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Environmental Chemistry
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Physical and Chemical Properties

Physical and Chemical Properties

Contents

- Identify properties of and changes in matter as physical or chemical
- Identify properties of matter as extensive or intensive

• تحديد خصائص المادة وتغيراتها الفيزيائية والكيميائية

• تحديد خصائص المادة على أنها واسعة النطاق أو مكثفة.

The characteristics that distinguish one substance from another are called properties. A physical property is a characteristic of matter that is not associated with a change in its chemical composition. Familiar examples of physical properties include density, color, hardness, melting and boiling points, and electrical conductivity. Some physical properties, such as density and color, may be observed without changing the physical state of the matter. Other physical properties, such as the melting temperature of iron or the freezing temperature of water, can only be observed as matter undergoes a physical change. A physical change is a change in the state or properties of matter without any accompanying change in the chemical identities of the substances contained in the matter. Physical changes are observed when wax melts, when sugar dissolves in coffee, and when steam condenses into liquid water (Figure 1). Other examples of physical changes include magnetizing and demagnetizing metals (as is done with common antitheft security tags) and grinding solids into powders (which can sometimes yield noticeable changes in color). In each of these examples, there is a change in the physical state, form, or properties of the substance, but no change in its chemical composition.

الخصائص التي تُميّز مادة عن أخرى تُسمى الخواص. الخاصية الفيزيائية هي خاصية للمادة لا ترتبط بتغير في تركيبها الكيميائي. من الأمثلة المألوفة على الخواص الفيزيائية: الكثافة، واللون، والصلابة، ودرجتي الانصهار والغليان، والتوصيل الكهربائي. يمكن ملاحظة بعض الخواص الفيزيائية، كالكثافة واللون، دون تغيير الحالة الفيزيائية للمادة.

أما الخواص الفيزيائية الأخرى، كدرجة انصهار الحديد أو درجة تجمد الماء، فلا تُلاحظ إلا عند خضوع المادة لتغير فيزيائي. التغير الفيزيائي هو تغير في حالة المادة أو خصائصها دون أي تغير مصاحب في الخصائص الكيميائية للمواد التي تحتويها. تُلاحظ التغيرات الفيزيائية عند ذوبان الشمع، وعند ذوبان السكر في القهوة، وعند تكثف البخار إلى ماء سائل الشكل (1). ومن الأمثلة الأخرى على التغيرات الفيزيائية: مغنطة المعادن وإزالة مغنطتها (كما هو الحال مع بطاقات الأمان الشائعة ضد السرقة)، وطحن المواد الصلبة إلى مسحوق (مما قد يؤدي أحياناً إلى تغيرات ملحوظة في اللون). في كل من هذه الأمثلة، هناك تغيير في الحالة الفيزيائية، أو الشكل، أو خصائص المادة، ولكن لا يوجد تغيير في تركيبها الكيميائي.



(a)



(b)

(a) Wax undergoes a physical change when solid wax is heated and forms liquid wax. (b) Steam condensing inside a cooking pot is a physical change, as water vapor is changed into liquid water.

(أ) يتعرض الشمع لتغير فيزيائي عندما يتم تسخين الشمع الصلب ويشكل شمعًا سائلًا

(ب) يعد تكثف البخار داخل وعاء الطهي تغيرًا فيزيائيًا، حيث يتحول بخار الماء إلى ماء سائل.

A chemical change always produces one or more types of matter that differ from the matter present before the change. The formation of rust is a chemical change because rust is a different kind of matter than the iron, oxygen, and water present before the rust formed. The explosion of nitroglycerin is a chemical change because the gases produced are very different kinds of matter from the original substance. Other examples of chemical changes include reactions that are performed in a lab (such as copper reacting with nitric acid), all forms of combustion (burning), and food being cooked, digested, or rotting (Figure 2).

يُنتج التغير الكيميائي دائماً نوعاً واحداً أو أكثر من المواد يختلف عن المادة الموجودة قبل التغير. يُعدّ تكوّن الصدأ تغيراً كيميائياً لأن الصدأ مادة مختلفة عن الحديد والأكسجين والماء الموجودة قبل تكوّنه. يُعدّ انفجار النيتروجلسرين تغيراً كيميائياً لأن الغازات الناتجة مواد مختلفة تماماً عن المادة الأصلية. ومن الأمثلة الأخرى على التغيرات الكيميائية التفاعلات التي تُجرى في المختبر (مثل تفاعل النحاس مع حمض النيتريك)، وجميع أشكال الاحتراق (الحرق)، وطهي الطعام أو هضمه أو تعفنه (الشكل 2).



(a)



(b)



(c)



(d)

(a) Copper and nitric acid undergo a chemical change to form copper nitrate and brown, gaseous nitrogen dioxide. (b) During the combustion of a match, cellulose in the match and oxygen from the air undergo a chemical change to form carbon dioxide and water vapor. (c) Cooking red meat causes a number of chemical changes, including the oxidation of iron in myoglobin that results in the familiar red-to-brown color change. (d) A banana turning brown is a chemical change as new, darker (and less tasty) substances form.

(أ) يخضع النحاس وحمض النيتريك لتغير كيميائي لتكوين نترات النحاس وثاني أكسيد النيتروجين الغازي البني. (ب) أثناء احتراق عود ثقاب، يخضع السليلوز في عود الثقاب والأكسجين من الهواء لتغير كيميائي لتكوين ثاني أكسيد الكربون وبخار الماء. (ج) يؤدي طهي اللحوم الحمراء إلى عدد من التغيرات الكيميائية، بما في ذلك أكسدة الحديد في الميوغلوبين مما يؤدي إلى تغيير اللون الأحمر إلى البني المألوف. (د) إن تحول الموز إلى اللون البني هو تغير كيميائي حيث تتشكل مواد جديدة أغمق (وأقل طعمًا).

Properties of matter fall into one of two categories. If the property depends on the amount of matter present, it is an extensive property. The mass and volume of a substance are examples of extensive properties; for instance, a gallon of milk has a larger mass than a cup of milk. The value of an extensive property is directly proportional to the amount of matter in question. If the property of a sample of matter does not depend on the amount of matter present, it is an intensive property. Temperature is an example of an intensive property. If the gallon and cup of milk are each at 20 °C (room temperature), when they are combined, the temperature remains at 20 °C. As another example, consider the distinct but related properties of heat and temperature. A drop of hot cooking oil splattered on your arm causes brief, minor discomfort, whereas a pot of hot oil yields severe burns. Both the drop and the pot of oil are at the same temperature (an intensive property), but the pot clearly contains much more heat (extensive property).

تنقسم خصائص المادة إلى فئتين. إذا كانت الخاصية تعتمد على كمية المادة الموجودة، فهي خاصية واسعة. كتلة وحجم المادة مثالان على الخصائص الواسعة؛ على سبيل المثال، جالون من الحليب له كتلة أكبر من كوب من الحليب. قيمة الخاصية الواسعة تتناسب طردياً مع كمية المادة المعنية. إذا كانت خاصية عينة من المادة لا تعتمد على كمية المادة الموجودة، فهي خاصية مكثفة. درجة الحرارة مثال على الخاصية المكثفة. إذا كان جالون وكوب الحليب كل منهما عند 20 درجة مئوية (درجة حرارة الغرفة)، فعند دمجهما، تبقى درجة الحرارة عند 20 درجة مئوية. كمثال آخر، ضع في اعتبارك الخصائص المتميزة ولكن المرتبطة للحرارة ودرجة الحرارة. قطرة من زيت الطهي الساخن المتناثر على ذراعك تسبب انزعاجاً قصيراً وبسيطاً، بينما ينتج عن قدر من الزيت الساخن حروق شديدة. كل من القطرة ووعاء الزيت لهما نفس درجة الحرارة (خاصية مكثفة)، ولكن من الواضح أن القدر يحتوي على حرارة أكبر بكثير (خاصية واسعة).

Measurements

Contents

- Explain the process of measurement
- Identify the three basic parts of a quantity
- Describe the properties and units of length, mass, volume, density, temperature, and time
- Perform basic unit calculations and conversions in the metric and other unit systems

شرح عملية القياس.

تحديد الأجزاء الأساسية الثلاثة للكمية.

وصف خصائص ووحدات الطول، والكتلة، والحجم، والكثافة، ودرجة الحرارة، والزمن.

• إجراء حسابات الوحدات الأساسية وتحويلها في النظام المتري وأنظمة الوحدات الأخرى.

Measurements provide much of the information that informs the hypotheses, theories, and laws describing the behavior of matter and energy in both the macroscopic and microscopic domains of chemistry. Every measurement provides three kinds of information: the size or magnitude of the measurement (a number); a standard of comparison for the measurement (a unit); and an indication of the uncertainty of the measurement. While the number and unit are explicitly represented when a quantity is written, the uncertainty is an aspect of the measurement result that is more implicitly represented and will be discussed later.

تُوفّر القياسات جزءًا كبيرًا من المعلومات التي تُبنى عليها الفرضيات والنظريات والقوانين التي تصف سلوك المادة والطاقة في المجالين المجهرى والعيانى للكيمياء. يُقدم كل قياس ثلاثة أنواع من المعلومات: حجم أو مقدار القياس (رقم)؛ ومعيّار مقارنة للقياس (وحدة)؛ ومؤشّرًا على عدم اليقين في القياس. في حين يُمثّل الرقم والوحدة صراحةً عند كتابة الكمية، فإن عدم اليقين هو جانب من جوانب نتيجة القياس يُمثّل بشكل ضمني.

Units, such as liters, pounds, and centimeters, are standards of comparison for measurements. A 2-liter bottle of a soft drink contains a volume of beverage that is twice that of the accepted volume of 1 liter. The meat used to prepare a 0.25-pound hamburger weighs one-fourth as much as the accepted weight of 1 pound. Without units, a number can be meaningless, confusing, or possibly life threatening. Suppose a doctor prescribes phenobarbital to control a patient's seizures and states a dosage of "100" without specifying units. Not only will this be confusing to the medical professional giving the dose, but the consequences can be dire: 100 mg given three times per day can be effective as an anticonvulsant, but a single dose of 100 g is more than 10 times the lethal amount.

Base Units of the SI System

Property Measured	Name of Unit	Symbol of Unit
length	meter	m
mass	kilogram	kg
time	second	s
temperature	kelvin	K
electric current	ampere	A
amount of substance	mole	mol
luminous intensity	candela	cd

Everyday measurement units are often defined as fractions or multiples of other units. Milk is commonly packaged in containers of 1 gallon (4 quarts), 1 quart (0.25 gallon), and one pint (0.5 quart). This same approach is used with SI units, but these fractions or multiples are always powers of 10. Fractional or multiple SI units are named using a prefix and the name of the base unit. For example, a length of 1000 meters is also called a kilometer because the prefix kilo means “one thousand,” which in scientific notation is 10^3 (1 kilometer = 1000 m = 10^3 m). The prefixes used and the powers to which 10 are raised are listed in Table 1.3.

Common Unit Prefixes

Prefix	Symbol	Factor	Example
femto	f	10^{-15}	1 femtosecond (fs) = 1×10^{-15} s (0.000000000000001 s)
pico	p	10^{-12}	1 picometer (pm) = 1×10^{-12} m (0.000000000001 m)
nano	n	10^{-9}	4 nanograms (ng) = 4×10^{-9} g (0.000000004 g)
micro	μ	10^{-6}	1 microliter (μ L) = 1×10^{-6} L (0.000001 L)

Common Unit Prefixes

Prefix	Symbol	Factor	Example
milli	m	10^{-3}	2 millimoles (mmol) = 2×10^{-3} mol (0.002 mol)
centi	c	10^{-2}	7 centimeters (cm) = 7×10^{-2} m (0.07 m)
deci	d	10^{-1}	1 deciliter (dL) = 1×10^{-1} L (0.1 L)
kilo	k	10^3	1 kilometer (km) = 1×10^3 m (1000 m)
mega	M	10^6	3 megahertz (MHz) = 3×10^6 Hz (3,000,000 Hz)
giga	G	10^9	8 gigayears (Gyr) = 8×10^9 yr (8,000,000,000 yr)
tera	T	10^{12}	5 terawatts (TW) = 5×10^{12} W (5,000,000,000,000 W)

SI Base Units

The initial units of the metric system, which eventually evolved into the SI system, were established in France during the French Revolution. The original standards for the meter and the kilogram were adopted there in 1799 and eventually by other countries. This section introduces four of the SI base units commonly used in chemistry.

وُضعت الوحدات الأولية للنظام المتري، والتي تطورت لاحقًا إلى نظام الوحدات الدولي (SI)، في فرنسا خلال الثورة الفرنسية. واعتمدت فرنسا المعايير الأصلية للمتر والكيلوغرام هناك عام ١٧٩٩، ثم اعتمدتها دول أخرى لاحقًا. يقدم هذا القسم أربعًا من وحدات النظام الدولي الأساسية الشائعة الاستخدام في الكيمياء.

SI Base Units

Length

The standard unit of **length** in both the SI and original metric systems is the **meter (m)**. A meter was originally specified as 1/10,000,000 of the distance from the North Pole to the equator. It is now defined as the distance light in a vacuum travels in 1/299,792,458 of a second. A meter is about 3 inches longer than a yard; one meter is about 39.37 inches or 1.094 yards. Longer distances are often reported in kilometers ($1 \text{ km} = 1000 \text{ m} = 10^3 \text{ m}$), whereas shorter distances can be reported in centimeters ($1 \text{ cm} = 0.01 \text{ m} = 10^{-2} \text{ m}$) or millimeters ($1 \text{ mm} = 0.001 \text{ m} = 10^{-3} \text{ m}$).

SI Base Units

Mass

The standard unit of mass in the SI system is the kilogram (kg). A kilogram was originally defined as the mass of a liter of water (a cube of water with an edge length of exactly 0.1 meter). It is now defined by a certain cylinder of platinum-iridium alloy, which is kept in France. Any object with the same mass as this cylinder is said to have a mass of 1 kilogram. One kilogram is about 2.2 pounds. The gram (g) is exactly equal to 1/1000 of the mass of the kilogram (10^{-3} kg).

SI Base Units

Temperature

Temperature is an intensive property. The SI unit of temperature is the kelvin (K). The IUPAC convention is to use kelvin (all lowercase) for the word, K (uppercase) for the unit symbol, and neither the word “degree” nor the degree symbol ($^{\circ}$). The degree Celsius ($^{\circ}\text{C}$) is also allowed in the SI system, with both the word “degree” and the degree symbol used for Celsius measurements. Celsius degrees are the same magnitude as those of kelvin, but the two scales place their zeros in different places. Water freezes at 273.15 K (0°C) and boils at 373.15 K (100°C) by definition, and normal human body temperature is approximately 310 K (37°C). The conversion between these two units and the Fahrenheit scale will be discussed later in this chapter.

SI Base Units

Time

The SI base unit of time is the second (s). Small and large time intervals can be expressed with the appropriate prefixes; for example, 3 microseconds = $0.000003 \text{ s} = 3 \times 10^{-6} \text{ s}$ and 5 megaseconds = $5,000,000 \text{ s} = 5 \times 10^6 \text{ s}$.

Alternatively, hours, days, and years can be used.

Derived SI Units

Volume

Volume is the measure of the amount of space occupied by an object. The standard SI unit of volume is defined by the base unit of length (Figure 3). The standard volume is a cubic meter (m^3), a cube with an edge length of exactly one meter. To dispense a cubic meter of water, we could build a cubic box with edge lengths of exactly one meter. This box would hold a cubic meter of water or any other substance.

A more commonly used unit of volume is derived from the decimeter (0.1 m, or 10 cm). A cube with edge lengths of exactly one decimeter contains a volume of one cubic decimeter (dm^3). A liter (L) is the more common name for the cubic decimeter.

A cubic centimeter (cm^3) is the volume of a cube with an edge length of exactly one centimeter. The abbreviation cc (for cubic centimeter) is often used by health professionals. A cubic centimeter is equivalent to a milliliter (mL) and is 1/1000 of a liter.

Derived SI Units

Volume

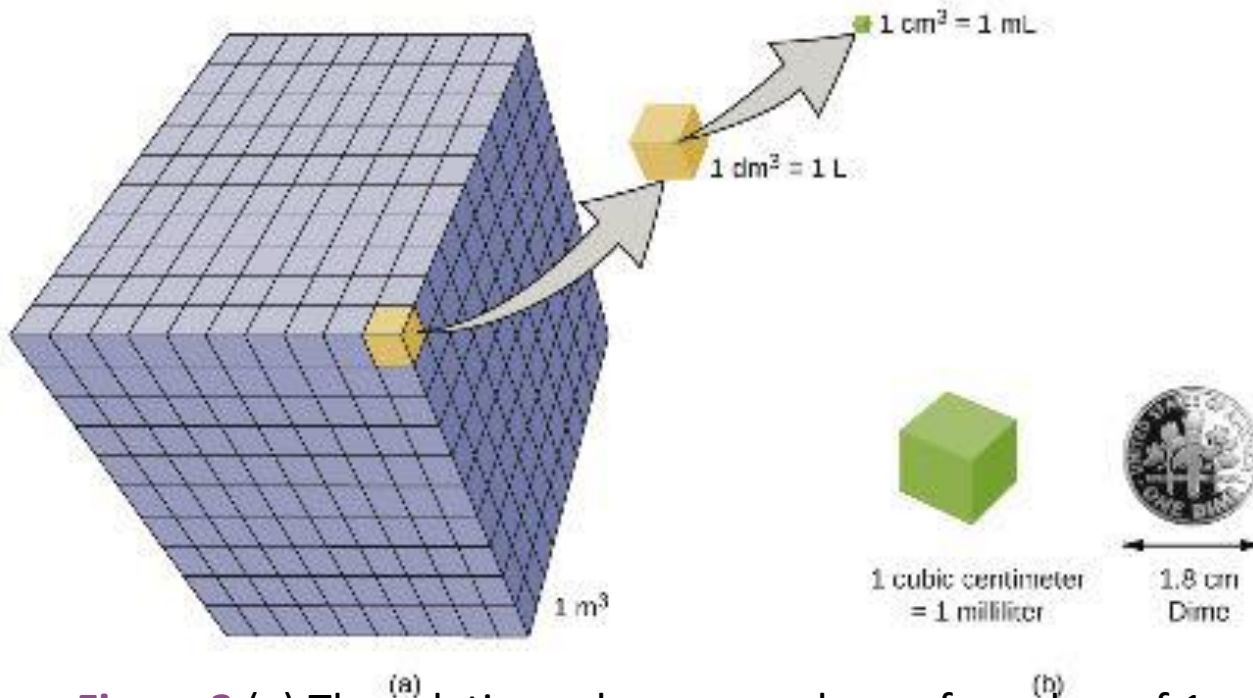


Figure 3 (a) The relative volumes are shown for cubes of 1 m³, 1 dm³ (1 L), and 1 cm³ (1 mL) (not to scale). (b) The diameter of a dime is compared relative to the edge length of a 1-cm³ (1-mL) cube.

Derived SI Units

Density

The density of a substance is the ratio of the mass of a sample of the substance to its volume. The SI unit for density is the kilogram per cubic meter (kg/m^3).

For many situations, however, this is an inconvenient unit, and we often use grams per cubic centimeter (g/cm^3) for the densities of solids and liquids, and grams per liter (g/L) for gases.

Although there are exceptions, most liquids and solids have densities that range from about 0.7 g/cm^3 (the density of gasoline) to 19 g/cm^3 (the density of gold). The density of air is about 1.2 g/L .

Derived SI Units

Density

Densities of Common Substances

Solids	Liquids	Gases (at 25 °C and 1 atm)
ice (at 0 °C) 0.92 g/cm ³	water 1.0 g/cm ³	dry air 1.20 g/L
oak (wood) 0.60–0.90 g/cm ³	ethanol 0.79 g/cm ³	oxygen 1.31 g/L
iron 7.9 g/cm ³	acetone 0.79 g/cm ³	nitrogen 1.14 g/L
copper 9.0 g/cm ³	glycerin 1.26 g/cm ³	carbon dioxide 1.80 g/L
lead 11.3 g/cm ³	olive oil 0.92 g/cm ³	helium 0.16 g/L
silver 10.5 g/cm ³	gasoline 0.70–0.77 g/cm ³	neon 0.83 g/L
gold 19.3 g/cm ³	mercury 13.6 g/cm ³	radon 9.1 g/L

Derived SI Units

Density

Example 1.1

Calculation of Density

Gold—in bricks, bars, and coins—has been a form of currency for centuries. In order to swindle people into paying for a brick of gold without actually investing in a brick of gold, people have considered filling the centers of hollow gold bricks with lead to fool buyers into thinking that the entire brick is gold. It does not work: Lead is a dense substance, but its density is not as great as that of gold, 19.3 g/cm^3 . What is the density of lead if a cube of lead has an edge length of 2.00 cm and a mass of 90.7 g ?

Solution

The density of a substance can be calculated by dividing its mass by its volume. The volume of a cube is calculated by cubing the edge length.

$$\begin{aligned}\text{volume of lead cube} &= 2.00 \text{ cm} \times 2.00 \text{ cm} \times 2.00 \text{ cm} = 8.00 \text{ cm}^3 \\ \text{density} &= \frac{\text{mass}}{\text{volume}} = \frac{90.7 \text{ g}}{8.00 \text{ cm}^3} = \frac{11.3 \text{ g}}{1.00 \text{ cm}^3} = 11.3 \text{ g/cm}^3\end{aligned}$$

(We will discuss the reason for rounding to the first decimal place in the next section.)

Check Your Learning

- (a) To three decimal places, what is the volume of a cube (cm^3) with an edge length of 0.843 cm ?
- (b) If the cube in part (a) is copper and has a mass of 5.34 g , what is the density of copper to two decimal places?

Answer: (a) 0.599 cm^3 ; (b) 8.91 g/cm^3