marks**

37.

$$CH_3COOH + H_2O \rightleftharpoons H_3O^+ + CH_3COO^-$$

	CH_3COOH	H_3O^+	CH_3COO^-
[I]	0.30	0	0
[C]	$-x$	$+x$	$+x$
[E]	$0.30-x$	x	x
	≈ 0.30		

$\leftarrow 1\frac{1}{2}$ marks

$$K_a = \frac{\left[H_3O^+\right]\left[CH_3COO^-\right]}{\left[CH_3COOH\right]} = 1.8\times10^{-5}$$

$$\frac{(x)(x)}{0.30} = 1.8\times10^{-5}$$

$$x^2 = 5.4\times10^{-6}$$

$$x = 2.32\times10^{-3}$$

$$\left[H_3O^+\right] = 2.32\times10^{-3}$$

$$pH = 2.63$$

$\leftarrow 1\frac{1}{2}$ **marks**

38.

$$CH_3COOH + H_2O \rightleftarrows H_3O^+ + CH_3COO^-$$

	CH_3COOH	H_3O^+	CH_3COO^-
$[\mathbf{I}]$	0.20	0	0
$[\mathbf{C}]$	$-x$	$+x$	$+x$
$[\mathbf{E}]$	$0.20 - x \approx 0.20$	x	x

$\leftarrow 1\frac{1}{2}$ **marks**

$$K_a = \frac{\left[H_3O^+\right]\left[CH_3COO^-\right]}{\left[CH_3COOH\right]} = \frac{(x)(x)}{0.20} = 1.8 \times 10^{-5}$$

$$x = 1.9 \times 10^{-3}$$

$$\left[H_3O^+\right] = 1.9 \times 10^{-3}\ M$$

$$pH = 2.72$$

$\leftarrow 1\frac{1}{2}$ **marks**

39.

$$H_2S \rightleftarrows H^+ + HS^-$$

	H_2S	H^+	HS^-
I	0.50	0	0
Δ C	$-x$	x	x
E	$0.50 - x$	x	x

$\leftarrow 1\frac{1}{2}$ **marks**

$(x$ is small, therefore $0.50 - x \approx 0.50)$ $\leftarrow \frac{1}{2}$ **mark**

$$K_a = \frac{\left[H^+\right]\left[HS^-\right]}{\left[H_2S\right]}$$ $\leftarrow \frac{1}{2}$ **mark** for expression

$$9.1 \times 10^{-8} = \frac{x^2}{0.50}$$ $\leftarrow \frac{1}{2}$ **mark** for substitution

$$x = 2.13 \times 10^{-4}\ M = \left[H^+\right]$$ $\leftarrow \frac{1}{2}$ **mark** for solving $\left[H^+\right]$

$$pH = -\log\left[H^+\right] = 3.67$$ $\leftarrow \frac{1}{2}$ **mark** for calculating pH

40. The pH for the resulting solution is 2.67
(note: complete solution is not given, full work must   be displayed for full marks)

41.

	HCN	$\rightleftharpoons$	H^+	+	CN^-	
I	0.10		0		0	
C	$-x$		$+x$		$+x$	$\leftarrow 1\frac{1}{2}$ marks
E	$0.10 - x$		x		x	
	≈ 10					
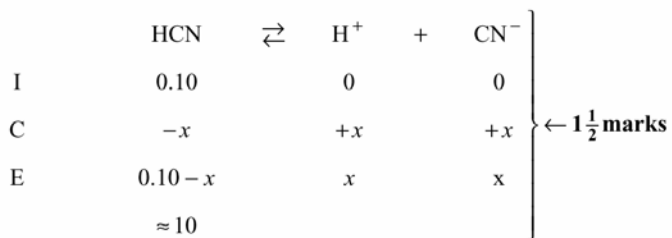
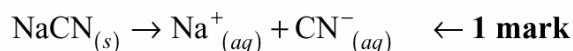$$K_a = \frac{\left[H^+\right]\left[CN^-\right]}{[HCN]}$$

$$4.8 \times 10^{-10} = \frac{(x)(x)}{(0.10)}$$

$$\sqrt{\left(4.8 \times 10^{-10}\right)\left(0.10\right)} = \sqrt{(x)^2} \quad \leftarrow 1\frac{1}{2} \text{ marks}$$

$$\left[H^+\right] = 6.9 \times 10^{-6} \quad \leftarrow \frac{1}{2} \text{ mark}$$

$$pH = -\log\left(6.9 \times 10^{-6}\right) = 5.16 \quad \leftarrow \frac{1}{2} \text{ mark}$$

---

42. a)

$$NaCN_{(s)} \rightarrow Na^+{}_{(aq)} + CN^-{}_{(aq)} \quad \leftarrow \textbf{1 mark}$$

b)

$$CN^-{}_{(aq)} + H_2O_{(\ell)} \rightleftharpoons HCN_{(aq)} + OH^-{}_{(aq)} \quad \leftarrow \textbf{1 mark}$$

c)

$$K_b = \frac{\left[HCN\right]\left[OH^-\right]}{\left[CN^-\right]}$$

$$K_b = \frac{K_w}{K_a}$$

$$= \frac{1.0 \times 10^{-14}}{4.9 \times 10^{-10}}$$

$$= 2.0 \times 10^{-5}$$

$\leftarrow \textbf{2 marks}$

NOTE: $\left(\frac{1}{2} \text{ mark}\right)$ **is deducted for incorrect significant figures.**

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43. a)

$$CO_3{}^{2-}{}_{(aq)} + H_2O_{(\ell)} \rightleftharpoons HCO_3{}^-{}_{(aq)} + OH^-{}_{(aq)} \quad \leftarrow \textbf{1 mark}$$

b)

$$K_b = \frac{K_w}{K_a} = \frac{1.0 \times 10^{-14}}{5.6 \times 10^{-11}} = 1.8 \times 10^{-4} \quad \leftarrow \textbf{1 mark}$$

44.

$$H_2O + HCO_3^- \rightarrow H_3O^+ + CO_3^{2-} \qquad \leftarrow \textbf{1 mark}$$
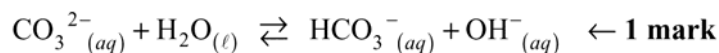
$$H_2O + HCO_3^- \rightarrow H_2CO_3 + OH^- \qquad \leftarrow \textbf{1 mark}$$
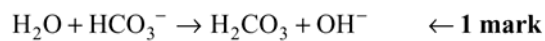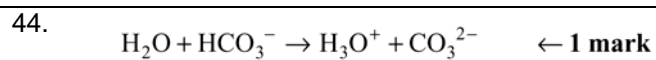
b)

$$K_b = \frac{K_w}{K_a} = \frac{1.0 \times 10^{-14}}{4.3 \times 10^{-7}} = 2.3 \times 10^{-8} \qquad \leftarrow \textbf{1 mark}$$
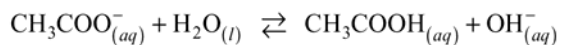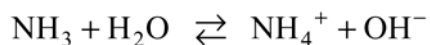
45. a)

$$CH_3COO_{(aq)}^- + H_2O_{(l)} \rightleftarrows CH_3COOH_{(aq)} + OH_{(aq)}^-$$

b)

$$K_b = \frac{K_w}{K_a}$$

$$= \frac{1.0 \times 10^{-14}}{1.8 \times 10^{-5}}$$

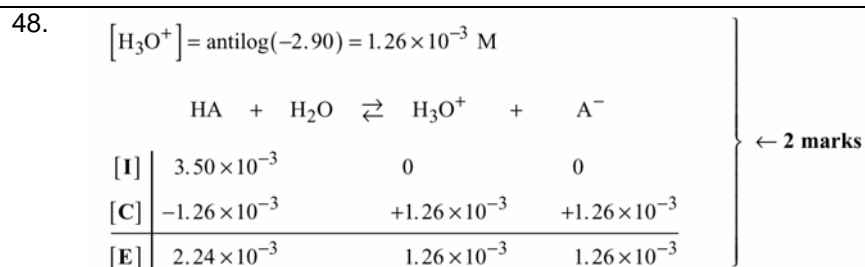$$= 5.6 \times 10^{-10}$$

46. a)

$$NH_3 + H_2O \rightleftarrows NH_4^+ + OH^-$$

b)

$$K_b = \frac{1.0 \times 10^{-14}}{5.7 \times 10^{-10}} = 1.8 \times 10^{-5}$$

47. a) K_b OCl$^-$ = 3.31 x 10^{-7} (b) K_a HOCl = 3.02 x 10^{-8}
*full solution not shown, ensure full work is displayed for full credit..

48.

$$\left[H_3O^+\right] = \text{antilog}(-2.90) = 1.26 \times 10^{-3} \text{ M}$$

	HA	+ H₂O ⇌	H_3O^+	+	A^-
[I]	3.50×10^{-3}		0		0
[C]	-1.26×10^{-3}		$+1.26 \times 10^{-3}$		$+1.26 \times 10^{-3}$
[E]	2.24×10^{-3}		1.26×10^{-3}		1.26×10^{-3}

← **2 marks**

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

$$= \frac{\left(1.26 \times 10^{-3}\right)\left(1.26 \times 10^{-3}\right)}{\left(2.24 \times 10^{-3}\right)}$$

$$= 7.1 \times 10^{-4}$$

← **1½ marks**

The unknown acid is citric acid.   ← **½ mark**
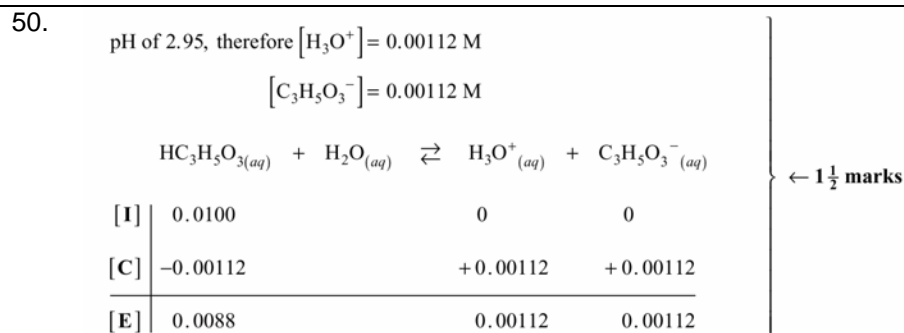

49.

$$\left[H_3O^+\right] = \text{antilog}(-2.95) = 1.122 \times 10^{-3} \text{ M}$$ ← **1 mark**

$$C_2H_5OCOOH_{(aq)} + H_2O_{(\ell)} \rightleftharpoons C_2H_5OCOO^-_{(aq)} + H_3O^+_{(aq)}$$

	C₂H₅OCOOH		C₂H₅OCOO⁻	H₃O⁺
[I]	0.0100		0	0
[C]	-1.122×10^{-3}		$+1.122 \times 10^{-3}$	$+1.122 \times 10^{-3}$
[E]	8.88×10^{-3}		1.122×10^{-3}	1.122×10^{-3}
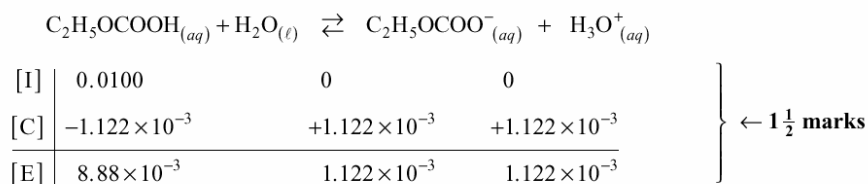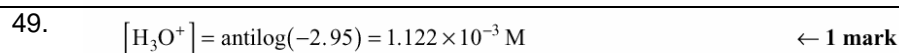
← **1½ marks**

$$K_a = \frac{\left[C_2H_5OCOO^-\right]\left[H_3O^+\right]}{\left[C_2H_5OCOOH\right]}$$

$$= \frac{\left(1.122 \times 10^{-3}\right)\left(1.122 \times 10^{-3}\right)}{\left(8.88 \times 10^{-3}\right)}$$

$$= 1.4 \times 10^{-4}$$

← **1½ marks**

50.

pH of 2.95, therefore $\left[H_3O^+\right] = 0.00112$ M

$$\left[C_3H_5O_3^-\right] = 0.00112 \text{ M}$$

	HC₃H₅O₃	+ H₂O ⇌	H_3O^+	+	$C_3H_5O_3^-$
[I]	0.0100		0		0
[C]	-0.00112		$+0.00112$		$+0.00112$
[E]	0.0088		0.00112		0.00112

← **1½ marks**

$$K_a = \frac{\left[H_3O^+\right]\left[C_3H_5O_3^-\right]}{\left[HC_3H_5O_3\right]}$$

$$= \frac{\left(1.12 \times 10^{-3}\right)^2}{0.0088}$$

$$= 1.4 \times 10^{-4}$$

← **1½ marks**

51.

For Example:

$$pOH = 2.60$$
$$[OH^-] = 2.51 \times 10^{-3}$$

$\leftarrow$ **1 mark**

	CH_3NH_2	$+$	H_2O	$\rightleftarrows$	$CH_3NH_3^+$	$+$	OH^-
[I]	0.0200				0		0
[C]	-2.51×10^{-3}				$+2.51 \times 10^{-3}$		$+2.51 \times 10^{-3}$
[E]	0.01749				2.51×10^{-3}		2.51×10^{-3}

$\leftarrow 1\frac{1}{2}$ **marks**

$$K_b = \frac{[CH_3NH_3^+][OH^-]}{[CH_3NH_2]}$$

$$= \frac{(2.51 \times 10^{-3})(2.51 \times 10^{-3})}{0.01749}$$

$$= 3.6 \times 10^{-4}$$

$\leftarrow 1\frac{1}{2}$ **marks**

$\left(\text{Deduct } \frac{1}{2} \textbf{ mark } \text{for incorrect significant figures.}\right)$

52.

$$[H_3O^+] = \text{antilog}(-2.24) = 5.75 \times 10^{-3} \text{ M}$$

$\leftarrow$ **1 mark**
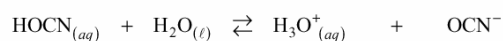
	$HOCN_{(aq)}$	$+$	$H_2O_{(\ell)}$	$\rightleftarrows$	$H_3O^+_{(aq)}$	$+$	OCN^-
[I]	0.100				0		0
[C]	-5.75×10^{-3}				$+5.75 \times 10^{-3}$		$+5.75 \times 10^{-3}$
[E]	0.0942				5.75×10^{-3}		5.75×10^{-3}

$\leftarrow 1\frac{1}{2}$ **marks**

$$K_a = \frac{[H_3O^+][OCN^-]}{[HOCN]}$$

$$= \frac{(5.75 \times 10^{-3})^2}{(0.0942)}$$

$$= 3.5 \times 10^{-4}$$

$\leftarrow 1\frac{1}{2}$ **marks**

Note to markers: $\frac{1}{2}$ **mark deduction for incorrect significant figures.**

53.

$\left[H^+\right] = 0.0036 \text{ mol/L}$ $\leftarrow \frac{1}{2}$ **mark**

The acid is monoprotic and can be represented by HX.

	HX	$\rightleftarrows$	H^+	$+$	X^-
[I]	0.200 M		0		0
[C]	-0.0036		$+0.0036$		$+0.0036$
[E]	0.1964		0.0036		0.0036

$\leftarrow 1\frac{1}{2}$ **marks**

$$K_a = \frac{\left[H^+\right]\left[X^-\right]}{\left[HX\right]}$$

$$= \frac{(0.0036)^2}{0.1964}$$

$$= 6.6 \times 10^{-5}$$

$\leftarrow 1\frac{1}{2}$ **marks**

The acid must be benzoic acid because the K_a values match. $\leftarrow \frac{1}{2}$ **mark**

---

54. a)

$$NaIO_{3(s)} \rightarrow Na^+_{(aq)} + IO_3^-_{(aq)} \qquad \leftarrow \textbf{1 mark}$$

b)

$$IO_3^-_{(aq)} + H_2O_{(l)} \rightleftarrows HIO_{3(aq)} + OH^-_{(aq)} \qquad \leftarrow \textbf{1 mark}$$

c)
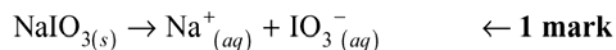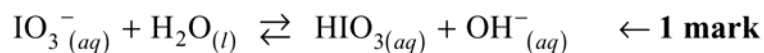
$$K_b = \frac{K_w}{K_a}$$

$$= \frac{1.0 \times 10^{-14}}{1.7 \times 10^{-1}}$$

$$= 5.9 \times 10^{-14}$$

$\leftarrow \textbf{1 mark}$

55.

$$PO_4^{3-}_{(aq)} + H_2O_{(\ell)} \rightleftarrows HPO_4^{2-}_{(aq)} + OH^-_{(aq)}$$

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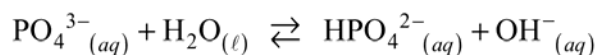
56. a) $H_2PO_4^-$ or HSO_3^- (for example)

b)

$$H_2PO_4^- + H_2O \rightleftarrows H_3O^+ + HPO_4^{2-}$$

or

$$HSO_3^- + H_2O \rightleftarrows H_3O^+ + SO_3^{2-}$$

57.

a)

$$HC_2O_4^- + HCO_3^- \rightleftharpoons C_2O_4^{2-} + H_2CO_3 \quad \leftarrow \textbf{1 mark}$$

b)

$$HC_2O_4^- \text{ and } H_2CO_3 \quad \leftarrow \textbf{1 mark}$$

c)

$HC_2O_4^-$ is a stronger acid than H_2CO_3 $\quad \leftarrow \textbf{1 mark}$

58.

a)

Acidic: $HSO_3^- + H_2O \rightleftharpoons H_3O^+ + SO_3^{2-} \quad \leftarrow \textbf{1 mark}$

Basic: $HSO_3^- + H_2O \rightleftharpoons H_2SO_3 + OH^- \quad \leftarrow \textbf{1 mark}$

b)
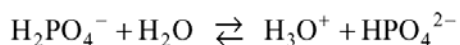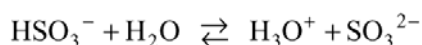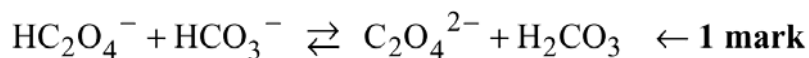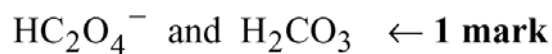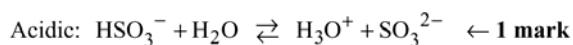
$$K_a = 1.0 \times 10^{-7} \qquad \leftarrow \tfrac{1}{2} \textbf{ mark}$$

$$\left. \begin{array}{l} K_b = \dfrac{1.0 \times 10^{-14}}{1.5 \times 10^{-2}} \\[2mm] = 6.7 \times 10^{-13} \end{array} \right\} \leftarrow \textbf{1 mark}$$
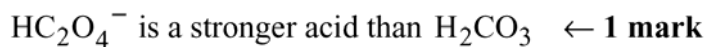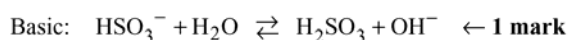
Since $K_a > K_b$, solution is acidic $\qquad \leftarrow \tfrac{1}{2} \textbf{ mark}$

59.

$$\left. \begin{array}{l} K_a \text{ for } HCO_3^- = 5.6 \times 10^{-11} \\[2mm] K_b \text{ for } HCO_3^- = \dfrac{K_w}{K_a \text{ of } H_2CO_3} = \dfrac{1.0 \times 10^{-14}}{4.3 \times 10^{-7}} \\[2mm] = 2.3 \times 10^{-8} \end{array} \right\} \leftarrow \textbf{2 marks}$$

Since $K_b > K_a$ for HCO_3^-, the solution is basic. $\quad \leftarrow \textbf{1 mark}$

60. a)

$$Na_2C_2O_4 \rightarrow 2Na^+ + C_2O_4^{2-}$$

b)

$$C_2O_4^{2-}{}_{(aq)} + H_2O_{(l)} \rightleftarrows HC_2O_4^-{}_{(aq)} + OH^-{}_{(aq)} \qquad \leftarrow \textbf{1 mark}$$
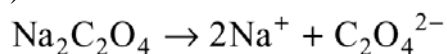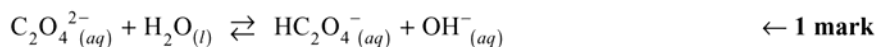
The formation of the OH^- caused the indicator to change colour. $\leftarrow$ **1 mark**

c)

$$K_b = \frac{K_w}{K_a}$$

$$= \frac{1.0 \times 10^{-14}}{6.4 \times 10^{-5}}$$

$$= 1.6 \times 10^{-10}$$

$\Big\}\leftarrow$ **1 mark**

61. a)

$$HInd + H_2O \rightleftarrows H_3O^+ + Ind^-$$
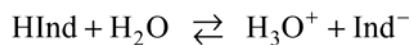
b) The indicator would be amber.

62.

pH at $6.3 \times 10^{-3} = 2.20$ $\leftarrow \frac{1}{2}$ **mark**

pH at $2.5 \times 10^{-4} = 3.60$ $\leftarrow \frac{1}{2}$ **mark**

Transition point pH $= \dfrac{2.20 + 3.60}{2}$ $\leftarrow \frac{1}{2}$ **mark**

$= 2.90$ $\leftarrow \frac{1}{2}$ **mark**

63. a)

$$Sr(OH)_2 + 2HCl \rightarrow SrCl_2 + 2H_2O$$

b)

$$H^+ + OH^- \rightarrow H_2O$$
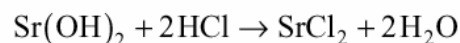
c) A solution of known concentration.**OR** A solution that has had its concentration determined by carrying out a titration against another solution of known concentration.{1mark}

d) The equivalence point in a titration is the point at which the moles of the reactants are in the ratio given by the balanced equation. {1 mark}

64.
  a)

For example:

The unknown is a weak acid.

The initial pH of 2.72 indicates that a weak acid is being titrated.

The equivalence or stoichiometric point has a pH of 8.88 which indicates that a basic salt is produced during this reaction.
NaOH is a strong base and therefore the acid must be weak.

$\left.\begin{array}{l}\ \\ \ \\ \ \\ \ \end{array}\right\}$ ← **3 marks**

  b)

Thymol blue would be a green colour.
<div align="center">**or**</div>
Phenolphthalein would be a faint pink colour.

$\left.\begin{array}{l}\ \\ \ \\ \ \end{array}\right\}$ ← **1 mark**

65.

Graph labels: S-shaped curve ← **1 mark**; Equivalence Point pH = 7 ← **1 mark**; Initial pH = 1 ← **1 mark**; 25 mL of 0.10 M NaOH for neutralization ← **1 mark**; y-axis: pH; x-axis: Volume of NaOH (mL)
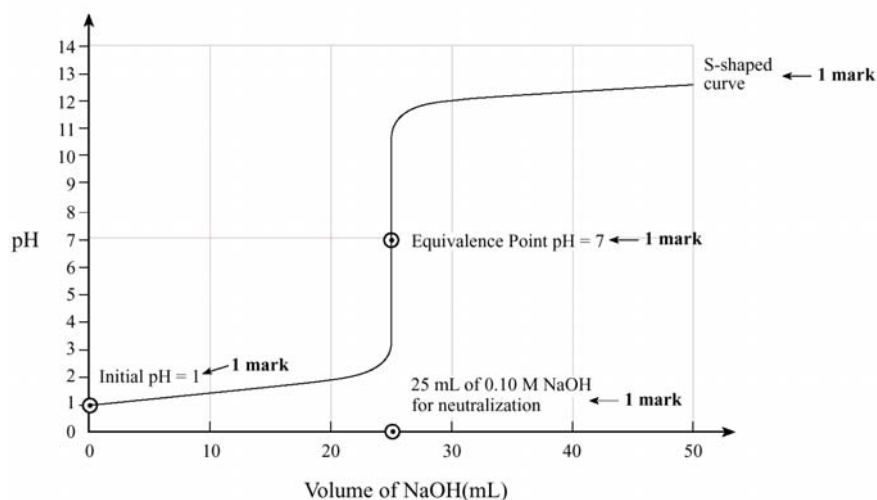
b) Phenolphthalein **-1 mark**

66.

$$2NaOH + H_2SO_4 \rightleftarrows Na_2SO_4 + 2H_2O$$
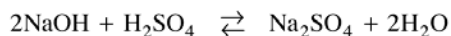
$\text{vol of } NaOH = 11.00 \text{ mL}$ ← **1 mark**

$\text{mol } NaOH = 0.01100\,L(0.115\,mol/L) = 1.265 \times 10^{-3}\,mol$ ← $\frac{1}{2}$ **mark**

$\text{mol } H_2SO_4 = \frac{1}{2}\left(1.265 \times 10^{-3}\,mol\ NaOH\right) = 6.325 \times 10^{-4}\,mol$ ← **1 mark**

$[H_2SO_4] = \dfrac{6.325 \times 10^{-4}\,mol}{0.02500\,L} = 0.0253\,M$ ← $\frac{1}{2}$ **mark**

67.

$$\text{Volume of HCl needed} = \frac{35.51\,\text{mL} + 35.49\,\text{mL}}{2} = 35.50\,\text{mL} \qquad \leftarrow \textbf{1 mark}$$

$$\text{mol Ba(OH)}_2 \text{ reacted} = 3.16\,\text{g} \times \frac{1\,\text{mol}}{171.3\,\text{g}} = 0.0184\,\text{mol} \qquad \leftarrow \textbf{1 mark}$$
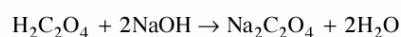
$$\text{mol HCl reacted} = 0.0184\,\text{mol} \times \frac{2\,\text{mol HCl}}{1\,\text{mol Ba(OH)}_2} = 0.0369\,\text{mol} \quad \leftarrow \textbf{1 mark}$$

$$[\text{HCl}] = \frac{0.0369\,\text{mol}}{0.03550\,\text{L}} = 1.04\,\text{M} \qquad \leftarrow \textbf{1 mark}$$

NOTE: $\left(\frac{1}{2}\ \textbf{mark}\right)$ **is deducted for incorrect significant figures.**

---

68. a)

$$H_2C_2O_4 + 2NaOH \rightarrow Na_2C_2O_4 + 2H_2O$$

$$\text{vol } H_2C_2O_4 = 16.00\,\text{mL} \qquad \leftarrow \textbf{1 mark}$$

$$\text{mol } H_2C_2O_4 = 0.01600\,\text{L}\,(0.175\,\text{mol/L}) = 2.800 \times 10^{-3}\,\text{mol} \qquad \leftarrow \tfrac{1}{2}\ \textbf{mark}$$

$$\text{mol NaOH} = 2 \times \text{mol } H_2C_2O_4 = 5.600 \times 10^{-3}\,\text{mol} \qquad \leftarrow \textbf{1 mark}$$

$$[\text{NaOH}] = \frac{5.600 \times 10^{-3}\,\text{mol}}{0.02500\,\text{L}} = 0.224\,\text{M} \qquad \leftarrow \tfrac{1}{2}\ \textbf{mark}$$

$\left(\text{Deduct } \tfrac{1}{2}\ \textbf{mark} \text{ for incorrect significant figures.}\right)$

b)

The $C_2O_4^{2-}$ ion resulting from the dissociation of $Na_2C_2O_4$ hydrolyzes to form a basic solution. $\left.\right\} \leftarrow \textbf{1 mark}$

69.

$$\text{mol } H_2SO_4 = 0.02500\,\text{L} \times 0.500\,\text{M} = 1.25 \times 10^{-2}\,\text{mol } H_2SO_4 \quad \leftarrow \textbf{1 mark}$$

$$\text{mol NaOH} = \frac{2}{1}\left(1.25 \times 10^{-2}\right) = 2.50 \times 10^{-2}\,\text{mol NaOH} \qquad \leftarrow \textbf{1 mark}$$

$$\text{mass of NaOH} = \frac{40.0\,\text{g}}{\text{mol}}\left(2.50 \times 10^{-2}\right)\text{mol} = 1.00\,\text{g} \qquad \leftarrow \textbf{1 mark}$$

(subtract $\tfrac{1}{2}$ **mark** for incorrect sig. fig)

70.

$$\text{mol } H_2C_2O_4 = 0.2500\,\text{L} \times 0.125\,\text{mol/L} = 0.03125\,\text{mol} \qquad \leftarrow \textbf{1 mark}$$

$$\text{mol NaOH} = 0.03125\,\text{mol } H_2C_2O_4 \times \frac{2\,\text{mol NaOH}}{\text{mol } H_2C_2O_4} = 0.0625\,\text{mol} \quad \leftarrow \textbf{1 mark}$$

$$\text{g NaOH} = 0.0625\,\text{mol NaOH} \times \frac{40.0\,\text{g NaOH}}{1\,\text{mol NaOH}} = 2.50\,\text{g NaOH} \quad \leftarrow \textbf{1 mark}$$

71. a)

$$NaOH + HF \rightarrow NaF + H_2O \qquad \leftarrow \textbf{1 mark}$$

b)

$$H^+ + OH^- \rightarrow H_2O \qquad \leftarrow \textbf{1 mark}$$

c)

$$NaF \qquad\qquad\qquad \leftarrow \tfrac{1}{2} \textbf{ mark}$$

$$F^- + H_2O \rightleftarrows HF + OH^- \qquad \leftarrow 1\tfrac{1}{2} \textbf{ marks}$$

72.
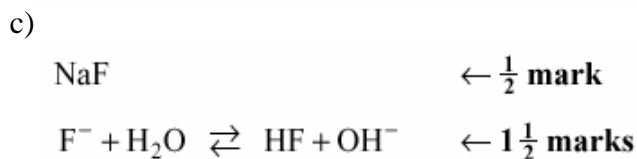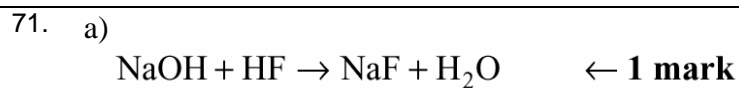
$$\left[H_3O^+\right] = 2 \times \left[H_2SO_4\right] = 2 \times 0.500\,M \times \frac{15.0\,mL}{50.0\,mL}$$
$$= 0.300\,M$$
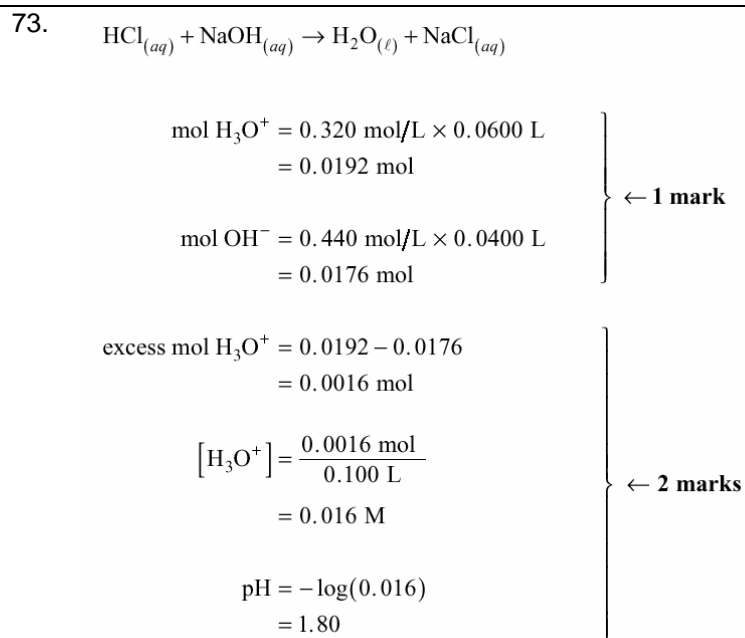$$\left[OH^-\right] = \left[NaOH\right] = 0.750\,M \times \frac{35.0\,mL}{50.0\,mL}$$
$$= 0.525\,M$$

$\leftarrow \textbf{2 marks}$

$$\text{Excess}\left[OH^-\right] = 0.525\,M - 0.300\,M$$
$$= 0.225\,M$$

$\leftarrow \textbf{1 mark}$

$$pOH = -\log(0.225)$$
$$= 0.648$$
$$pH = 14.00 - 0.648$$
$$= 13.352$$

$\leftarrow \textbf{1 mark}$

$\left(\text{Deduct } \tfrac{1}{2} \textbf{ mark} \text{ for incorrect significant figures.}\right)$

73.

$$HCl_{(aq)} + NaOH_{(aq)} \rightarrow H_2O_{(\ell)} + NaCl_{(aq)}$$

$$\text{mol } H_3O^+ = 0.320\,mol/L \times 0.0600\,L$$
$$= 0.0192\,mol$$

$$\text{mol } OH^- = 0.440\,mol/L \times 0.0400\,L$$
$$= 0.0176\,mol$$

$\leftarrow \textbf{1 mark}$

$$\text{excess mol } H_3O^+ = 0.0192 - 0.0176$$
$$= 0.0016\,mol$$

$$\left[H_3O^+\right] = \frac{0.0016\,mol}{0.100\,L}$$
$$= 0.016\,M$$

$$pH = -\log(0.016)$$
$$= 1.80$$

$\leftarrow \textbf{2 marks}$

74.

Excess HNO_3 = 0.0300 mol – 0.0280 mol since reaction is 1:1 $\left.\right\}$ ← **1 mark**

$\qquad$ = 0.0020 mol

$[HNO_3] = [H^+] = 0.0020 \text{ mol} \div 0.0250 \text{ L}$ $\left.\right\}$

$\qquad\qquad$ = 0.080 M $\qquad\qquad\qquad$ $\left.\right\}$ ← **1 mark**

$\qquad$ pH = 1.10

75.

$HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(1)}$

mol HCl = 0.500 M × 0.0200 L = 0.0100 mol $\left.\right\}$ ← **1 mark**

mol NaOH = 0.300 M × 0.0300 L = 0.00900 mol

$\qquad$ Excess mol HCl = mol H_3O^+ = 0.0010 mol $\qquad$ ← **1 mark**

$\qquad\qquad [H_3O^+] = \dfrac{0.0010 \text{ mol}}{0.0500 \text{ L}} = 0.020 \text{ M}$ $\qquad$ ← **1 mark**

$\qquad\qquad$ pH = $-\log(0.020) = 1.70$ $\qquad$ ← **1 mark**
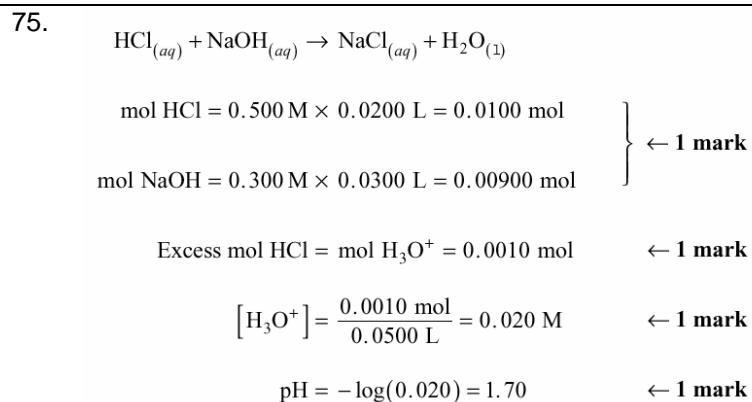
76.

mol HCl $= (0.0600 \text{ L})(0.150 \text{ M}) = 0.00900 \text{ mol}$ $\qquad$ ← $\frac{1}{2}$ **mark**

mol KOH $(0.1400 \text{ L})(0.100 \text{ M}) = 0.0140 \text{ mol}$ $\qquad$ ← $\frac{1}{2}$ **mark**

$\qquad$ mol excess KOH = 0.0050 mol $\qquad$ ← **1 mark**

$\qquad [KOH] = 0.0050 \text{ mol} / 0.2000 \text{ L} = 0.025 \text{ M}$ $\qquad$ ← **1 mark**

$\qquad$ pOH $= -\log[OH^-] = 1.60$ $\qquad$ ← $\frac{1}{2}$ **mark**

$\qquad$ pH $= 14.00 - \text{pOH} = 12.40$ $\qquad$ ← $\frac{1}{2}$ **mark**

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77. a)

$\qquad H_3PO_4 + H_2O \rightleftarrows H_3O^+ + H_2PO_4^-$
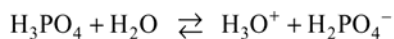
b) a buffer solution forms and resists a change in pH

78.

a) $CH_3COOH + H_2O \rightleftarrows CH_3COO^- + H_3O^+$ ←**1 mark**

OR

$CH_3COO^- + H_2O \rightleftarrows CH_3COOH + OH^-$ ←**1 mark**
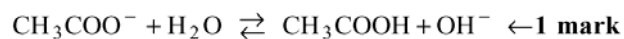
b) The CH_3COOH will increase while the CH_3COO^- will decrease. ←**1 mark**
The added H_3O^+ reacts with CH_3COO^- to produce CH_3COOH. ←**1 mark**

c) The pH remains relatively constant. ←**1 mark**

79.

CO_2 dissolves in water to make an acidic solution. ← **1 mark**

$CO_2 + H_2O \rightleftarrows H_2CO_3$ ← **1 mark**

or

$H_2CO_3 + H_2O \rightleftarrows H_3O^+ + HCO_3^-$