STEWART M. BROOKS

INTEGRATED BASIC SCIENCE

FOURTH EDITION

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STEWART M. BROOKS

Chairman, Science Curriculum,
School of Nursing, Newton-Wellesley Hospital,
Newton Lower Falls, Massachusetts

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THIS BOOK

is for

Louise and Clayton

PREFACE

Integrated Basic Science traces its roots to the early 1950s and to a movement that resulted in the establishment of a number of integrated science programs within various nursing curricula. Specifically, the first edition was in response to an expressed need for a single text that encompassed anatomy and physiology, chemistry, and microbiology as these sciences apply to nursing and other areas of health care. This book essentially continues to be the only work of its kind. It has done well in a variety of health science programs, including nursing. Further, it has proved useful both as a reference textbook and as a review in programs that divide the basic subject areas. All in all, the text has a multidimensional appeal, and every effort has been made to perfect this advantage in the present edition. Of special note, the chapters on measurement and basic physics have been streamlined, and the chapters on basic inorganic chemistry, basic organic chemistry, basic medical microbiology, and the cell have been expanded. Above all, I have been ever mindful of readability, trying my best to be clear and concise. In closing, I wish to thank the many teachers and students who have used this work and all those who are willing to give the new edition a try.

Stewart M. Brooks

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Chapter 1

MEASUREMENT

"Weights and measures," wrote John Quincy Adams in 1821, "may be ranked among the necessaries of life to every individual of human society." One can hardly argue with this statement. Indeed, it applies more today than in 1821, and in biological areas, especially, we witness a steady rise in metrological matters occasioned by the day-to-day influx of physics and chemistry. The blood alone affords a large selection of measurements, ranging from grams per deciliter to millimeters of mercury. The purpose of the present chapter is to provide a workable understanding of these and all the other measurements the reader will encounter throughout this work.

The International System of Units (SI)

The International System of Units is a modernized version of the metric system established by international agreement. It provides a logical and interconnecting framework for all measurements in science, industry, and commerce. Officially abbreviated SI (from the French *Le Système Internationale d'Unité*), the system is built upon a foundation of seven base units, plus two supplementary units. All other SI units are derived from these units. Multiples and submultiples are expressed in a decimal system (Table 1-1). The official definitions of the base units and their more common derived units are presented below.

METER. The **meter** (symbol m) is the SI unit of length, equivalent to 39.37 inches. It was defined in 1790 as one ten-millionth (10^{-7}) of the earth's quadrant passing through Paris, but was redefined in 1960 as the length equal to 1,650,763.73 wavelengths in a vacuum of the orange-red line of the spectrum of krypton 86 (Fig. 1-1). Derived units include the *square meter* (m^2), the SI unit of area, and the *cubic meter* (m^3), the SI unit of volume. The **liter** (symbol l), although not an SI unit, is commonly used to measure the volume of liquids and gases.

KILOGRAM. The **kilogram** (symbol kg) is the SI unit of mass,* equivalent to about 2.2046 pounds. By definition it is the mass of a cylinder of platinum-iridium alloy kept by the International Bureau of Weights and Measures at Paris. A duplicate in the custody of the National Bureau of Standards serves as the mass standard for the United States (Fig. 1-2). Interestingly, the kilogram is the only base unit still defined by an artifact. Derived units include the newton, the pascal, the joule, and the watt. The **newton** (symbol N) is the SI unit of force required to accelerate a mass of one kilogram one meter per second (or $N = kg \cdot m/s^2$) (Fig. 1-3). The **pascal** (symbol Pa), the SI unit of pressure, is equal to one newton per square meter (or $Pa = N/m^2$). The **joule** (symbol J) is the SI unit of work and energy of any kind; it is equal to the work done when the point of

*Although the terms *mass* and *weight* are fundamentally quite distinct, they are often used interchangeably. The mass of a body is the quantity of matter it contains, whereas weight is a measure of the gravitational attraction for a body. An object of a certain mass weighs more on the earth than it would on the moon.

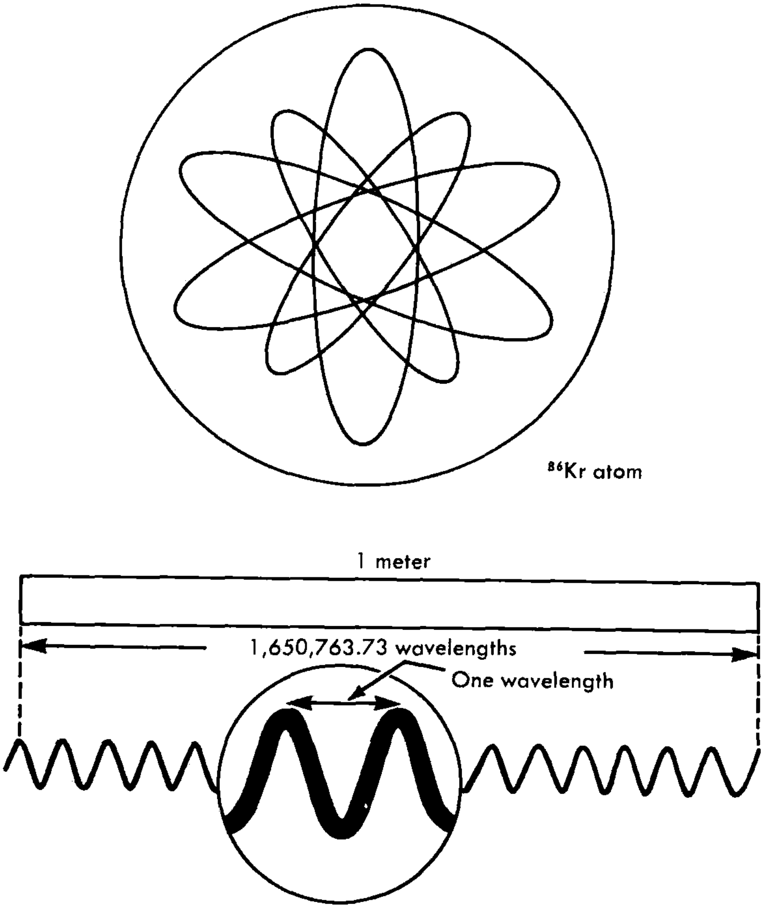

Fig. 1-1. The meter, the SI unit of length, is equal to 1,650,763.73 wavelengths in a vacuum of the orange-red radiation of krypton (Kr-86). This is equal to 39.37 inches. (Courtesy National Bureau of Standards.)

application of a force of one newton is displaced one meter in the direction of the force (or J = N · m). The SI unit for power of any kind is the **watt** (W), which is equal to one joule per second (or W = J/s).

SECOND. The **second** (symbol s), the SI unit of time, is defined as the duration of 9,192,631,770 cycles of radiation associated with a specified transition of the cesium-133 atom. Derived units include the *meter per second* (m/s) for speed, *meter per second per second* (m/s^2) for acceleration, and **hertz** (Hz). One hertz equals one cycle per second.

AMPERE. The **ampere** (symbol A), the SI unit for electric current, is defined as the current that, if maintained in each of two long parallel wires separated by one meter in free space, would produce a force between the two wires (because of their magnetic fields) of 2×10^{-7} newton for each meter of length (Fig. 1-4). Derived units include the **volt** (symbol V) for voltage and **ohm** (Ω) for electric resistance. Volts equal watts divided by amperes (or V = W/A) and ohms equal volts divided by amperes (or Ω = V/A).

KELVIN. The **kelvin** (symbol K with no degree sign), the SI unit of temperature, is equal to $^{1}/_{273.16}$ of the thermodynamic tem-

Table 1-1. Metric system

Length

1 nanometer (nm)	=	0.000000001 meter
1 micrometer (μm)	=	0.000001 meter
1 millimeter (mm)	=	0.001 meter
1 centimeter (cm)	=	0.01 meter
1 decimeter (dm)	=	0.1 meter
meter (m)	=	1 meter
1 dekameter (dkm)	=	10 meters
1 hectometer (hm)	=	100 meters
1 kilometer (km)	=	1,000 meters

Weight

1 microgram (μg)	=	0.000001 gram
1 milligram (mg)	=	0.001 gram
1 centigram (cg)	=	0.01 gram
1 decigram (dg)	=	0.1 gram
gram (g)	=	1 gram
1 dekagram (dkg)	=	10 grams
1 hectogram (hg)	=	100 grams
1 kilogram (kg)	=	1,000 grams

Volume

1 microliter (μl)	=	0.000001 liter
1 milliliter (ml)	=	0.001 liter
1 centiliter (cl)	=	0.01 liter
1 deciliter (dl)	=	0.1 liter
liter (l or L)	=	1.0 liter
1 dekaliter (dkl)	=	10 liters
1 hectoliter (hl)	=	100 liters
1 kiloliter (kl)	=	1,000 liters

Metric-English equivalents

1 meter (m)	=	39.37 inches
1 centimeter (cm)	=	0.3937 inch
1 kilometer (km)	=	0.6214 mile
1 kilogram (kg)	=	2.204 pounds
1 liter (l or L)	=	1.057 quarts (liquid)
1 yard (yd)	=	0.914 meter
1 foot (ft)	=	30.48 centimeters
1 inch (in)	=	2.54 centimeters
1 mile (mi)	=	1.61 kilometers
1 ounce (oz) (avoir.)	=	28.35 grams
1 pound (lb)	=	453.59 grams
1 quart (qt) (liquid)	=	0.956 liter
1 quart (dry)	=	1.101 liters

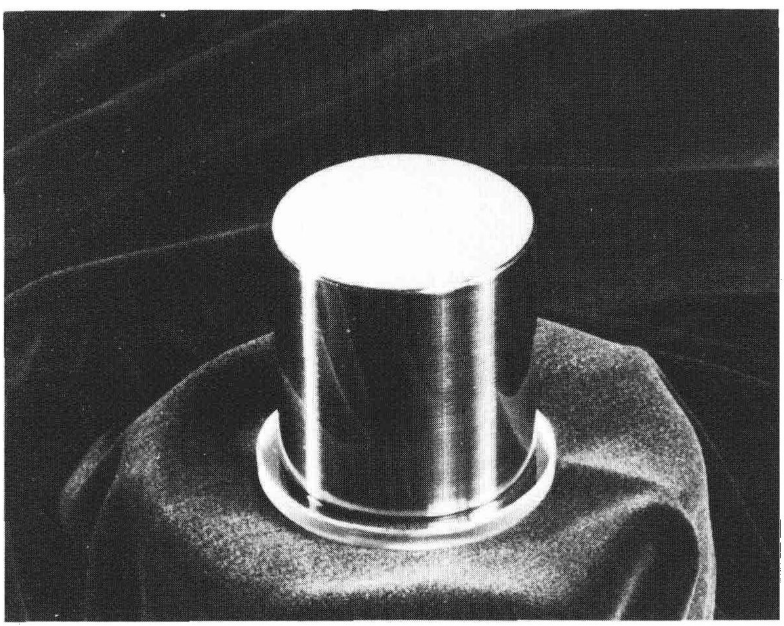

Fig. 1-2. Prototype kilogram 20, the mass standard in the custody of the National Bureau of Standards. It is an exact duplicate of the mass kept by the Internal Bureau of Standards at Sèvres, France. (Courtesy National Bureau of Standards.)

perature of the triple point of water. The temperature 0 K is called *absolute zero*. On the **Celsius** temperature scale, water freezes at about 0° C and boils at about 100° C. A Celsius degree is defined as an interval of 1 K, and the Celsius temperature 0° C is defined as 273.15 K.

MOLE. The **mole** (symbol mol) is the SI unit for the amount of substance of a system that contains as many elemental entities as there are atoms in 0.012 kilogram of carbon 12. In actual use the elementary entities must be given and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles. The SI unit of concentration (amount of substance) is the **mole per cubic meter** (mol/m^3).

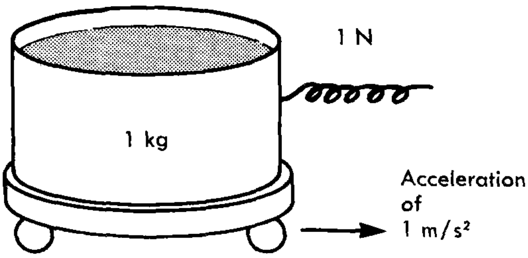

Fig. 1-3. The newton (N), the SI unit of force, is the force that, when applied to a 1-kilogram mass, will produce an acceleration of 1 meter per second per second. (Courtesy National Bureau of Standards.)

CANDELA. The **candela** (symbol cd), the SI unit of luminous intensity, is defined as the luminous intensity of 1/600,000 of a square meter of a blackbody at the temperature of freezing platinum (2045 K); the **lumen** (symbol lm) is the SI unit of light flux. A source having an intensity of 1 candela in all directions radiates a light flux of 4π lumens.

SUPPLEMENTARY UNITS. As noted previously, SI employs two supplementary units —**radian** and **steradian.** The radian is the plane angle with its vertex at the center of a circle that is subtended by an arc equal in length to the radius (Fig. 1-5). The steradian is the solid angle with the vertex at the center of a sphere that is subtended by an area of the spherical surface equal to that of a square with sides equal in length to the radius.

Density

The density of a substance refers to its mass per unit volume under specified or standard conditions of pressure and temperature. For liquids and solids this usually takes the form of **grams per milliliter** (g/ml) or **grams per cubic centimeter** (g/cm^3 or g/cc); for gases **grams per liter** (g/l) is the typical expression.* The density of water, a useful fact to keep in mind, is 1 g/ml (at 4° C).

*For practical purposes the milliliter and cubic centimeter may be considered equal.

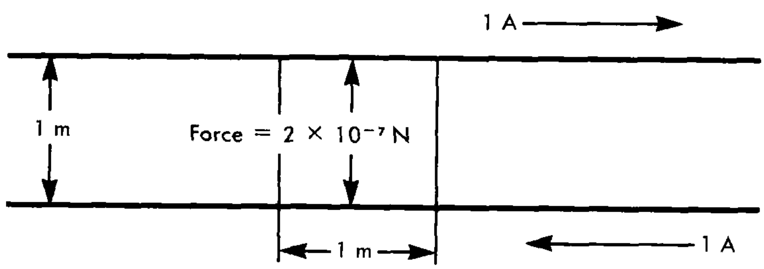

Fig. 1-4. The ampere (A) is defined as the current that, if maintained in each of two long parallel wires (above) separated by 1 meter in free space, would produce a force between the two wires (because of magnetic fields) of 2×10^{-7} newton for each meter of length.