Chemistry

The Acidic Environment

New Revised Edition

Marilyn Schell
Margaret Hogan

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Contents

Use the table of contents to record your progress through this book. As you complete each topic, write the date completed, then tick one of the three remaining columns to guide your revision for later. The column headers use the following codes:

?? = Don't understand this very well at all. RR = Need to revise this. OK = Know this.

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Science Press
Bag 7023 Marrickville NSW 1475 Australia
Tel: (02) 9516 1122 Fax: (02) 9550 1915
sales@sciencepress.com.au
www.sciencepress.com.au

Introduction

Each book in the *Surfing* series contains a summary, with occasional more detailed sections, of all the mandatory sections of the syllabus, along with questions and answers.

It is envisaged this book will be useful in class for both initial understanding and revision, while the more traditional textbook can remain at home for more detailed analysis.

All types of questions – multiple choice, short response, structured response and free response – are provided. Questions are written in exam style and use the verbs specified by the Board of Studies so that you will become familiar with the concepts of the topic and answering questions in the required way.

Answers to all questions are included.

A topic test at the end of the book contains an extensive set of summary questions, including multiple choice and free response questions. These cover every aspect of the topic, and are useful for revision and exam practice. Marking guidelines are supplied where appropriate.

Verbs To Watch

When you are answering questions in this book, your textbook or any examinations, make sure you answer what the question is asking. To do this you will have to know what each of the terms below means – they dictate what sort of an answer is required. It is essential that you learn their meanings as required by the Board of Studies. Your exam answers will be marked according to what these terms indicate your answer should be saying.

account, account for State reasons for, report on, give an account of, narrate a series of events or transactions.
analyse Identify components and the relationships among them, draw out and relate implications.
apply Use, utilise, employ in a particular situation.
appreciate Make a judgement about the value of something.
assess Make a judgement of value, quality, outcomes, results or size.
calculate Determine from given facts, figures or information.
clarify Make clear or plain.
classify Arrange into classes, groups or categories.
compare Show how things are similar or different.
construct Make, build, put together items or arguments.
contrast Show how things are different or opposite.
critically (analyse/evaluate) Add a degree or level of accuracy, depth, knowledge and understanding, logic, questioning, reflection and quality to an analysis or evaluation.
deduce Draw conclusions.
define State the meaning of and identify essential qualities.
demonstrate Show by example.
describe Provide characteristics and features.
discuss Identify issues and provide points for and against.
distinguish Recognise or note/indicate as being distinct or different from, note difference between things.
evaluate Make a judgement based on criteria.
examine Inquire into.
explain Relate cause and effect, make the relationship between things evident, provide why and/or how.
extract Choose relevant and/or appropriate details.
extrapolate Infer from what is known.
identify Recognise and name.
interpret Draw meaning from.
investigate Plan, inquire into and draw conclusions about.
justify Support an argument or conclusion.
outline Sketch in general terms; indicate the main features.
predict Suggest what may happen based on available information.
propose Put forward a point of view, idea, argument or suggestion for consideration or action.
recall Present remembered ideas, facts or experiences.
recommend Provide reasons in favour.
recount Retell a series of events.
summarise Express concisely the relevant details.
synthesise Put together various elements to make a whole.

1 Acidic, Basic or Neutral

Common substances can be classified as acidic, basic or neutral according to how they change the colour of indicators. An **indicator** is a substance that changes colour if placed in an acid or a base. It is an organic molecule whose colour depends on the acidity of the solution in which it is dissolved.

Some plants contain dyes that are naturally occurring indicators. Many flower petals and also red cabbage leaves release an indicator dye when boiled in water. Lichens that grow on trees and rocks can be used to make the indicator, called litmus.

Commercial indicators can be sold as solutions or dried onto paper strips. Some common commercial indicators and the colour changes they undergo are shown in Table 1.1.

Table 1.1 Indicators and colour change.

Indicator	Colour in acid	Colour in base
Litmus	Red (below pH = 5)	Blue (above pH = 7.6)
Phenolphthalein	Colourless (below pH = 8.3)	Red (above pH = 10.0)
Bromothymol blue	Yellow (below pH = 6.0)	Blue (above pH = 7.6)
Methyl orange	Red (below pH = 3.1)	Yellow (above pH = 4.4)

Universal indicator is a mixture of several dyes. It can turn a range of colours, from red, orange, yellow or green to purple as the pH rises (the solution becomes more basic).

Indicator molecules can have complicated formulas. To simplify, we can show them as HIn, where H represents a hydrogen atom and In represents the 'rest' of the indicator molecule. Indicator molecules ionise, forming a hydrogen ion and an indicator ion, and this forms an equilibrium.

$$HIn \rightleftharpoons H^+ + In^-$$

Yellow Blue

The HIn molecule is a different colour to the In^- ion. For example, in an acid, bromothymol blue exists as yellow molecules; in a base it ionises, forming blue ions. If there are roughly equal numbers of HIn molecules and In^- ions then the indicator will be green (blue + yellow).

Uses of indicators include:

- **Testing of soil acidity/basicity**
  When testing the pH of substances such as soil, the colour of the soil can hide the indicator colour change. To prevent this, a neutral white powder, such as barium sulfate can be added to the top layer of damp soil before adding the indicator.
- **Checking the water in swimming pools**
  The pH of swimming pool water needs to be kept close to 7.4 so as not to cause skin and eye discomfort.
- **Testing aquarium water**
  Fish are sensitive to the pH of water so it must be maintained at a suitable level. Saltwater fish may need a pH of about 8.5.
- **Finding the end point of an acid-base reaction**
  Indicators are used to do this in a quantitative technique called a titration.

About pH

You will recall that the pH of a substance tells us about its acidity or basicity and indicates the concentration of hydrogen ions (H^+) in solution.

A pH of 7 is considered neutral, a pH below 7 is acidic and a pH above 7 is basic. The **LOWER the pH**, the more hydrogen ions are present so the **more ACIDIC** the substance is. We will learn more about pH later.

For You To Do

1. Using the information in Table 1.1, deduce the pH range between which each of the following indicators changes colour.
   (a) Phenolphthalein. (b) Methyl orange.
2. You are given two containers of acids and told that one has a pH of 2.5 and the other has a pH of 4.8. Which of the indicators in Table 1.1 would be best to distinguish between these two substances? Justify your choice.

Use Table 1.1 to answer Questions 3 and 4.

3. A solution that turns blue with litmus and bromothymol blue and colourless with phenolphthalein has a pH between:
   (A) 5 and 10
   (B) 6 and 4.4
   (C) 10 and 7.6
   (D) 7.6 and 8.3
4. Four solutions are tested with different indicators and the results are shown in the following table. Which solution is strongly acidic?

Solution	Indicator	Colour
(A)	Litmus	Mauve-pink
(B)	Bromothymol blue	Blue
(C)	Methyl orange	Red
(D)	Phenolphthalein	Red

5. If you have not already done so, use indicators to test each of the following common household chemicals for acidity/basicity. Then complete the table.

Chemical	Formula	Acidity	Home use
Acetic (ethanoic) acid	CH_3COOH		In vinegar, to flavour and preserve food
Ethanol			
	$NaHCO_3$		Bicarbonate of soda used to make cakes rise and to safely neutralise acids
Magnesium sulfate			Epsom salts – for constipation
Hydrochloric acid			

6. (a) Outline why it is necessary to check the pH of swimming pool water.
   (b) Find out what is added to swimming pools when the water has a pH which is too (i) low; (ii) high.
7. You performed a first-hand investigation to prepare and test a natural indicator.
   (a) Outline the method you used in this investigation.
   (b) Justify your choice of chemicals used to test this indicator.
8. Outline the problem involved in testing soil acidity/basicity and how this is overcome.
9. List the following substances in order of acidity, starting with the least acidic: ethanol, sodium hydrogen carbonate, orange juice, white vinegar, caustic soda drain cleaner.
10. Some plants grow best in acidic soil, whereas others prefer neutral or basic soil. The following list shows the recommended pH of soil for a variety of plants.

Vegetables	pH	Flowers	pH
Beans	5.5-7.5	Pansies	5.5-6.5
Beetroot	7-8	Camellias	4.5-5.5
Pumpkin	5.5-7	Poppies	6-7.5
Tomatoes	6-7	Sweet peas	7-8
Onions	6-7	Azaleas	4.5-5.5

Two Year 12 students, Tamara and Gemma, tested the soil in their gardens at home. Tamara's soil had a pH of 5.0 and Gemma's soil had a pH of 7.5.
   (a) Whose soil is more acidic?
   (b) Identify two flowers that would grow well together in Tamara's garden.
   (c) Identify one vegetable and one flower that would grow well in Gemma's garden.
11. A group of Year 12 students chopped up parts of a variety of plants, ground them in a mortar and pestle and boiled them in water. They tested small amounts of the liquid collected from each plant with vinegar and then with bicarbonate of soda. The results they obtained were:

Plant	Original colour	Colour in vinegar	Colour in bicarbonate of soda
Red rose petals	Red	Pink	Green
Red geranium petals	Red	Orange	Yellow
Marigold petals	Yellow	Yellow	Yellow
Nasturtium petals	Orange	Yellow	Yellow
Red cabbage leaf	Purple	Pink	Green
Spinach leaf	Green	Yellow-green	Yellow-green

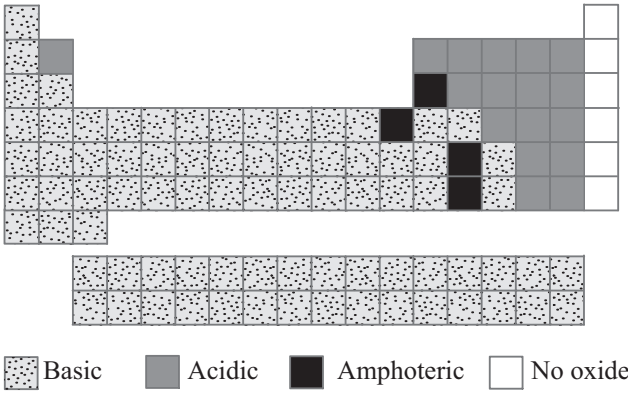
   (a) Analyse these results to identify which of the plants tested would NOT be good indicators.
   (b) Outline your reasons for your answer to (a).
   (c) Predict the colour that would be produced if the following substances were placed in dilute hydrochloric acid.
      (i) Cabbage leaf.
      (ii) Geranium petals.
   (d) Predict the colour that would be produced if the following substances were placed in sodium hydroxide solution.
      (i) Marigold petals.
      (ii) Red rose petals.
   (e) Deduce the characteristics that would make a good indicator.
12. Check your knowledge with this quick quiz.
   (a) A chemical that changes colour in acid or base is called an _____.
   (b) Identify two chemicals used in the home that are acidic.
   (c) Identify the basic chemical used to clean drains and ovens.
   (d) Describe the colour change when litmus paper is added to a base.
   (e) Identify a natural substance that can act as an indicator.
   (f) The greater the hydrogen ion concentration of a solution, the (higher/lower) its pH and the more (acidic/basic) the solution.

2 Acidic and Basic Oxides

In general the oxides of the elements on the left side of the periodic table (the metals) form basic oxides and those on the right of the table (non-metals) form acidic oxides. (See Figure 2.1.) However, there are some exceptions:

- The inert gases in group 8 do not form oxides.
- Some oxides are amphoteric – they have some acidic properties and some basic properties.
- Some only dissolve slightly in water and form neutral solutions, e.g. CO, N_2O.

Figure 2.1 Acidic/basic oxides and the periodic table.



We can distinguish whether an oxide is acidic or basic by looking at its effect on an indicator or seeing if it reacts with an acid or a base.

- **Oxides of non-metals act as acids** when they come in contact with water; they turn litmus red.

  Non-metal oxide + water → acid
  E.g. $SO_2(s) + H_2O(l) \rightarrow H_2SO_3(aq)$

- **Acidic oxides react with a base** to form water.

  Acidic oxide + base → water + salt
  E.g. $SO_2(s) + 2NaOH(aq) \rightarrow H_2O(l) + Na_2SO_3(aq)$

- **Oxides of metals act as bases**. They react with water to form an hydroxide and turn litmus blue.

  Metal oxide + water → base
  E.g. $MgO(s) + H_2O(l) \rightarrow Mg(OH)_2(aq)$

- **Basic oxides react with an acid** to form water.

  Basic oxide + acid → water + salt
  E.g. $MgO(s) + 2HCl(aq) \rightarrow H_2O(l) + MgCl_2(aq)$

Acidic oxides in the atmosphere

The atmosphere contains acidic oxides of carbon, nitrogen and sulfur and these dissolve in rainwater to form acid rain. These acidic oxides are produced naturally, but their concentrations in the atmosphere have increased considerably since the Industrial Revolution. (See Topics 7-10.)

For You To Do

1. (a) Define:
   (i) Acidic oxide.
   (ii) Basic oxide.
   (b) Identify the acidic oxides from the following list and justify your decisions.
   (i) Carbon dioxide.
   (ii) Calcium oxide.
   (iii) Nitrogen dioxide.
   (iv) Potassium oxide.
2. Outline the relationship between position of elements in the periodic table and the acidity/basicity of oxides.
3. When sulfur is burnt in air or oxygen an acidic oxide is formed.
   (a) Identify the reactants and the product.
   (b) Write the combustion equation.
4. Write equations to show the action of water on:
   (a) Sulfur dioxide.
   (b) Sulfur trioxide.
   (c) Diphosphorus pentoxide.
5. In the Preliminary course you would have compared the composition and bonding of metal and non-metal oxides. Complete the following table to summarise this.

	Metal oxide	Non-metal oxide
Consists of	Metal + non-metal (O_2)	
Bonding		
State at room temperature		Gas

6. State whether each of the following oxides is acidic or basic.
   (a) A colourless gas that dissolves in water to form a solution with pH = 2.
   (b) White pellets that dissolve in water to form a solution that turns universal indicator purple.
7. Check your knowledge with this quick quiz.
   (a) Is carbon dioxide acidic or basic?
   (b) Acidic oxides are formed by the combustion of _____.
   (c) Identify two examples of basic oxides.
   (d) Identify the compound produced when carbon dioxide reacts with water.
   (e) Identify the product of the reaction between an acidic oxide and a base.