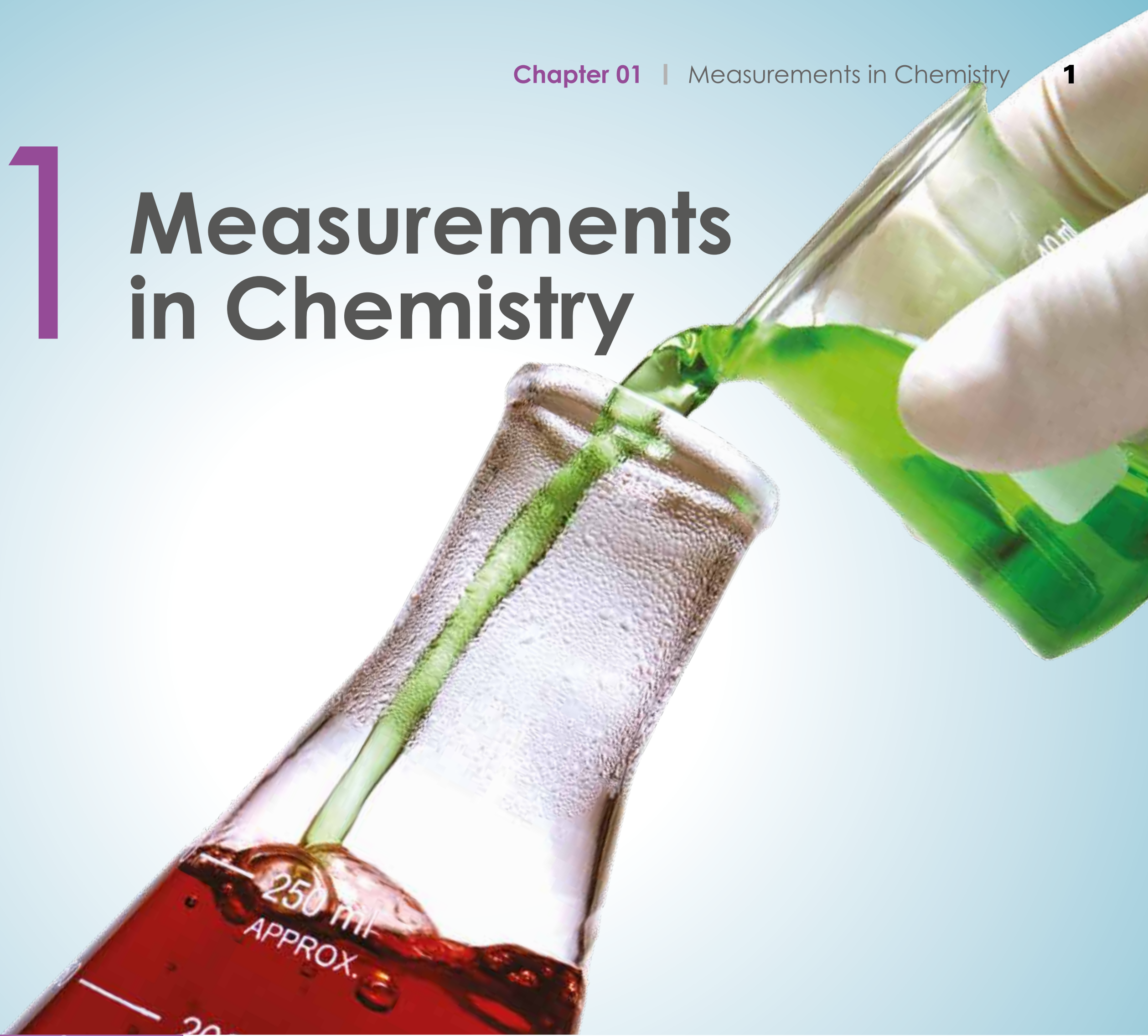
01 Measurements in Chemistry



Introduction

Chemistry is an experimental science and many of the experiments are quantitative in nature. This chapter introduces students to the units of measurement used in this course and the instruments used to make these measurements. Students are also introduced to the use of simple laboratory apparatus including the use of sensors and data loggers, and the various laboratory techniques. The materials in Sections A.3 and A.4 on *Common Chemical Apparatus* and Laboratory Techniques on pages 4 to 22 of the Practical Workbook should also be referred to while teaching this chapter.

Chapter Opener (page 2)

Carry out an 'Inquiry Preview.' Before beginning to study the chapter, get students to preview the ideas to be studied in the chapter. Students can work by themselves or in pairs.

The preview can be done is several ways:

- Students look at the chapter headings. These will give an overall idea of what is to be learnt.
- Students think about what they already know about the topic. They might even write this down.
- Students look *quickly* through the chapter and write down questions that they would like to be answered. Remind them to use the '6W1H' words when writing questions. Then, as the chapter is studied, the questions can be answered.

Initially, the preview could be done as a class activity. But, with more experience, previews for later chapters can be done individually or in small groups.

Learning Outcomes

After completing this chapter, you should be able to:

- name appropriate apparatus for the measurement of time, temperature, mass and volume
- suggest suitable apparatus, given relevant information, for a variety of simple experiments

Teaching Notes for

ChemMystery (page 3)

A lake divided — how did a railroad affect the Great Salt Lake?

The Great Salt Lake has no outlet (besides evaporation) and has very high salinity, about 3 to 5 times saltier than the ocean. Its three major tributaries deposit around 1 million tonnes of minerals in the lake each year, and since water (but not the minerals) is constantly being evaporated, the concentration of minerals increases further.

The water-surface elevation of the south part of the lake is usually about 0.6 m higher than that of the north part because most of the inflow to the lake occurs from the south.

The salts of the lake are primarily sodium chloride (common salt), although small amounts of other elements and salts are also present, including magnesium chloride, potassium carbonate (potash) and potassium sulfate.

Initial Team Investigation

- The density of a solution is its mass per unit volume. The greater the salinity, the greater the mass of salt dissolved in every unit volume and thus greater the density.
- The causeway caused the elevation of the southern part to rise which resulted in extensive flooding, especially of roads, farms and other facilities around the higher southern arm of the lake.

Websites for Reference

http://nowthatsnifty.blogspot.com/2009/06/great-salt-lake-facts-and-information.html
http://geology.utah.gov/utahgeo/gsl/lakedivided.htm

Teaching pointers

1.1 What are the Basic Physical Quantities Used in Experiments? (page 4)

Remind students of the limitations of the senses and the need for instruments in order to obtain accurate measurements. Pictures of ancient measuring instruments would make an interesting introduction, both for the physical quantities being measured and the degree of accuracy. These would then be compared with modern instruments to compare units and degree of accuracy. For example, the use of a finger to judge temperature is inaccurate. A liquid-in-glass thermometer gives a more accurate and objective measure of temperature. And a data sensor is even more accurate than a liquid-in-glass thermometer.

1. Revise the idea of the SI system of units. SI stands for *Système Internationale d'Unités* (in French) or International System of Units (in English). It has been the system used by scientists since 1960.
2. (Optional) Get students to carry out an activity on the comparison of measurements used today with those used in earlier times. Refer to the Extension activity 'History of Measurement in Science' on page 12 of the Textbook.
3. A unit for a physical quantity has a name and a symbol. For example, a common unit for measuring volume is the cubic centimetre with the symbol cm^3.

1.2 How are Physical Quantities Measured in Experiments? (page 4)

1. The unit for volume is a *derived* unit. It is derived from the unit of length, multiplied three times, i.e. length × length × length. Thus the SI unit for volume, the cubic metre (m^3) is derived from the SI unit for length, the metre (m). Other derived units in Chemistry are density (from mass and volume) and reaction rate/speed (from amount of reactant consumed and time).
2. Show the class the various apparatus used to measure volume and discuss the functions of each. Demonstrate the use of a measuring cylinder, a pipette and a burette using *coloured* water and the levels of accuracy obtained.
3. A simple laboratory exercise to evaluate students' skills in reading a burette:
   - Half-fill a burette with coloured water.
   - Allow students to read from the burette and record the volume.
   - Write down the volumes recorded by the students on the board. There is usually a spread of volumes.
4. The litre (*l*) is a metric unit but not an SI unit. 1 litre (*l*) = 1 cubic decimetre (1 dm^3). Show some drink containers containing liquids in litres and ask students to state the volumes of liquid they can contain. (This allows students to link their previous experiences they have had in seeing and handling such containers to the topic.)
5. Point out the importance of using a pipette filler to fill a pipette, instead of using the mouth. This is to prevent liquids, which may be harmful, from accidentally being sucked into the mouth.
6. Refer to the Practical Workbook, pages 23 – 24 for more information on measuring volumes of liquids.

(page 4)

Mystery Clue

Density is a rate that compares mass and volume.

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

7. If students have not done the 'finger thermometer' experiment in Lower Secondary Science, this could be carried out to show the need for accurate instruments to measure temperature. See 'Notes for Teachers' below.

8. Refer to the Practical Workbook, page 24 for more information on measuring temperatures.

9. Discuss errors involved in measuring time for a chemical reaction, such as the inaccuracy when starting and stopping a timing device due to human errors. Although the readings on many stop clocks and stopwatches can be read to one or more decimal places, such accuracy is not needed in 'O' Level experiments.

10. For mass, it is useful to let students hold objects of different masses, e.g. 1 kg and 100 g to give them the feel of these measures. This activity combines their sense of sight with their sense of touch, thereby enhancing their concept of mass.

    Mass should not be confused with weight, although these two terms are often used interchangeably in daily life. Students who are studying Physics will learn the difference between mass and weight. You may also demonstrate the use of different kinds of balances. See also the Practical Workbook pages 25 of for the procedures for using balances.

11. Give students a few questions on converting masses from one unit to another, e.g. kg to mg and vice versa.

(page 4)

Mystery Clue

Each cubic centimetre has a mass of 1.25 grams.

Notes for Teachers

The finger thermometer experiment

Fill one beaker with hot water, another with iced water and another with water at room temperature. Place a finger of one hand in the hot water and a finger of the other hand in the iced water for about a minute. Then place both fingers in the beaker of water at room temperature. The finger from the hot water feels cool while the finger from the iced water feels warm. The finger does not make a good thermometer.

Broken mercury-in-glass thermometers

Mercury is poisonous. If a mercury-in-glass thermometer breaks, collect the large drops of mercury immediately. Cover any remaining mercury with zinc dust or a paste of sulfur and lime and leave for a few hours. Dispose of the mixture in a sealed plastic bag.

Significant figures

Significant figures are used to express errors in measurements. When we record a measurement, we write:

- all the digits that are certain, and
- an extra digit to show the uncertainty.

All these are called *significant figures*.

Thus, if we read the volume of liquid in a burette as 23.6 cm^3, there are three significant figures — 2, 3 and 6:

- the '2' and '3' are certain, and
- the '6' is not certain.

Here are some other examples:

- 64.8 °C (three significant figures)
- 45.83 cm (four significant figures)
- 58.2 g (three significant figures)
- 58.0 g (also three significant figures)

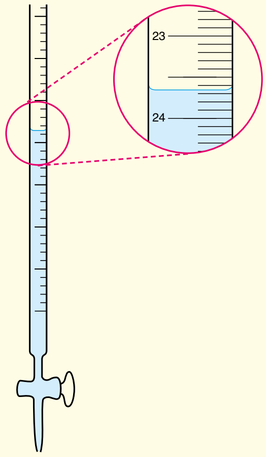
  This '0' *is* a significant figure.

- 0.0706 g (three significant figures)
  These '0's are *not* significant figures.

For the number 91 670, the '0' may or may not show uncertainty. It is more accurately written, for example, as:

- 9.167×10^4 (four significant figures) or
- 9.1670×10^4 (five significant figures).

To illustrate the use of significant figures when taking a measurement, look at the diagram below.



We know that the volume lies between 23 cm^3 and 24 cm^3. Since the smallest gradation on this measuring cylinder is '1', we are uncertain about the value of the first decimal place. Therefore, we estimate this figure. One person might say 23.6 cm^3 while another might say 23.7 cm^3. The '23' is certain; the uncertainty lies in the first decimal place. So, if we were to record the volume as 23.6 cm^3, the reading has three significant figures — the '2' and '3' being certain and the '6' not certain.

Note: For 'O' Level Chemistry, the use of significant figures is not always strictly adhered to. Thus, the temperature on a thermometer is taken to the nearest 0.5 °C even though more accurate estimates of the decimal place may be possible. Similarly, for a 100 cm^3 measuring cylinder, volumes are taken to the nearest cm^3 even though estimates of the first decimal point may be possible.

Skills Practice (page 7)

1. **(a)** Beaker.
   (b) Burette.
   (c) Gas syringe.
   (d) A 25.0 cm^3 pipette.
2. Temperature with liquid-in-glass thermometers is measured to 0.5 °C. Therefore, the reading would be either 48.0 °C or 48.5 °C.
3. A triple beam balance is accurate to only 0.1 g, so the mass should be recorded as 28.4 g.
4. The liquid could spill onto the balance and damage it, e.g. an acid could corrode the metal pan of the balance.

Notes on Skills Practice

These are designed to give students the opportunity to reinforce and summarise materials studied and to identify any errors or misconceptions so that they can be corrected before moving onto the next section. They can be carried out in a number of ways.

These are several suggestions:

- Answers can be done orally in class so that the teacher can monitor progress.
- Questions can be incorporated into homework and checked orally as a class activity in the next lesson.
- Students could prepare questions on the section(s). Then, working in pairs, they can test each other on the concepts. At the same time, they can identify points of confusion and try to clear up these confusions.

Teaching pointers

1.3 What are the Apparatus Set-ups for Some Simple Experiments? (page 8)

1. Begin this section by familiarising students with common chemical apparatus (shown in Section A.3 on pages 4 to 8 of the Practical Workbook). It is useful to classify apparatus into categories according to their function. For example, one category may be containers for liquids and solids. This would include test tubes, beakers and reagent bottles. Another category is heating apparatus which includes the Bunsen burner, tripod, wire gauze and heat-resistant mat.

2. The teacher could demonstrate the set-up of some of the apparatus shown. For example, to demonstrate collecting gas from a reaction, set up the apparatus in Figure 1.15. Add about 2 g of marble chips and 50 cm^3 of 0.5 mol/dm^3 hydrochloric acid to the conical flask to generate carbon dioxide gas.

3. In addition, students might be asked to assemble some of the other apparatus shown in the textbook, but *without* adding substances that react. A little practice now will mean that when they have to use the apparatus later, students can focus on the experiment and not on the assembly of the apparatus.

4. As an alternative to point 3, show the disassembled apparatus in Figures 1.12 to 1.15 and, with textbooks closed, provide information on gases (e.g. soluble in water, denser than air) and get the class to suggest how they would collect the gas. They can then carry out the assembly of this apparatus.

Practical Workbook (page 9)

- **Experiment 1.1**

This is an introductory experiment on the use of a temperature sensor. The way the sensor is connected to the computer interface and the way it is being used will depend on the kind of sensor it is. The teacher should first demonstrate how to set up and use the equipment. The emphasis in the experiment is on the use of the sensor and the graph of temperature against time on the monitor. Do not expect an equation for the reaction at this time.

Chemistry Inquiry (page 9)

Use of Data Loggers

A new feature in this course is the inclusion throughout the textbook (though not in every chapter) of a section called "Chemistry Inquiry". This has a question or problem that requires students to use concepts in the chapter to answer or solve, mainly through group discussions. In addition, most focus on a question or problem that requires a key skill, together with a comment on that skill. For details on the skills used, teachers can refer to the topic of 'The Explicit Teaching of Competencies and Skills' on pages 22–26 of this Teacher's Resource File.

Group Discussion

1. Measurements are always taken at the right time, avoiding the possibility of human error. In the laboratory, students can have an accurate set of measurements for their experiments. The measurements can be displayed in real time as a graph on the computer. This allows industry to monitor the changes in the measured variable throughout the process.
2. The data logging system is considerably more expensive than traditional measuring instruments. The data logging system can break down and result in lost measurements.

Teachers can also refer to the section "Data Logging with sensors" in the Practical Workbook pages 28–29. Measurement used in this course with dater loggers and sensors are temperature, time, pH and gas pressure (optional).

Skills Practice (page 82)

1. **(a)** Burette (accurate to 0.1 cm^3)
   (b) Pipette (designed to accurately measure fixed volumes, including 25.0 cm^3).
2. Burette, which allows for a series of volumes to be volumes with a total volume of up to 50 cm^3 to be measured out.
3. The two gases are soluble in water. (Ammonia, which is less dense than air, is collected by upward delivery / downward displacement of air. Chlorine, which is denser than air, is collected by downward delivery / upward displacement of air.)
4. Time. It is taken so that the change of temperature with time can be shown on a graph.

01 Chapter Review

Note: Refer to the 'Notes on Chapter Review' under 'About this Package' on pages 16 – 17 at the beginning of this Teacher's Resource File. The notes provide a rationale and suggestions for the four parts of each chapter review, namely *concept link*, *self-management* (which includes misconception analysis, self-check and self-reflection), *practice* and *extension*.

Self-Management

Misconception Analysis (page 11)

1. **True** A physical quantity is any quantity that can be measured, e.g. length, volume, mass.
2. **False** For example, the SI unit for mass is the kilogram. But in the laboratory, most measurements of mass are in grams.
3. **False** For example, the measurement of volume using a pipette is very precise.
4. **False** Timing devices can be more accurate than 1 second, but human errors as to when to start and stop a timing device in an experiment mean that it is usually necessary to only record times to 1 second.
5. **True** For example, temperature can be measured with a temperature sensor as well as with a thermometer.

Practice

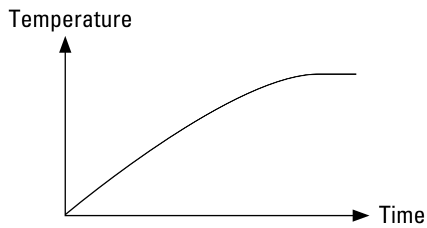
Structured Questions (page 11 – 12)

1. (a) Burette (b) Beaker
   (c) Test tube (d) Measuring cylinder
2. (a) (i) Cubic metre, m^3
   (ii) It is a very large unit and so is less convenient for the smaller volumes of liquids usually encountered in Chemistry experiments.
   (b) (i) Cubic centimetre (ii) cm^3
   (c) (i) Burette (ii) To 0.05 cm^3
3. (a) 53.5 cm^3
   (b) To the nearest 0.5 cm^3
   (c) In a burette, the gradations are reversed. The zero is at the top of a burette, whereas it is at the bottom of a measuring cylinder.
4.

Quantity to be measured	Name of apparatus used to measure the quantity	Unit in which the quantity is measured
The mass of salt in a beaker	Balance	Gram (g)
The temperature of boiling water	Thermometer	Degree Celsius (°C)
The volume of water in a beaker	Measuring cylinder	Cubic centimetre (cm^3)
The time it takes to boil 200 cm^3 of water in a beaker	Clock/Stopwatch	Second (s)

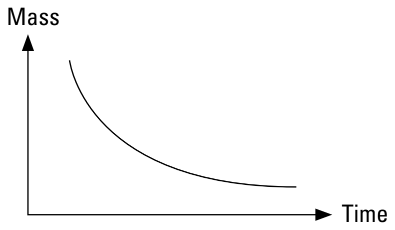
Table 1.2

5. (a) **X** – temperature sensor/probe. **Y** – connector/interface/ data logger. **Z** – computer.
   (b) (i) To measure the temperature of the reaction mixture
   (ii) To display the data on the monitor/screen, often in the form of a graph
   (c) (i)



   (ii) Vertical axis – temperature. Horizontal axis – time.

6. (a) During the reaction, the marble is used up, and the (carbon dioxide) gas produced escapes from the flask.
   (b) (i) Vertical axis – mass. Horizontal axis – time.
   (ii)

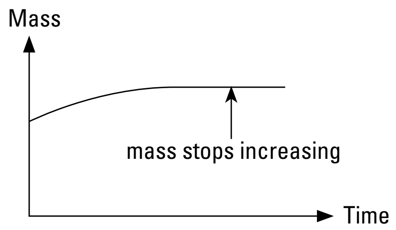


   (iii) As the speed of the reaction decreases with time, the gradient of the graph decreases. When the reaction ends, the graph is flat/horizontal.

Free Response Question (page 12)

Place a bag of silica gel on a balance connected to a computer to record its mass over a period of time. The mass increases as water is absorbed. Plot a graph of mass against time. When the mass stops increasing, the silica gel is no longer absorbing water.

Expected graph:



Extension (page 12)

You may want the students to take either one of the following approaches:

1. Students could research on a variety of measurements used in various countries during different time periods and present their findings on the history of measurement in science chronologically.

2. Students could research on a particular measurement of interest, e.g. temperature, and review its historical development from the invention of the first thermometer by Galileo right up to the modern thermometers.