Acids and Bases

1. It requires 37.0 mL of 0.0500 mol/L NaOH(aq) to neutralize 100.0 mL of gastric juice. We can assume that HCl(aq) is the only acid present in gastric juice.
   a) Calculate the concentration of HCl(aq) present in gastric juice. (Value: 2)
   b) Calculate the pH of gastric juice. (Value: 1)
   c) Calculate the number of grams of HCl(aq) per 100 mL of gastric juice. (Value: 1)

2. Ascorbic acid (vitamin C) is a weak monoprotic acid that has the formula $HC_6H_7O_6$ and Ka = 8.0×10^{-5}. What is the pH of a 0.035 mol/L solution of ascorbic acid? (Value: 4)

3. The pH of a 0.072 mol/L solution of benzoic acid ($HC_7H_5O_2$) is 2.68. Calculate the numerical value of the Ka for this acid. (Value: 4)

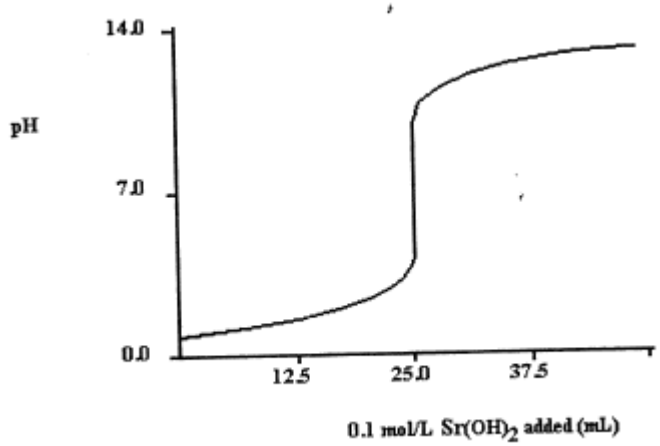
4. What is the pH of a solution formed by mixing 100.0 mL of a 0.150 mol/L HCl(aq) with 150.0 mL of 0.0900 mol/L NaOH(aq)? (Value: 4)

5. Acetylsalicylic acid (ASA) is the most widely used drug in the world. ASA has the chemical formula, $C_8H_7O_2COOH$, and its K_a equals 3.27×10^{-4}. Calculate the pH of a 0.250 mol/L ASA solution. (Value: 4)

6. Calculate the $H_3O^+(aq)$ ion concentration of the resulting solution if 20.0 mL of 0.200 mol/L HCl(aq) is mixed with 30.0 mL of 0.350 mol/L NaOH(aq). (Value: 4)

7. Calculate the $[H^+]$ in a solution of 0.10 mol/L hypochlorous acid, HOCl. The K_a value of HOCl is 2.9×10^{-8}. (Value: 4)

8. A student titrated 45.0 mL of a nitric acid solution of unknown concentration with a 0.10 mol/L strontium hydroxide solution. A pH meter was used to obtain the following titration curve:



   a) Based on the results shown on the graph, calculate the concentration of the nitric acid solution. (Value: 2)
   b) What would be an appropriate indicator for this titration and why? (Value: 1)

9. a) A chemistry laboratory has solutions of four indicators: methyl orange, phenol red, phenolphthalein, and alizarin yellow R. Use the information given in the Chemistry Data Booklet to choose an appropriate indicator for each of the following titrations, and give your reasons in each case. (The concentrations of all acid and base solutions are in the 0.10 to 0.30 mol/L range.)
      i) $CH_3COOH(aq)$ with NaOH(aq) (value: 1)
      ii) HCl(aq) with $NH_3(aq)$ (value: 1)
      iii) HCl(aq) with NaOH(aq) (value: 1)
   b) For which titration would you have more than one choice among the above indicators? Which indicators could be used in this titration? (value: 1)

10. Originally, Arrhenius believed that there must be the same number of positive and negative ions in a solution. However, the modern theory of electrolytes states that the total positive ionic charge must equal the total negative ionic charge. Is there a difference between these two statements? If so, why did Arrhenius' original theory have to be modified? (Value: 3)

11. Butanoic acid, C_3H_7COOH, is found in rancid butter and has a well-deserved, malodorous reputation (it stinks). In a well-ventilated room, 0.20 moles of the acid are dissolved in water to give 500 mL of a solution whose pH is found to be 2.60. Assuming that butyric acid is monoprotic (it has only one ionizable proton), calculate K_a for the acid.

12. The K_w of water at 25°C is 1.0×10^{-14}, and the thermochemical equation for the reaction is:
$H_2O(l) \leftrightarrows H^+(aq) + OH^-(aq) \quad \Delta H = +56$ kJ
Predict, giving your reason, how the Kw will change if the temperature is increases. (value: 2)

13. The $HCO_3^-(aq)$ ion is capable of acting as either a Brønsted-Lowry acid or base. Illustrate this behaviour by writing balanced equations for its reactions with $CN^-(aq)$ ions and with $HNO_3(aq)$. (Value: 2)

14. Three solutions are known to have pH values of 4.5, 6.0, and 8.0. Using two acid-base indicators (Chemistry Data Booklet, page 8), describe how you would distinguish among them. (Value: 4)

15. The following data show how the pH changes during a titration when 0.100 mol/L NaOH(aq) is added to 10.0 mL of aqueous acetic acid (CH_3COOH).

mL NaOH	0.0	1.0	2.0	3.0	4.0	6.0	7.0	8.0	10.0	14.0
pH	2.9	4.0	4.3	4.7	5.2	5.5	6.4	11.2	12.0	12.4

a) Using graph paper, plot the pH titration curve. Determine the value of the end-point pH. (Value: 2)
b) Calculate the concentration of $CH_3COOH(aq)$ (Value: 2)
c) Use the information provided in this question and your answer in part (b) to calculate the numerical value of Ka for $CH_3COOH(aq)$ (Value: 2)

16. A set of six solutions was prepared for a demonstration. The solutions were:

0.05 mol/L $Ba(OH)_2(aq)$	0.10 mol/L NaOH(aq)	0.05 mol/L $H_2SO_4(aq)$
0.10 mol/L HCl(aq)	0.10 mol/L $CH_3COOH(aq)$	0.10 mol/L $NH_3(aq)$

Before the solutions were labelled, they became scrambled, and the technician was forced to label the bottles A to F. The technician tested all six solutions and four mixtures (prepared by mixing equal volumes of two solutions) first in a conductivity apparatus and then with bromothymol blue. The technician knew that of the possible mixtures of acids and bases only the following would produce an insoluble salt:

$$Ba(OH)_2(aq) + H_2SO_4(aq) \leftrightarrows BaSO_4(s) + H_2O(l)$$

Solution(s)	Ability to Conduct Electricity	Colour of Bromothymol Blue
A only	good	yellow
B only	poor	blue
C only	poor	yellow
D only	good	blue
E only	good	blue
F only	good	yellow
A & D mixed	good	green
A & E mixed	good	green
D & F mixed	good	green
E & F mixed	poor	green

a) Classify the solutions A to F as: strong acids, weak acids, strong bases, or weak bases. (Value: 2)
b) Explain the differences in the tests results of mixture E & F compared with the other mixtures, and identify solutions E and F. (Value: 2)
c) Match the letters A to D with the appropriate solutions. (Value: 2)

17. a) Give one similarity and one difference between the Arrhenius and the Brønsted-Lowry definitions of acids and bases. (Value: 2)
    b) Explain how well CH_3COOH fits into each definition. (Value: 2)
    c) Explain how well NH_3 fits into each definition. (Value: 2)

18. Construct a graph of pH versus volume of base added for the titration of 50.0 mL of 0.0500 M HI with 0.0750 M NaOH, based on the calculations below. (Value: 1)
    a) How many mL of base are required to neutralize the HI? (Value: 1)
    b) What is the pH before any base is added? (Value: 1)
    c) What is the pH after the addition of 25.0 mL of NaOH? (Value: 2)
    d) What is the pH after 30.0 mL of NaOH has been added? (Value: 1)
    e) What is the pH at the equivalence point? (Value: 1)
    f) What is the pH after 35.0 mL of NaOH have been added? (Value: 2)

19. Using the K_a table in your Data Booklet, determine the $[OH^-]$ of 0.068 M of HCN. (Value: 3)

20. One possible way of combating the effects of acid rain on some small lakes is to spread limestone (calcium carbonate) in lakes to neutralize the acid. The following equation illustrates the reaction:

$$CaCO_3(aq) + 2\ H_3O^+(aq) \rightarrow Ca^{2+}(aq) + CO_2(g) + 3\ H_2O(l)$$

    The cabin owners on the lake whose volume is 4.0×10^{10} L wish to neutralize the acid in their lake. They must determine the amount of acid in the lake by titration of small samples with standardized NaOH.

    a) As an assignment, you are required to develop a procedure to determine the molarity of the sodium hydroxide, NaOH, to be used in the titrations. You have a supply of a solid acid, potassium hydrogen phthalate, $KHC_8H_4O_4$, (a monoprotic acid) with which to standardize the NaOH solution. Write a step-by-step **experimental procedure** that you or anyone else could follow to obtain the essential data necessary to determine the concentration of the NaOH solution. You have access to a lab containing all equipment normally available in a high school lab, a supply of distilled water, and all the indicators in your data booklet. (Value: 5)

    b) One of the owners (a high school chemistry teacher) collected samples of the water and has one of her students perform titrations to determine the concentration of hydrogen ions in the water. In one sample, 40.0 mL of the NaOH standardized in (a) (1.00×10^{-3} mol/L) was required to neutralize 1.00 L of lake water. What is the maximum number of tonnes of calcium carbonate needed to neutralize the acid present in the lake? (1 tonne = 10^6 g) (Value: 5)

    c) Acid rain normally has a pH between 5.0 –5.5 in our region. The prevailing winds in our region blow our own sources of acid rain to the east. What are the industrial sources of acid rain that fall in our region? Explain how it is possible for the lakes to reach a pH less than 5. (Value: 3)

    d) In some spring seasons, an acid shock hits the freshwater streams just as the fish eggs hatch, and sometimes the hatchlings cannot survive in this environment. Discuss the source of the acid shock. (Value: 2)

21. HF ($K_a = 6.6 \times 10^{-4}$) and HCN ($K_a = 6.2 \times 10^{-10}$) are two weak acids that appear in this equilibrium:

$$HCN(aq) + F^-(aq) \leftrightarrows HF(aq) + CN^-(aq)$$

    a) Use this information to explain qualitatively which direction of the reaction is favoured. (Value: 2)
    b) Using K_a expressions and the K_a values provided, calculate the numerical value of the equilibrium constant for the reaction. (Value: 3)
    c) How do your answers to (a) and (b) compare? (Value: 1)

22. a) Write equations for the reactions of the amphoteric substance, HS^-, with HCl and with KOH. (Value: 2)
    b) Write the formula for the conjugate base of HSO_4^-. (Value: 1)
    c) Write the formula for the conjugate acid of HSO_4^-. (Value: 1)

23. a) Calculate the pH of a 2.5×10^{-3} mol/L NaOH solution. (Value: 2)
    b) Calculate the pH of a solution of HCl(aq) made by diluting 3.50 mL of 12.0 mol/L HCl to a final volume of 500.0 mL. (Value: 2)

24. The hydrogen ion concentration of any weak acid can be calculated using its initial concentration and K_a value. The K_a of benzoic acid, C_6H_5COOH, equals 6.46×10^{-5}.

a) Complete the following table for benzoic acid. Show your calculations. (Value: 3)

Initial Concentration (mol/L)	$[H^+]$	% ionization
0.010	7.7×10^{-4}	7.7%
0.050		
0.10		
0.30		

b) Plot a curve of percent ionization (y axis) versus initial concentration of the benzoic acid using the data from part (a). (Value: 2)

c) It is generally accepted that the quadratic equation is needed to calculate $[H^+]$ when the percent ionization exceeds 5%. Using your graph, determine the range of initial benzoic acid concentrations that make the use of the quadratic equation ***necessary***. (Value: 1)

25. a) Write equations for the reactions of the amphoteric substance, HPO_4^{2-}, with
i) with HCl ii) with KOH. (Value: 2)

b) Write the formula for the conjugate base of each of these species:
i) H_2SO_4 ii) PH_4^+ (Value: 1)

c) Write the formula for the conjugate acid of each of these species:
i) HPO_4^{2-} ii) NO_3^- (Value: 1)

26. a) What is the pH of a 0.155 mol/L HCl solution? (Value: 1)

b) Calculate the volume of 0.120 mol/L NaOH needed to neutralize 25.0 mL of a 0.155 mol/L HCl (Value: 2)

c) Explain why the endpoint of an acid-base titration does not always coincide with the equivalence point. (Value: 1)

27. The data given in the table has been compiled for 0.10 mol/L aqueous solutions of these compounds: CH_3COOH, HBr, HCN, H_2SO_4, Na_2HBO_3, $NaHCO_3$, and NaH_2PO_4. Complete the **COMPOUND** column of the table. In the table, n/a means not applicable. (Pages 8 and 9 of the Chemistry Data Booklet may be useful.) (Value: 6)

Compound	pH	Orange IV Colour	Reaction with zinc	mL needed to neutralize 20 mL 0.10 mol/L NaOH	mL needed to neutralize 20 mL 0.10 mol/L HCl
		red	fast	10	n/a
		yellow		20	20
		yellow		10	20
	5.1		slow		n/a
		yellow		20	10
		red	fast		n/a
	2.9		slow		n/a