Chapter 1

Introduction: Matter and Measurement

Visualising Concepts

1.1 Pure elements contain only one kind of atom. Atoms can be present singly or as tightly bound groups called molecules. Compounds contain two or more kinds of atoms bound tightly into molecules. Mixtures contain more than one kind of atom and/or molecule, not bound into discrete particles.
(a) pure element: i
(b) mixture of two elements: v, vi
(c) pure compound: iv
(d) mixture of an element and a compound: ii, iii

1.2 After a physical change, the identities of the substances involved are the same as their identity before the change. That is, molecules retain their original composition. During a chemical change, at least one new substance is produced; rearrangement of atoms into new molecules occurs.
The diagram represents a chemical change, because the molecules after the change are different than the molecules before the change.

1.3

(a)	time	(b)	density	(c)	length	(d)	area
(e)	temperature	(f)	volume	(g)	temperature		

1.4 Measurements (darts) that are close to each other are precise. Measurements that are close to the 'true value' (the bull's eye) are accurate.
(a) Figure ii represents data that are both accurate and precise. The darts are close to the bull's eye and each other.
(b) Figure i represents data that are precise but inaccurate. The darts are near each other but their centre point (average value) is far from the bull's eye.
(c) Figure iii represents data that are imprecise, but their average value is accurate. The darts are far from each other, but their average value, or geometric centre point, is close to the bull's eye.

1.5 (a) 7.5 cm. There are two significant figures in this measurement; the number of cm can be read precisely, but there is some estimating (uncertainty) required to read tenths of a centimetre. Listing two significant figures is consistent with the convention that measured quantities are reported so that there is uncertainty in only the last digit.

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Classification and Properties of Matter

1.6 (a) heterogeneous mixture
(b) homogeneous mixture (If there are undissolved particles, such as sand or decaying plants, the mixture is heterogeneous.)
(c) pure substance
(d) homogeneous mixture

1.7 (a) homogeneous mixture
(b) heterogeneous mixture (particles in liquid)
(c) pure substance
(d) heterogeneous mixture

1.8 (a) S (b) K (c) Cl (d) Cu
(e) Si (f) N (g) Ca (h) He

1.9 (a) C (b) Na (c) F (d) Fe
(e) P (f) Ar (g) Ni (h) Ag

1.10 (a) lithium (b) aluminium (c) lead (d) sulfur
(e) bromine (f) tin (g) chromium (h) zinc

1.11 (a) cobalt (b) iodine (c) krypton
(d) mercury (e) arsenic (f) titanium
(g) potassium (h) germanium

1.12 $A(s) \xrightarrow{\text{heat}} B(s) + C(g)$

When solid carbon is burned in excess of oxygen gas, the two elements combine to form a gaseous compound, carbon dioxide. Clearly, substance C is this compound. Since C is produced when A is heated in the absence of oxygen (from air), both the carbon and oxygen in C must have been present in A originally. A is, therefore, a compound composed of two or more elements chemically combined. Without more information on the chemical or physical properties of B, we cannot determine absolutely whether it is an element or a compound. However, few if any elements exist as white solids, so B is probably also a compound.

1.13 *Physical properties*: silvery white (colour); lustrous; melting point = 649 °C; boiling point = 1105 °C; density at 20 °C = 1.738 g cm^{-3}; pounded into sheets (malleable); drawn into wires (ductile); good conductor.

Chemical properties: burns in air to give intense white light; reacts with Cl_2 to produce brittle white solid.

1.14 (a) chemical (b) physical (c) physical
(d) chemical (e) chemical

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1.15 (a) Take advantage of the different water solubilities of the two solids. Add water to dissolve the sugar; filter this mixture, collecting the sand on the filter paper and the sugar water in the flask. Evaporate the water from the flask to recrystallise solid sugar.

(b) Either the melting-point difference or magnetism difference between iron and sulfur can be used to separate these two elements. Heat the mixture until the sulfur melts, then decant (pour off) the liquid sulfur. Or use a magnet to attract the iron particles, leaving the solid sulfur behind.

1.16 Take advantage of differences in physical properties to separate the components of a mixture. First heat the liquid to 100 °C to evaporate the water. This is conveniently done in a distillation apparatus (FIGURE 1.8) so that the water can be collected. After the water is completely evaporated and **if** there is a residue, measure the physical properties of the residue such as colour, density, and melting point. Compare the observed properties of the residue to those of table salt, NaCl. If the properties match, the colourless liquid contained table salt. If the properties don not match, the liquid contained a different dissolved solid. If there is no residue, no dissolved solid is present.

Units of Measurement

1.17 (a) $1\ \text{mg} = 1\times10^{-3}\ \text{g}$; $25.5\times(1\times10^{-3}\ \text{g}) = 0.0255\ \text{g} = 2.55\times10^{-2}\ \text{g}$

(b) $1\ \text{m} = 1\times10^{9}\ \text{nm}$; $4.0\times10^{-10}\times(1\times10^{9}\ \text{nm}) = 0.40\ \text{nm}$

(c) $1\ \text{mm} = 1\times10^{3}\ \mu\text{m}$; $0.575\times(1\times10^{3}\ \mu\text{m}) = 575\ \mu\text{m}$

1.18 (a) $1\ \text{kg} = 1\times10^{3}\ \text{g}$; $9.5\times10^{-2}\times(1\times10^{3}\ \text{g}) = 95\ \text{g}$

(b) $1\ \mu\text{m} = 1\times10^{3}\ \text{m}$; $0.0023\times(1\times10^{3}\ \text{nm}) = 2.3\ \text{nm}$

(c) $1\ \text{s} = 1\times10^{3}\ \text{ms}$; $7.25\times10^{-4}\times(1\times10^{3}\ \text{ms}) = 0.725\ \text{ms}$

1.19 (a) $\text{density} = \dfrac{\text{mass}}{\text{volume}} = \dfrac{39.73\ \text{g}}{25.0\ \text{cm}^3} = 1.59\ \text{g cm}^{-3}$

Carbon tetrachloride, with a density of 1.59 g cm^{-3}, is more dense than water, 1.00 g cm^{-3}; carbon tetrachloride will sink rather than float on water.

(b) $75.00\ \text{cm}^3\times21.45\ \text{g cm}^{-3} = 1.609\times10^{3}\ \text{g} = 1.609\ \text{kg}$

(c) $\dfrac{87.50\ \text{g}}{1.738\ \text{g cm}^{-3}} = 50.35\ \text{cm}^3$

1.20 (a) volume = length^3 (cm^3); density = mass/volume (g cm^{-3})

volume = $(1.500)^3\ \text{cm}^3 = 3.375\ \text{cm}^3$

$\text{density} = \dfrac{76.31\ \text{g}}{3.375\ \text{cm}^3} = 22.61\ \text{g cm}^{-3}$ osmium

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(b) $65.8 \text{ mL} = 65.8 \text{ cm}^3$

$65.8 \text{ cm}^3 \times 4.51 \text{ g cm}^{-3} = 297 \text{ g titanium}$

(c) $0.1500 \times 1 \times 10^3 \text{ cm}^{-3} \times 0.8787 \text{ g cm}^{-3} = 131.8 \text{ g benzene}$

1.21 (a) $\text{density} = \dfrac{38.5 \text{ g}}{45 \text{ cm}^{-3}} = 0.86 \text{ g cm}^{-3}$

The substance is probably toluene with a density of 0.866 g cm^{-3}.

(b) $\dfrac{45.0 \text{ g}}{1.114 \text{ g cm}^{-3}} = 40.4 \text{ cm}^3 \text{ ethylene glycol}$

(c) $(5.00 \text{ cm})^3 \times 8.90 \text{ g cm}^{-3} = 1.11 \times 10^3 \text{ g} = 1.11 \text{ kg nickel}$

Uncertainty in Measurement

1.22 Exact: (c, d)

1.23 Exact: (a), (d) (The number of students is exact on any given day.)

1.24 (a) 3 (b) 2 (c) 5 (d) 3 (e) 5

1.25 (a) 5 (b) 3 (c) 4 (d) 4 (e) 6

1.26 (a) 1.025×10^2 (b) 6.570×10^5 (c) 8.543×10^{-3}

(d) 2.579×10^{-4} (e) -3.572×10^{-2}

1.27 (a) 1.28×10^4 km (b) 4.001×10^4 km

1.28 (a) 12.0550 + 9.05 = 21.105 = 21.11

For additions and/or subtractions, the figure with the fewest decimal places, in this example 9.05 with two decimal places, determines the decimal places in the resulting number.

(b) 257.2 − 19.789 = 237.4

The figure with the fewest decimal place is 257.2 with one decimal place. Therefore, the resulting number must also have one decimal place.

(c) $(6.21 \times 10^3) \times (0.1050) = 652$

For multiplications and/or divisions, the figure with the fewest significant figures, in this example 6.21 with three significant figures, determines how many significant figures must be in the resulting number.

(d) $0.0577/0.753 = 7.66 \times 10^{-2}$

Since both figures have three significant figures, the resulting number must also have three.

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1.29 (a) $(320.55 - 6104.5/2.3) = -2.3 \times 10^3$

The intermediate result of the fraction has two significant figures, therefore, only two numbers, the thousands and the hundreds place, are significant in the resulting figure.

(b) $(285.3 \times 10^5 - 0.01200 \times 10^5) \times 2.8954 = 8.260 \times 10^7$

Since additions and/or subtractions depend on decimal places, both numbers must have the same exponent to determine decimal places. The intermediate result of the subtraction has one decimal place. Multiplications depend on the count of significant numbers; therefore, the resulting figure must have four significant numbers.

(c) $(0.0045 \times 20{,}000.0) + (2813 \times 12) = 3.4 \times 10^4$
(2 sig fig $\times$ 6 sig fig) + (4 sig fig $\times$ 2 sig fig) = 2 sig fig

(2 sig fig, 0 dec pl) + (2 sig fig, 0 dec pl) = 2 sig fig

(d) $863 \times [1255 - (3.45 \times 108)] = 7.62 \times 10^5$
3 sig fig x [4 sig fig, 0 dec pl – (3 sig fig, 0 dec pl) = 3 sig fig

Additional Exercises

1.30 *Composition* is the contents of a substance, the kinds of elements that are present and their relative amounts.

Structure is the arrangement of these contents.

1.31 (a) A gold coin is probably a *solid solution*. Pure gold (element 79) is too soft to be used for coinage, so other metals are added. However, the simple term 'gold coin' does not give a specific indication of the other metals in the mixture.

A cup of coffee is a *solution* if there are no suspended solids (coffee grounds). It is a heterogeneous mixture if there are grounds. If sugar is added, the homogeneity of the mixture depends on how thoroughly the components are mixed. If milk or cream is added, the suspended particles of fat and protein will make the cup of coffee a heterogeneous mixture.

A wood plank is a *heterogeneous mixture* of cellulose, lignin, water, and other components. The different domains in the mixture have different proportions of these materials and are visible as wood grain or knots.

(b) The ambiguity in each of these examples is that the name of the substance does not provide a chemically complete description of the material. We must rely on mental images, and these vary from person to person.

1.32 (a) A *hypothesis* is a possible explanation for certain phenomena based on preliminary experimental data.

A *theory* may be more general, and has a significant body of experimental evidence to support it; a theory has withstood the test of experimentation.

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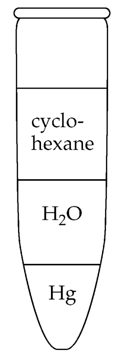
(b) A scientific *law* is a summary or statement of natural behaviour; it tells how matter behaves.

A *theory* is an explanation of natural behaviour; it attempts to explain why matter behaves the way it does.

1.33 The most dense liquid, Hg, will sink; the least dense, cyclohexane, will float; H_2O will be in the middle.



1.34 (a) density = (35.66 g – 14.23 g)/4.59 cm^3 = 4.67 g cm^{-3}

(b) $\frac{34.5 \times (1 \times 10^3 \text{ g})}{13.5 \text{ g cm}^{-3}} = 2560 \text{ cm}^3$

(c) $V = 4/3\ \pi\ r^3 = 4/3\ \pi\ (28.9 \text{ cm})^3 = 1.0111 \times 10^5 \text{ cm}^3$

$= 1.01 \times 10^5 \text{ cm}^3$

$m = V \times \rho = 1.01 \times 10^5 \text{ cm}^3 \times 19.3 \text{ g cm}^{-3} = 1.95 \times 10^6 \text{ g}$

The sphere weighs 1950 kg. The thief is unlikely to be able to carry the sphere.

Note: This is an exercise where 'intermediate rounding' occurs. In this manual, when a solution is given in steps, the intermediate result will be rounded to the correct number of significant figures. However, the **unrounded** number will be used in subsequent calculations. The final answer will appear with the correct number of significant figures. That is, calculators need not be cleared and new numbers entered in the middle of a calculation sequence. This may result in a small discrepancy in the last significant digit between student-calculated answers and those given in the manual. These variations occur in any analysis of numerical data.

For example, in this exercise the volume of the sphere, $1.0111 \times 10^5 \text{ cm}^3$, is rounded to $1.01 \times 10^5 \text{ cm}^3$, but 1.0111×10^5 is retained in the subsequent calculation of mass, 1.95×10^6 g. In this case, $1.01 \times 10^5 \text{ cm}^3 \times 19.3 \text{ g cm}^{-3}$ also yields 1.95×10^6 g. In other exercises, the correctly rounded results of the two methods may not be identical.

1.35 $0.500 \times (1 \times 10^3 \text{ cm}^3) \times 1.28 \text{ g cm}^{-3} = 640 \text{ g battery acid}$

$$640 \text{ g battery acid} \times \frac{38.1 \text{ g sulfuric acid}}{100 \text{ g battery acid}} = 243.84 \text{ g} = 244 \text{ g sulfuric acid}$$

1.36 (a) Let x be mass of Au in jewellery

$9.85 - x$ = mass of Ag in jewellery

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The total volume of jewellery = volume of Au + volume of Ag

$$0.675\ \text{cm}^3 = \frac{x\ \text{g}}{19.3\ \text{g cm}^{-3}} + (9.85 - x)\ \text{g} \times \frac{1}{10.5\ \text{g cm}^{-3}}$$

$$0.675 = \frac{x}{19.3} + \frac{9.85 - x}{10.5} \quad \text{(To solve, multiply both sides by } (19.3 \times 10.5))$$

$$0.675\ (19.3)\ (10.5) = 10.5\ x + (9.85 - x)(19.3)$$

$$136.79 = 10.5\ x + 190.105 - 19.3\ x$$

$$-53.315 = -8.8\ x$$

$$x = 6.06$$

x = 6.06 g Au; 9.85 g total − 6.06 g Au = 3.79 g Ag

$$\text{mass\% Au} = \frac{6.06\ \text{g Au}}{9.85\ \text{g jewelry}} \times 100 = 61.5\%\ \text{Au}$$

(b) 24 carats $\times$ 0.615 = 15 carat gold

1.37 A solution can be separated into components by physical means, so separation would be attempted. If the liquid is a solution, the solute could be a solid or a liquid; these two kinds of solutions would be separated differently. Therefore, divide the liquid into several samples and do different tests on each. Try evaporating the solvent from one sample. If a solid remains, the liquid is a solution and the solute is a solid. If the result is negative, try distilling a sample to see if two or more liquids with different boiling points are present. If this result is negative, the liquid is probably a pure substance, but negative results are never entirely conclusive. We might not have tried the appropriate separation technique.

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