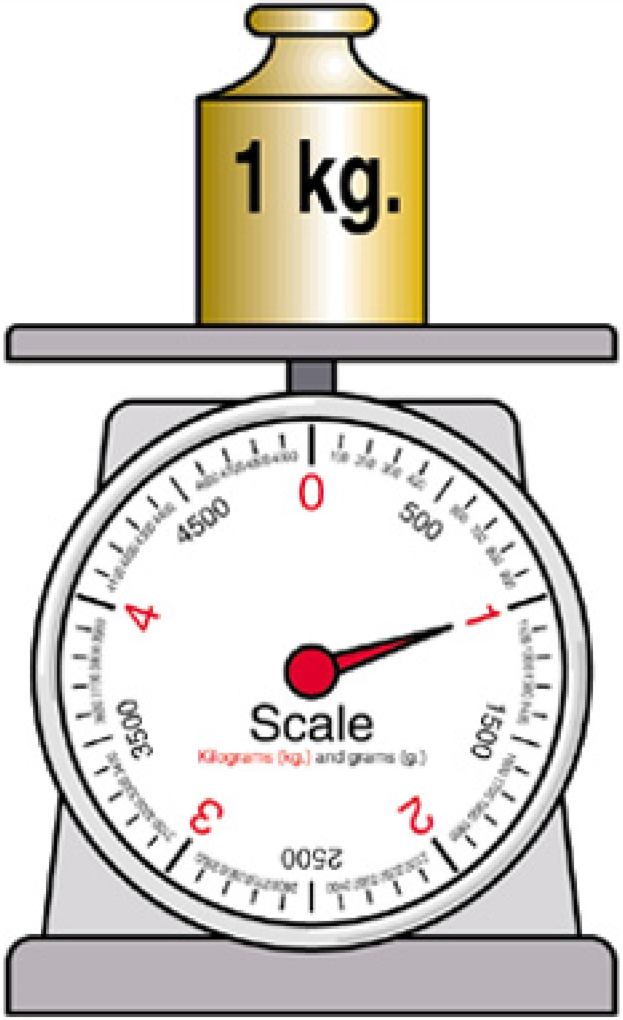
Units of Mass



1 kilogram = 1000 grams

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Kilogram

Kilogram

A computer-generated image of the *international prototype kilogram* (IPK). The IPK *is* the kilogram. The IPK, which is roughly the size of a golf ball, sits here alongside a ruler. The IPK is made of a platinum-iridium alloy and is stored in a vault at the International Bureau of Weights and Measures in Sèvres, France. Like the other prototypes, the edges of the IPK have a four-angle chamfer to minimize wear. For other kilogram-related images.

Unit information	
Unit system:	SI base unit
Unit of...	Mass
Symbol:	kg
Unit conversions	
1 kg in...	is equal to...
U.S. customary	≈ 2.205 pounds
Natural units	≈ 4.59×10^7 Planck masses ≈$1.356392733(68) \times 10^{50}$ hertz

The **kilogram** (symbol: kg) is the base unit of mass in the International System of Units (**SI**, from the French ***S****ystème* ***i****nternational d'unités*), which is the modern standard governing the metric system. The kilogram is defined as being equal to the mass of the *international prototype kilogram* (IPK), which is almost exactly equal to the mass of one liter of water. It is the only SI base unit with an SI prefix as part of its name. It is also the only SI unit that is still defined by an artifact, whereas all other SI units have been redefined using a fundamental physical property that can be reproduced in adequately equipped laboratories.

In everyday usage, the mass of an object is often referred to as its weight though these are in fact different concepts and quantities. In scientific contexts, mass refers to the amount of matter in an object, whereas weight refers to the force experienced by an object due to gravity once it has come to rest against another object. In other words, an object with a mass of one kilogram will weigh one kilogram on Earth, less on Mars, much more on Saturn, and nothing in space and in free fall close to planets and other objects. Throughout most of the world, force is measured with the SI unit newton and the non-SI unit kilogram-force. Similarly, the avoirdupois (or *international*) pound, used in both the imperial system and U.S. customary units, is a unit of mass and its related unit of force is the pound-force. The avoirdupois pound is defined as exactly 0.45359237 kg, making one kilogram approximately equal to 2.2046 avoirdupois pounds.

Many units in the SI system are defined relative to the kilogram, so its stability is important. After the international prototype kilogram had been found to vary in mass over time, the International Committee for Weights and Measures (known also by its French-language initials CIPM) recommended in 2005 that the kilogram be redefined in terms of a fundamental constant of nature. No final decision is expected before 2015.

Nature of mass

The chains on the swing hold all the child’s weight. If one were to stand behind her at the bottom of the arc and try to stop her, one would be acting against her inertia, which arises purely from mass, not weight.

The kilogram is a unit of mass, the measurement of which corresponds to the general, everyday notion of how “heavy” something is. However, mass is actually an *inertial* property; that is, the tendency of an object to remain at constant velocity unless acted upon by an outside force. According to Sir Isaac Newton's 324-year-old laws of motion and an important formula that sprang from his work, $F = ma$, an object with a mass, m, of one kilogram will accelerate, a, at one meter per second per second (about one-tenth the acceleration due to earth’s gravity) when acted upon by a force, F, of one newton.

While the *weight* of matter is entirely dependent upon the strength of gravity, the *mass* of matter is invariant. Accordingly, for astronauts in microgravity, no effort is required to hold objects off the cabin floor; they are “weightless”. However, since objects in microgravity still retain their mass and inertia, an astronaut must exert ten times as much force to accelerate a 10-kilogram object at the same rate as a 1-kilogram object.

On earth, a common swing set can demonstrate the relationship of force, mass, and acceleration without being appreciably influenced by weight (downward force). If one were to stand behind a large adult sitting stationary in a swing and give him a strong push, the adult would accelerate relatively slowly and swing only a limited distance forwards before beginning to swing backwards. Exerting that same effort while pushing on a small child would produce much greater acceleration.

History

Early definitions

On 7 April 1795, the gram was decreed in France to be equal to "the absolute weight of a volume of water equal to the cube of the hundredth part of the meter, at the temperature of melting ice." The concept of using a specified volume of water to define a unit measure of mass was first advanced by the English philosopher John Wilkins in 1668.

Since trade and commerce typically involve items significantly more massive than one gram, and since a mass standard made of water would be inconvenient and unstable, the regulation of commerce necessitated the manufacture of a *practical realization* of the water-based definition of mass. Accordingly, a provisional mass standard was made as a single-piece, metallic artifact one thousand times more massive than the gram—the kilogram.

At the same time, work was commissioned to precisely determine the mass of a cubic decimeter (one liter) of water. Although the decreed definition of the kilogram specified water at 0 °C—its highly stable *temperature* point—the French chemist, Louis Lefèvre-Gineau and the Italian naturalist, Giovanni Fabbroni after several years of research chose to redefine the standard in 1799 to water's most stable *density* point: the temperature at which water reaches maximum density, which was measured at the time as 4 °C. They concluded that one cubic decimeter of water at its maximum density was equal to 99.9265% of the target mass of the provisional kilogram standard made four years earlier. That same year, 1799, an all-platinum kilogram prototype was fabricated with the objective that it would equal, as close as was scientifically feasible for the day, the mass of one cubic decimeter of water at 4 °C. The prototype was presented to the Archives of the Republic in June and on 10 December 1799, the prototype was formally ratified as the *kilogramme des Archives* (Kilogram of the Archives) and the kilogram was defined as being equal to its mass. This standard stood for the next ninety years.

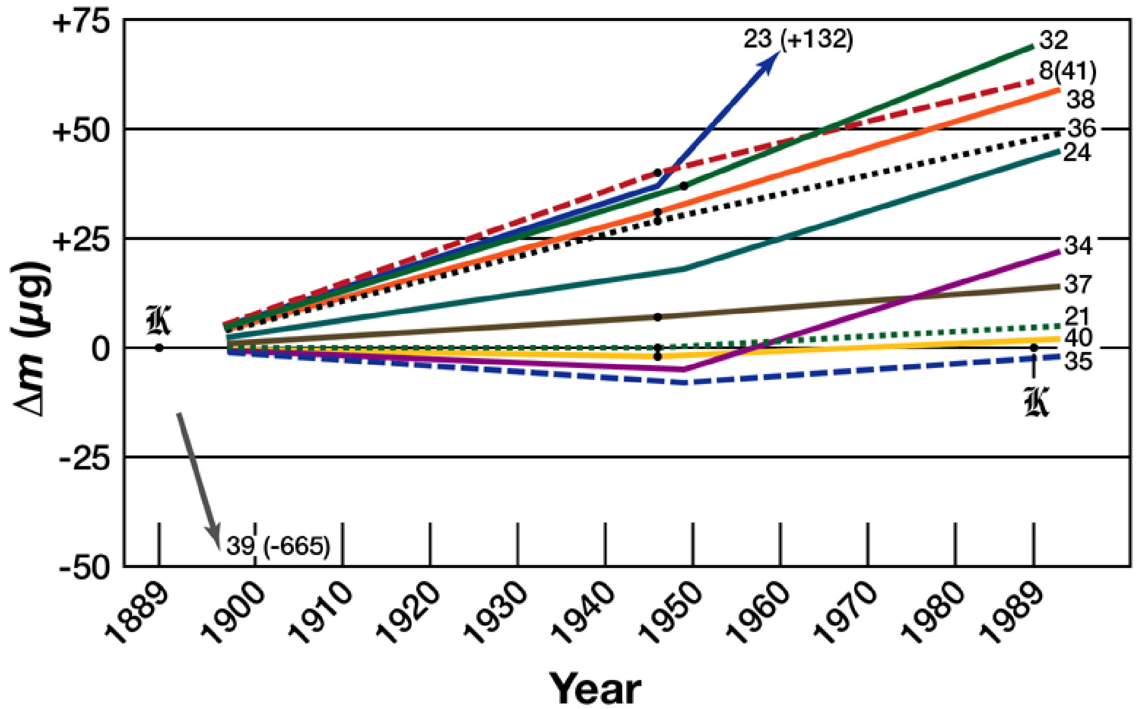
International prototype kilogram

The Metre Convention was signed on 20 May 1875 and established the SI system, which since 1889 defines the magnitude of the kilogram to be equal to the mass of the *international prototype kilogram*, often referred to in the professional metrology world as the "IPK". The IPK is made of a platinum alloy known as "Pt-10Ir", which is 90% platinum and 10% iridium (by mass) and is machined into a right-circular cylinder (height = diameter) of 39.17 millimeters to minimize its surface area. The addition of 10% iridium improved upon the all-platinum Kilogram of the Archives by greatly increasing hardness while still retaining platinum's many virtues: extreme resistance to oxidation, extremely high density (more than twice as dense as lead and more than 21 times as dense as water), satisfactory electrical and thermal conductivities, and low magnetic susceptibility. The IPK and its six sister copies are stored at the International Bureau of Weights and Measures (known by its French-language initials BIPM) in an environmentally monitored safe in the lower vault located in the basement of the BIPM's House of Breteuil in Sèvres on the outskirts of Paris. Three independently controlled keys are required to open the vault. Official copies of the IPK were made available to other nations to serve as their national standards. These are compared to the IPK roughly every 50 years.

The IPK is one of three cylinders made in 1879. In 1883, it was found to be indistinguishable from the mass of the Kilogram of the Archives made eighty-four years prior, and was formally ratified as *the* kilogram by the 1st CGPM in 1889.

Modern measurements of Vienna Standard Mean Ocean Water, which is pure distilled water with an isotopic composition representative of the average of the world's oceans, show it has a density of 0.999975 ±0.000001 kg/L at its point of maximum density (3.984 °C) under one standard atmosphere (760 torr) of pressure. Thus, a cubic decimeter of water at its point of maximum density is only 25 parts per million less massive than the IPK; that is to say, the 25 milligram difference shows that the scientists over 212 years ago managed to make the mass of the Kilogram of the Archives equal that of a cubic decimeter of water at 4 °C to within the mass of a single excess grain of rice.

Stability of the international prototype kilogram



Mass drift over time of national prototypes K21–K40, plus two of the IPK's sister copies: K32 and K8(41). All mass changes are relative to the IPK. The initial 1889 starting-value offsets relative to the IPK have been nulled. The above are all *relative* measurements; no historical mass-measurement data is available to determine which of the prototypes has been most stable relative to an invariant of nature. There is the distinct possibility that *all* the prototypes gained mass over 100 years and that K21, K35, K40, and the IPK simply *gained less* than the others.

By definition, the error in the measured value of the IPK's mass is exactly zero; the IPK *is* the kilogram. However, any changes in the IPK's mass over time can be deduced by comparing its mass to that of its official copies stored throughout the world, a process called "periodic verification." For instance, the U.S. owns four 90% platinum / 10% iridium (Pt-10Ir) kilogram standards, two of which, K4 and K20, are from the original batch of 40 replicas delivered in 1884. The K20 prototype was designated as the primary national standard of mass for the U.S. Both of these, as well as those from other nations, are periodically returned to the BIPM for verification.

Note that none of the replicas has a mass precisely equal to that of the IPK; their masses are calibrated and documented as offset values. For instance, K20, the U.S.'s primary standard, originally had an official mass of 1 kg − 39 micrograms (µg) in 1889; that is to say, K20 was 39 µg less than the IPK. A verification performed in 1948 showed a mass of 1 kg − 19 µg. The latest verification performed in 1999 shows a mass precisely identical to its original 1889 value. Quite unlike transient variations such as this, the

U.S.'s check standard, K4, has persistently declined in mass relative to the IPK—and for an identifiable reason. Check standards are used much more often than primary standards and are prone to scratches and other wear. K4 was originally delivered with an official mass of 1 kg − 75 µg in 1889, but as of 1989 was officially calibrated at 1 kg − 106 µg and ten years later was 1 kg − 116 µg. Over a period of 110 years, K4 lost 41 µg relative to the IPK.

Beyond the simple wear that check standards can experience, the mass of even the carefully stored national prototypes can drift relative to the IPK for a variety of reasons, some known and some unknown. Since the IPK and its replicas are stored in air (albeit under two or more nested bell jars), they gain mass through adsorption of atmospheric contamination onto their surfaces. Accordingly, they are cleaned in a process the BIPM developed between 1939 and 1946 known as "the BIPM cleaning method" that comprises lightly rubbing with a chamois soaked in equal parts ether and ethanol, followed by steam cleaning with bi-distilled water, and allowing the prototypes to settle for 7–10 days before verification. Cleaning the prototypes removes between 5 and 60 µg of contamination depending largely on the time elapsed since the last cleaning. Further, a second cleaning can remove up to 10 µg more. After cleaning—even when they are stored under their bell jars—the IPK and its replicas immediately begin gaining mass again. The BIPM even developed a model of this gain and concluded that it averaged 1.11 µg per month for the first 3 months after cleaning and then decreased to an average of about 1 µg per year thereafter. Since check standards like K4 are not cleaned for routine calibrations of other mass standards—a precaution to minimize the potential for wear and handling damage—the BIPM's model of time-dependent mass gain has been used as an "after cleaning" correction factor.

K48, above, came from the second batch of kilogram replicas to be produced. It was delivered to Denmark in 1949 with an official mass of 1 kg + 81 µg. Like all other replicas, it is stored under two nested bell jars virtually all the time. Still, its mass and that of the IPK diverged markedly in only 40 years; the mass of K48 was certified as 1 kg + 112 µg during the 1988–1992 periodic verification.

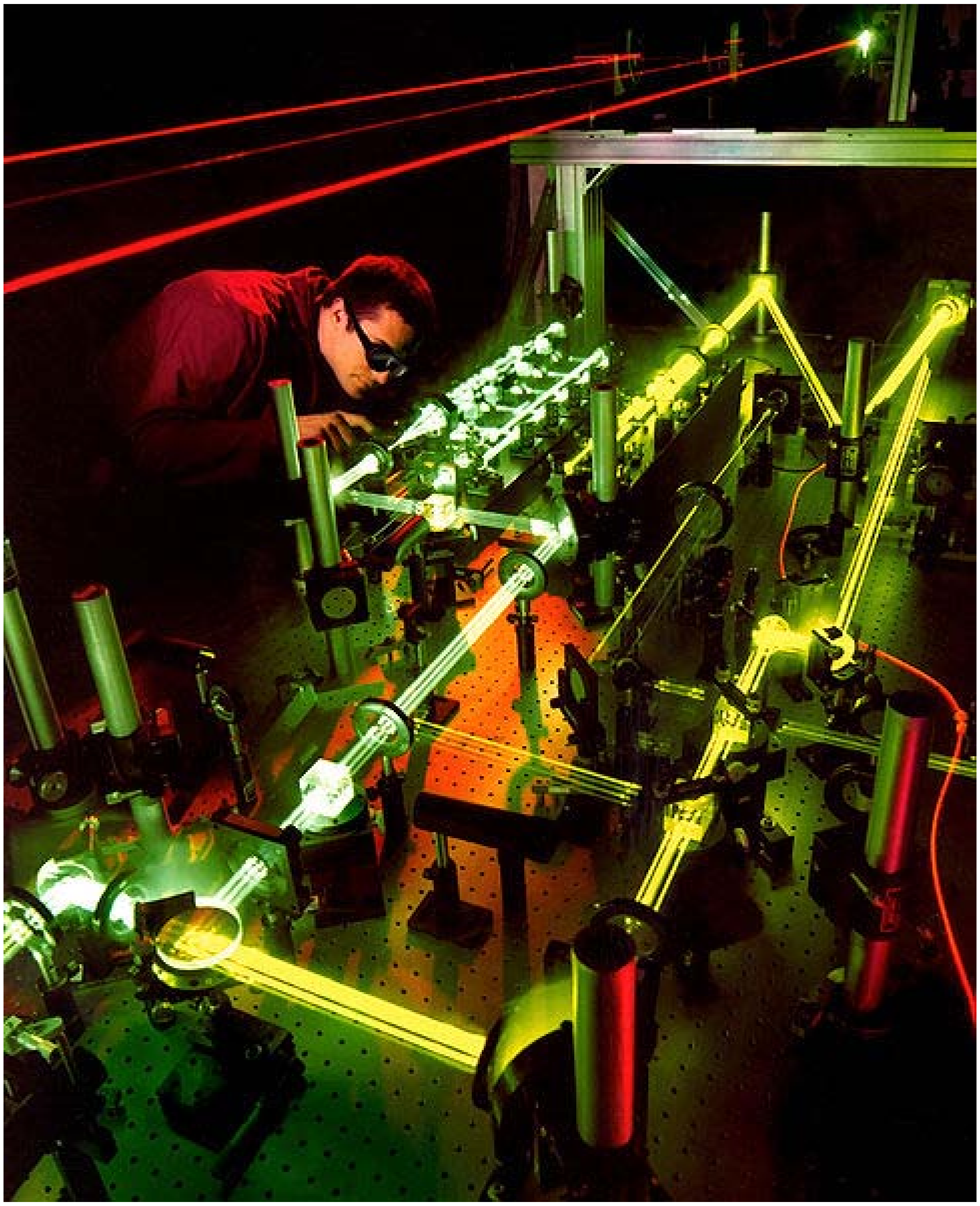
Because the first forty official copies are made of the same alloy as the IPK and are stored under similar conditions, periodic verifications using a large number of replicas—especially the national primary standards, which are rarely used—can convincingly demonstrate the stability of the IPK. What has become clear after the third periodic verification performed between 1988 and 1992 is that masses of the entire worldwide ensemble of prototypes have been slowly but inexorably diverging from each other. It is also clear that the mass of the IPK lost perhaps 50 µg over the last century, and possibly significantly more, in comparison to its official copies. The reason for this drift has eluded physicists who have dedicated their careers to the SI unit of mass. No plausible mechanism has been proposed to explain either a steady decrease in the mass of the IPK, or an increase in that of its replicas dispersed throughout the world. This *relative* nature of the changes amongst the world's kilogram prototypes is often misreported in the popular press, and even some notable scientific magazines, which often state that the IPK simply "lost 50 µg" and omit the very important caveat of *"in comparison to its official copies*." Moreover, there are no technical means available to determine whether or not the entire worldwide ensemble of prototypes suffers from even greater long-term trends upwards or downwards because their mass "relative to an invariant of nature is unknown at a level below 1000 µg over a period of 100 or even 50 years." Given the lack of data identifying which of the world's kilogram prototypes has been most stable in absolute terms, it is equally as valid to state that the first batch of replicas has, as a group, gained an average of about 25 µg over one hundred years in comparison to the IPK.

What *is* known specifically about the IPK is that it exhibits a short-term instability of about 30 µg over a period of about a month in its after-cleaned mass. The precise reason for this short-term instability is not understood but is thought to entail surface effects: microscopic differences between the prototypes' polished surfaces, possibly aggravated by hydrogen absorption due to catalysis of the volatile organic compounds that slowly deposit onto the prototypes as well as the hydrocarbon-based solvents used to clean them.

It has been possible to rule out many explanations of the observed divergences in the masses of the world's prototypes proposed by scientists and the general public. The BIPM's FAQ explains, for example, that the divergence is dependent on the amount of time elapsed between measurements and not dependent on the number of times the artifacts have been cleaned or possible changes in gravity or environment.

Scientists are seeing far greater variability in the prototypes than previously believed. The increasing divergence in the masses of the world's prototypes and the short-term instability in the IPK has prompted research into improved methods to obtain a smooth surface finish using diamond-turning on newly manufactured replicas and has intensified the search for a new definition of the kilogram.

Importance of the kilogram



The magnitude of many of the units comprising the SI system of measurement, including most of those used in the measurement of electricity and light, are highly dependent upon the stability of a 132-year-old, golf ball-size cylinder of metal stored in a vault in France.

The stability of the IPK is crucial because the kilogram underpins much of the SI system of measurement as it is currently defined and structured. For instance, the newton is defined as the force necessary to accelerate one kilogram at one meter per second squared. If the mass of the IPK were to change slightly, so too must the newton by a proportional degree. In turn, the pascal, the SI unit of pressure, is defined in terms of the newton. This chain of dependency follows to many other SI units of measure. For instance, the joule, the SI unit of energy, is defined as that expended when a force of one newton acts through one meter. Next to be affected is the SI unit of power, the watt, which is one joule per second. The ampere too is defined relative to the newton, and ultimately, the kilogram. With the magnitude of the primary units of electricity thus determined by the kilogram, so too follow many others; namely, the coulomb, volt, tesla, and weber. Even units used in the measure of light would be affected; the candela—following the change in the watt—would in turn affect the lumen and lux.

Because the magnitude of many of the units comprising the SI system of measurement is ultimately defined by the mass of a 132-year-old, golf ball-sized piece of metal, the quality of the IPK must be diligently protected to preserve the integrity of the SI system. Yet, in spite of the best stewardship, the average mass of the worldwide ensemble of prototypes and the mass of the IPK have likely diverged another 5.1 μg since the third periodic verification 22 years ago. Further, the world's national metrology laboratories must wait for the fourth periodic verification to confirm whether the historical trends persisted.

Fortunately, *definitions* of the SI units are quite different from their *practical realizations*. For instance, the meter is *defined* as the distance light travels in a vacuum during a time interval of $^1\!/_{299,792,458}$ of a second. However, the meter's *practical realization* typically takes the form of a helium-neon laser, and the meter's length is *delineated*—not defined—as 1,579,800.298728 wavelengths of light from this laser. Now suppose that the official measurement of the second was found to have drifted by a few parts per billion (it is actually extremely stable). There would be no automatic effect on the meter because the second—and thus the meter's length—is abstracted via the laser comprising the meter's practical realization. Scientists performing meter calibrations would simply continue to measure out the same number of laser wavelengths until an agreement was reached to do otherwise. The same is true with regard to the real-world dependency on the kilogram: if the mass of the IPK was found to have changed slightly, there would be no automatic effect upon the other units of measure because their practical realizations provide an insulating layer of abstraction. Any discrepancy would eventually have to be reconciled though because the virtue of the SI system is its precise mathematical and logical harmony amongst its units. If the IPK's value were definitively proven to have changed, one solution would be to simply redefine the kilogram as being equal to the mass of the IPK plus an offset value, similarly to what is currently done with its replicas; e.g., "the kilogram is equal to the mass of the IPK + 42 parts per billion" (equivalent to 42 μg).

The long-term solution to this problem, however, is to liberate the SI system's dependency on the IPK by developing a practical realization of the kilogram that can be reproduced in different laboratories by following a written specification. The units of measure in such a practical realization would have their magnitudes precisely defined and expressed in terms of fundamental physical constants. While major portions of the SI system would still be based on the kilogram, the kilogram would in turn be based on invariant, universal constants of nature. While this is a worthwhile objective and much work towards that end is ongoing, no alternative has yet achieved the uncertainty of a couple parts in 10^8 (~20 μg) required to improve upon the IPK. However, as of April 2007, the U.S.'s National Institute of Standards and Technology (NIST) had an implementation of the watt balance that was approaching this goal, with a demonstrated uncertainty of 36 µg.

Proposed future definitions

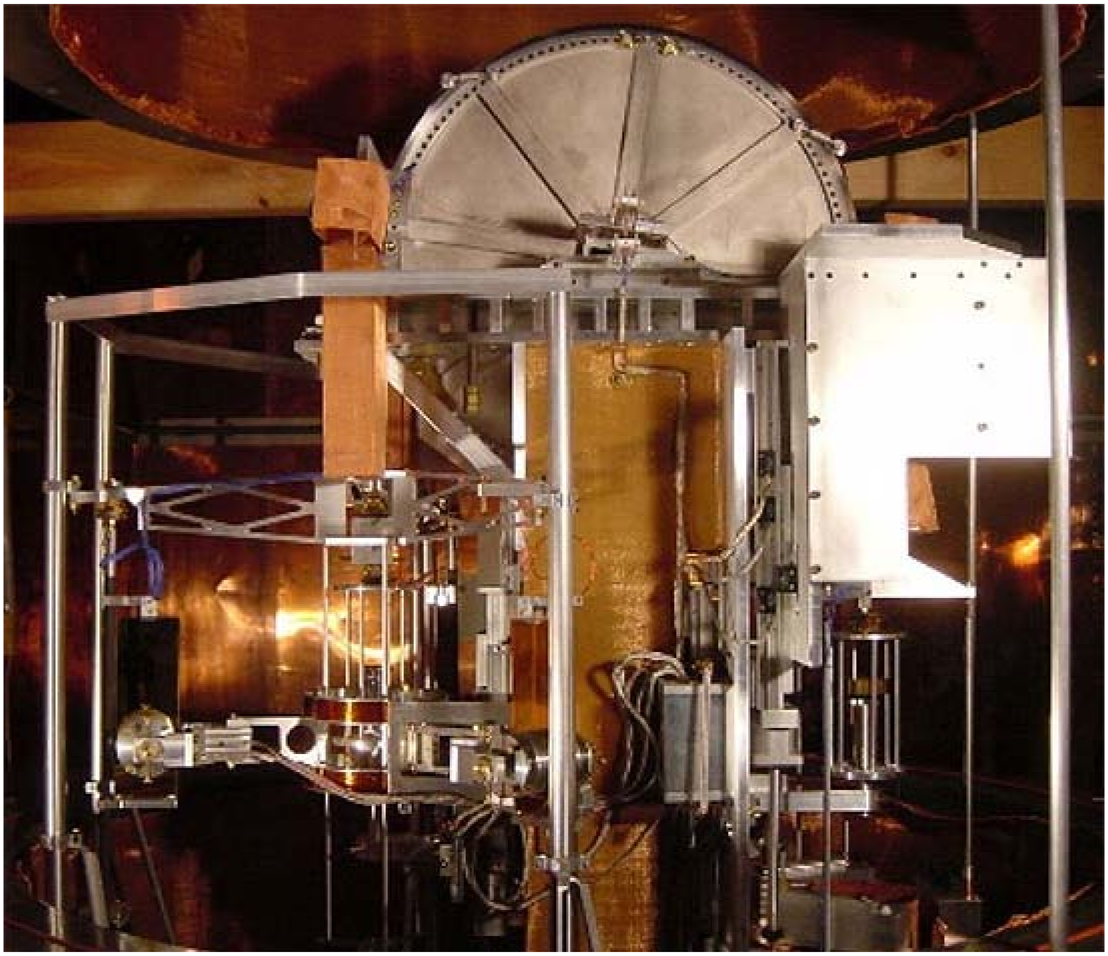
In the following sections, wherever numeric equalities are shown in 'concise form'—such as 1.85487(14)×10^{43}
—the two digits between the parentheses denote the uncertainty at 1σ standard deviation (68% confidence level) in the two least significant digits of the significand.

The kilogram is the only SI unit that is still defined by an artifact. Note that the meter was also once defined as an artifact (a single platinum-iridium bar with two marks on it). However, it was eventually redefined in terms of invariant, fundamental constants of nature (the wavelength of light emitted by krypton, and later the speed of light) so that the standard can be reproduced in different laboratories by following a written specification. Today, physicists are investigating various approaches to doing the same with the kilogram.

In October 2010, the International Committee for Weights and Measures (known by its French-language initials CIPM) voted to submit a resolution for consideration at the General Conference on Weights and Measures (CGPM), to "take note of an intention" that the kilogram be defined in terms of the Planck constant, *h*. Such a definition would theoretically permit any apparatus that was capable of delineating the kilogram in terms of the Planck constant to be used as long as it possessed sufficient precision, accuracy and stability. The watt balance (discussed below) may be able to do this.

In getting to the threshold of replacing the last artifact that underpins much of the International System of Units (SI), a variety of other fundamentally different technologies were considered and explored over many years. Some of the approaches are fundamentally very different from each other. They too are covered below. Some of these now-abandoned approaches were based on equipment and procedures that would have enabled the reproducible production of new, kilogram-mass prototypes on demand (albeit with extraordinary effort) using measurement techniques and material properties that are ultimately based on, or traceable to, fundamental constants. Others were based on devices that measured either the acceleration or weight of hand-tuned, kilogram test masses and which expressed their magnitudes in electrical terms via special components that permit traceability to fundamental constants. All approaches depend on converting a weight measurement to a mass, and therefore require the precise measurement of the strength of gravity in laboratories. All approaches would have precisely fixed one or more constants of nature at a defined value.

The watt balance



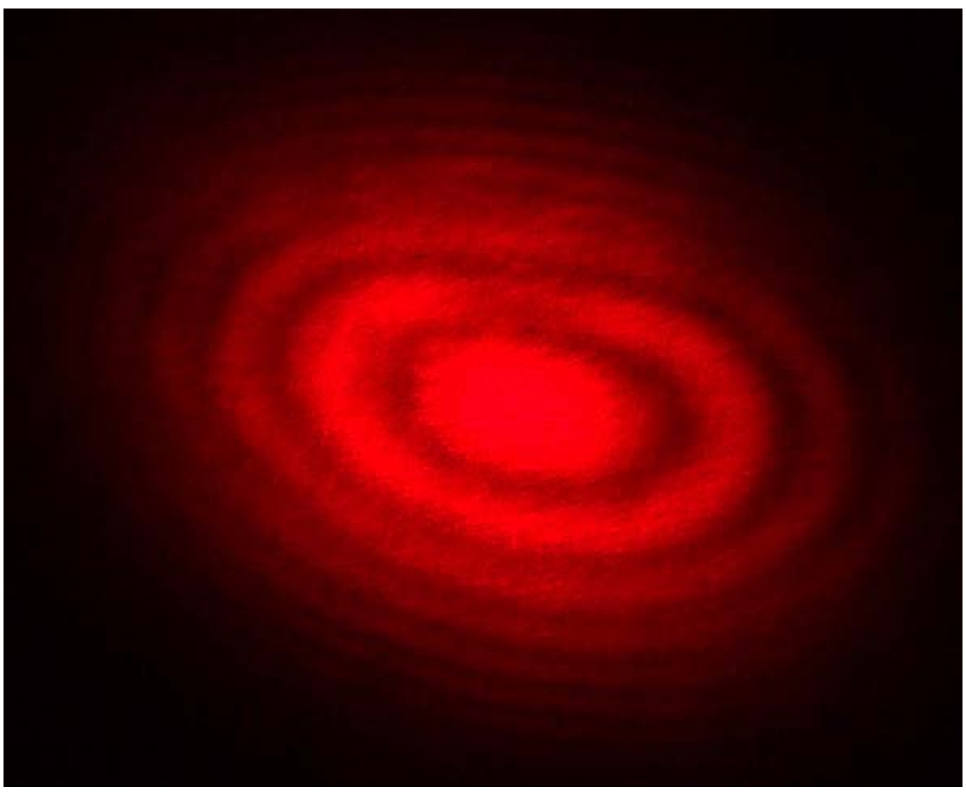
The NIST's watt balance is a project of the U.S. Government to develop an "electronic kilogram." The vacuum chamber dome, which lowers over the entire apparatus, is visible at top.

The watt balance is essentially a single-pan weighing scale that measures the electric power necessary to oppose the weight of a kilogram test mass as it is pulled by earth's gravity. It is a variation of an ampere balance in that it employs an extra calibration step that nulls the effect of geometry. The electric potential in the watt balance is delineated by a Josephson voltage standard, which allows voltage to be linked to an invariant constant of nature with extremely high precision and stability. Its circuit resistance is calibrated against a quantum Hall resistance standard.

The watt balance requires exquisitely precise measurement of the local gravitational acceleration ***g*** in the laboratory, using a gravimeter. For instance, the NIST compensates for earth's gravity gradient of 309 µGal per meter when the elevation of the center of the gravimeter differs from that of the nearby test mass in the watt balance; a change in the weight of a one-kilogram test mass that equates to about 316 µg/m.

In April 2007, the NIST's implementation of the watt balance demonstrated a combined relative standard uncertainty (CRSU) of 36 μg and a short-term resolution of 10–15 μg. The UK's National Physical Laboratory's watt balance demonstrated a CRSU of 70.3 μg in 2007. That watt balance was disassembled and shipped in 2009 to Canada's Institute for National Measurement Standards (part of the National Research Council), where research and development with the device could continue.

If the CGPM adopts the new proposal and the new definition of the kilogram becomes part of the SI, the Planck constant (*h*), which is a measure that relates the energy of photons to their frequency, would be precisely fixed; for example, to $h = 6.626069 \times 10^{-34}$ J·s (from the 2006 CODATA value of $6.62606896(33) \times 10^{-34}$ J·s). Once agreed upon internationally, the kilogram would no longer be defined as the mass of the IPK. With the definition of the kilogram in terms of electric power and a frequency (the Planck constant's J·s), electric power would be directly identical to mechanical power by definition rather than being a derivative. All the remaining units in the International System of Units (the SI) that today have dependencies upon the kilogram and the joule would also fall in place, their magnitudes ultimately defined, in part, in terms of photon oscillations rather than a 132-year-old metal artifact stored in a vault.



the local gravitational acceleration ***g*** is measured with exceptional precision with the help of a laser interferometer. The laser's pattern of interference fringes—the dark and light bands above—blooms at an ever faster rate as a free-falling corner reflector drops inside an absolute gravimeter. The pattern's frequency sweep is timed by an atomic clock.

Gravity and the nature of the watt balance, which oscillates test masses up and down against the local gravitational acceleration $\boldsymbol{g}$, are exploited so that mechanical power is compared against electrical power, which is the square of voltage divided by electrical resistance. However, $\boldsymbol{g}$ varies significantly—nearly one percent—depending upon where on earth's surface the measurement is made. There are also subtle seasonal variations in $\boldsymbol{g}$ due to changes in underground water tables, and larger semimonthly and diurnal changes due to tidal distortions in the earth's shape caused by the moon. Although $\boldsymbol{g}$ would not be a term in the *definition* of the kilogram, it would be crucial in the *delineation* of the kilogram when relating energy to power. Accordingly, $\boldsymbol{g}$ must be measured with at least as much precision and accuracy as are the other terms, so measurements of $\boldsymbol{g}$ must also be traceable to fundamental constants of nature. For the most precise work in mass metrology, $\boldsymbol{g}$ is measured using dropping-mass absolute gravimeters that contain an iodine-stabilized helium–neon laser interferometer. The fringe-signal, frequency-sweep output from the interferometer is measured with a rubidium atomic clock. Since this type of dropping-mass gravimeter derives its accuracy and stability from the constancy of the speed of light as well as the innate properties of helium, neon, and rubidium atoms, the 'gravity' term in the delineation of an all-electronic kilogram is also measured in terms of invariants of nature—and with very high precision. For instance, in the basement of the NIST's Gaithersburg facility in 2009, when measuring the gravity acting upon Pt-10Ir test masses (which are denser, smaller, and have a slightly lower center of gravity inside the watt balance than stainless steel masses), the measured value was typically within 8 ppb of 9.80101644 m/s^2.

The virtue of electronic realizations like the watt balance is that the definition and dissemination of the kilogram would no longer be dependent upon the stability of kilogram prototypes, which must be very carefully handled and stored. It would free physicists from the need to rely on assumptions about the stability of those prototypes. Instead, hand-tuned, close-approximation mass standards would simply be weighed and documented as being equal to one kilogram plus an offset value. With the watt balance, while the kilogram would be *delineated* in electrical and gravity terms, all of which are traceable to invariants of nature; it would be *defined* in a manner that is directly traceable to just three fundamental constants of nature. The Planck constant defines the kilogram in terms of the second and the meter. By fixing the Planck constant, the *definition* of the kilogram would depend only on the *definitions* of the second and the meter. The definition of the second depends on a single defined physical constant: the ground state hyperfine splitting frequency of the caesium 133 atom $\boldsymbol{\Delta\nu(^{133}Cs)_{hfs}}$. The meter depends on the second and on an additional defined physical constant: the speed of light $\boldsymbol{c}$. If the Kilogram is redefined in this manner, mass artifacts—physical objects calibrated in a watt balance, including the IPK—would no longer be part of the definition, but would instead become *transfer standards*.

Scales like the watt balance also permit more flexibility in choosing materials with especially desirable properties for mass standards. For instance, Pt-10Ir could continue to be used so that the specific gravity of newly produced mass standards would be the same as existing national primary and check standards (≈21.55 g/ml). This would reduce the relative uncertainty when making mass comparisons in air. Alternately, entirely different materials and constructions could be explored with the objective of producing mass standards with greater stability. For instance, osmium-iridium alloys could be investigated if platinum's propensity to absorb hydrogen (due to catalysis of VOCs and hydrocarbon-based cleaning solvents) and atmospheric mercury proved to be sources of instability. Also, vapor-deposited, protective ceramic coatings like nitrides could be investigated for their suitability to isolate these new alloys.

The challenge with watt balances is not only in reducing their uncertainty, but also in making them truly *practical* realizations of the kilogram. Nearly every aspect of watt balances and their support equipment requires such extraordinarily precise and accurate, state-of-the-art technology that—unlike a device like an atomic clock—few countries would currently choose to fund their operation. For instance, the NIST's watt balance used four resistance standards in 2007, each of which was rotated through the watt balance every two to six weeks after being calibrated in a different part of NIST headquarters facility in Gaithersburg, Maryland. It was found that simply moving the resistance standards down the hall to the watt balance after calibration altered their values 10 ppb (equivalent to 10 µg) or more. Present-day technology is insufficient to permit stable operation of watt balances between even biannual calibrations. If the kilogram is defined in terms of the Planck constant, it is likely there will only be a few—at most—watt balances initially operating in the world.

Alternative approaches to redefining the kilogram that were fundamentally different from the watt balance were explored to varying degrees with some abandoned, as follows:

Atom-counting approaches

Carbon-12

Though not offering a practical realization, this definition would precisely define the magnitude of the kilogram in terms of a certain number of carbon-12 atoms. Carbon-12 (^{12}C) is an isotope of carbon. The mole is currently defined as "the quantity of entities (elementary particles like atoms or molecules) equal to the number of atoms in 12 grams of carbon-12." Thus, the current definition of the mole requires that $^{1000}/_{12}$ (83⅓) moles of ^{12}C has a mass of precisely one kilogram. The number of atoms in a mole, a quantity known as the Avogadro constant, is experimentally determined, and the current best estimate of its value is $6.02214179(30)\times10^{23}$ entities per mole (CODATA, 2006). This new definition of the kilogram proposes to fix the Avogadro constant at precisely 6.02214179×10^{23} with the kilogram being defined as "the mass equal to that of $^{1000}/_{12} \cdot 6.02214179\times10^{23}$ atoms of ^{12}C."

The accuracy of the measured value of the Avogadro constant is currently limited by the uncertainty in the value of the Planck constant—a measure relating the energy of photons to their frequency. That relative standard uncertainty has been 50 parts per billion (ppb) since 2006. By fixing the Avogadro constant, the practical effect of this proposal would be that the uncertainty in the mass of a ^{12}C atom—and the magnitude of the kilogram—

could be no better than the current 50 ppb uncertainty in the Planck constant. Under this proposal, the magnitude of the kilogram would be subject to future refinement as improved measurements of the value of the Planck constant become available; electronic realizations of the kilogram would be recalibrated as required. Conversely, an electronic *definition* of the kilogram, which would precisely fix the Planck constant, would continue to allow 83⅓ moles of ^{12}C to have a mass of precisely one kilogram but the number of atoms comprising a mole (the Avogadro constant) would continue to be subject to future refinement.

A variation on a ^{12}C-based definition proposes to define the Avogadro constant as being precisely $84{,}446{,}886^3$ ($\approx 6.02214098 \times 10^{23}$) atoms. An imaginary realization of a 12-gram mass prototype would be a cube of ^{12}C atoms measuring precisely 84,446,886 atoms across on a side. With this proposal, the kilogram would be defined as "the mass equal to $84{,}446{,}886^3 \times 83⅓$ atoms of ^{12}C." The value 84,446,886 was chosen because it has a special property; its cube (the proposed new value for the Avogadro constant) is evenly divisible by twelve. Thus with this definition of the kilogram, there would be an integer number of atoms in one gram of ^{12}C: 50,184,508,190,229,061,679,538 atoms.

Avogadro project

One of the master opticians at the Australian Centre for Precision Optics (ACPO) is holding a 1 kg, single-crystal silicon sphere for the Avogadro project. These spheres are among the roundest man-made objects in the world. If the best of these spheres were scaled to the size of earth, its high point—a continent-size area—would gently rise to a maximum elevation of only 2.4 meters above "sea level."

Another Avogadro constant-based approach, known as the *Avogadro project*, would define and delineate the kilogram as a softball-size (93.6 mm diameter) sphere of silicon atoms. Silicon was chosen because a commercial infrastructure with mature processes for creating defect-free, ultra-pure monocrystalline silicon already exists to service the semiconductor industry. To make a practical realization of the kilogram, a silicon boule (a rod-like, single-crystal ingot) would be produced. Its isotopic composition would be measured with a mass spectrometer to determine its average relative atomic mass. The boule would be cut, ground, and polished into spheres. The size of a select sphere would be measured using optical interferometry to an uncertainty of about 0.3 nm on the radius—roughly a single atomic layer. The precise lattice spacing between the atoms in its crystal structure (≈192 pm) would be measured using a scanning X-ray interferometer. This permits its atomic spacing to be determined with an uncertainty of only three parts per billion. With the size of the sphere, its average atomic mass, and its atomic spacing known, the required sphere diameter can be calculated with sufficient precision and low uncertainty to enable it to be finish-polished to a target mass of one kilogram.

Experiments are being performed on the Avogadro Project's silicon spheres to determine whether their masses are most stable when stored in a vacuum, a partial vacuum, or ambient pressure. However, no technical means currently exist to prove a long-term stability any better than that of the IPK's because the most sensitive and accurate measurements of mass are made with dual-pan balances like the BIPM's FB-2 flexure-strip balance. Balances can only compare the mass of a silicon sphere to that of a reference mass. Given the latest understanding of the lack of long-term mass stability with the IPK and its replicas, there is no known, perfectly stable mass artifact to compare against. Single-pan scales, which measure weight relative to an invariant of nature, are not precise to the necessary long-term uncertainty of 10–20 parts per billion. Another issue to be overcome is that silicon oxidizes and forms a thin layer (equivalent to 5–20 silicon atoms) of silicon dioxide (quartz) and silicon monoxide. This layer slightly increases the mass of the sphere, an effect which must be accounted for when polishing the sphere to its finish dimension. Oxidation is not an issue with platinum and iridium, both of which are noble metals that are roughly as cathodic as oxygen and therefore don't oxidize unless coaxed to do so in the laboratory. The presence of the thin oxide layer on a silicon-sphere mass prototype places additional restrictions on the procedures that might be suitable to clean it to avoid changing the layer's thickness or oxide stoichiometry.

All silicon-based approaches would fix the Avogadro constant but vary in the details of the definition of the kilogram. One approach would use silicon with all three of its natural isotopes present. About 7.78% of silicon comprises the two heavier isotopes: ^{29}Si and ^{30}Si. As described in *Carbon-12* above, this method would *define* the magnitude of the kilogram in terms of a certain number of ^{12}C atoms by fixing the Avogadro constant; the silicon sphere would be the *practical realization.* This approach could accurately delineate the magnitude of the kilogram because the masses of the three silicon nuclides relative to ^{12}C are known with great precision (relative uncertainties of 1 ppb or better). An alternative method for creating a silicon sphere-based kilogram proposes to use isotopic separation techniques to enrich the silicon until it is nearly pure ^{28}Si, which has a relative atomic mass of 27.9769265325(19). With this approach, the Avogadro constant would not only be fixed, but so too would the atomic mass of ^{28}Si. As such, the definition of the kilogram would be decoupled from ^{12}C and the kilogram would instead be defined as $^{1000}/_{27.9769265325} \cdot 6.02214179\times10^{23}$
atoms of ^{28}Si (≈35.74374043 fixed moles of ^{28}Si atoms). Physicists could elect to define the kilogram in terms of ^{28}Si even when kilogram prototypes are made of natural silicon

(all three isotopes present). Even with a kilogram definition based on theoretically pure ^{28}Si, a silicon-sphere prototype made of only nearly pure ^{28}Si would necessarily deviate slightly from the defined number of moles of silicon to compensate for various chemical and isotopic impurities as well as the effect of surface oxides.

Ion accumulation

Another Avogadro-based approach, ion accumulation, since abandoned, would have defined and delineated the kilogram by precisely creating new metal prototypes on demand. It would have done so by accumulating gold or bismuth ions (atoms stripped of an electron) and counted them by measuring the electrical current required to neutralize the ions. Gold (^{197}Au) and bismuth (^{209}Bi) were chosen because they can be safely handled and have the two highest atomic masses among the mononuclidic elements that is effectively non-radioactive (bismuth) or is perfectly stable (gold).

With a gold-based definition of the kilogram for instance, the relative atomic mass of gold could have been fixed as precisely 196.9665687, from the current value of 196.9665687(6). As with a definition based upon carbon-12, the Avogadro constant would also have been fixed. The kilogram would then have been defined as "the mass equal to that of precisely $^{1000}/_{196.9665687} \cdot 6.02214179\times10^{23}$
atoms of gold" (precisely 3,057,443,620,887,933,963,384,315 atoms of gold or about 5.07700371 fixed moles).

In 2003, German experiments with gold at a current of only 10 μA demonstrated a relative uncertainty of 1.5%. Follow-on experiments using bismuth ions and a current of 30 mA were expected to accumulate a mass of 30 g in six days and to have a relative uncertainty of better than 1 ppm. Ultimately, ion-accumulation approaches proved to be unsuitable. Measurements required months and the data proved too erratic for the technique to be considered a viable future replacement to the IPK.

Among the many technical challenges of the ion-deposition apparatus was obtaining a sufficiently high ion current (mass deposition rate) while simultaneously decelerating the ions so they could all deposit onto a target electrode embedded in a balance pan. Experiments with gold showed the ions had to be decelerated to very low energies to avoid sputtering effects—an phenomenon whereby ions that had already been counted ricochet off the target electrode or even dislodged atoms that had already been deposited. The deposited mass fraction in the 2003 German experiments only approached very close to 100% at ion energies of less than around 1 eV (<1 km/s for gold).

If the kilogram had been defined as a precise quantity of gold or bismuth atoms deposited with an electric current, not only would the Avogadro constant and the atomic mass of gold or bismuth have to have been precisely fixed, but also the value of the elementary charge (*e*), likely to $1.602176487\times10^{-19}$
C (from the present 2006 CODATA value of $1.602176487(40)\times10^{-19}$
). Doing so would have effectively defined the ampere as a flow of $^{1}/_{1.602176487\times10^{-19}}$
(6,241,509,647,120,417,390) electrons per second past a fixed point in an electric circuit.

The SI unit of mass would have been fully defined by having precisely fixed the values of the Avogadro constant and elementary charge, and by exploiting the fact that the atomic masses of bismuth and gold atoms are invariant, universal constants of nature.

Beyond the slowness of making a new mass standard and the poor reproducibility, there were other intrinsic shortcomings to the ion-accumulation approach that proved to be formidable obstacles to ion-accumulation-based techniques becoming a practical realization. The apparatus necessarily required that the deposition chamber have an integral balance system to enable the convenient calibration of a reasonable quantity of transfer standards relative to any single internal ion-deposited prototype. Furthermore, the mass prototypes produced by ion deposition techniques would have been nothing like the freestanding platinum-iridium prototypes currently in use; they would have been deposited onto—and become part of—an electrode imbedded into one pan of a special balance integrated into the device. Moreover, the ion-deposited mass wouldn’t have had a hard, highly polished surface that can be vigorously cleaned like those of current prototypes. Gold, while dense and a noble metal (resistant to oxidation and the formation of other compounds), is extremely soft so an internal gold prototype would have to be kept well isolated and scrupulously clean to avoid contamination and the potential of wear from having to remove the contamination. Bismuth, which is an inexpensive metal used in low-temperature solders, slowly oxidizes when exposed to room-temperature air and forms other chemical compounds and so would not have produced stable reference masses unless it was continually maintained in a vacuum or inert atmosphere.

Ampere-based force

A magnet floating above a superconductor bathed in liquid nitrogen demonstrates perfect diamagnetic levitation via the Meissner effect. Experiments with an ampere-based definition of the kilogram flipped this arrangement upside-down: an electric field accelerated a superconducting test mass supported by fixed magnets.

This approach would define the kilogram as “the mass which would be accelerated at precisely 2×10^{-7} m/s^2 when subjected to the per-meter force between two straight parallel conductors of infinite length, of negligible circular cross section, placed one meter apart in vacuum, through which flow a constant current of $^1/_{1.602176487\times10^{-19}}$ (≈6,241,509,647,120,417,390) elementary charges per second.”

Effectively, this would define the kilogram as a derivative of the ampere rather than present relationship, which defines the ampere as a derivative of the kilogram. This redefinition of the kilogram would specify elementary charge (*e*) as precisely

1.602176487×10−19
coulomb rather than the current 2006 CODATA value of 1.602176487(40)×10−19
. Effectively, the coulomb would be the sum of 6,241,509,647,120,417,390 elementary charges. It would necessarily follow that the ampere (one coulomb per second) would also become an electrical current of this precise quantity of elementary charges per second passing a given point in an electric circuit. The virtue of a practical realization based upon this definition is that unlike the watt balance and other scale-based methods, all of which require the careful characterization of gravity in the laboratory, this method delineates the magnitude of the kilogram directly in the very terms that define the nature of mass: acceleration due to an applied force. Unfortunately, it is extremely difficult to develop a practical realization based upon accelerating masses. Experiments over a period of years in Japan with a superconducting, 30 g mass supported by diamagnetic levitation never achieved an uncertainty better than ten parts per million. Magnetic hysteresis was one of the limiting issues. Other groups performed similar research that used different techniques to levitate the mass.

SI multiples

Because SI prefixes may not be concatenated (serially linked) within the name or symbol for a unit of measure, SI prefixes are used with the *gram*, not the kilogram, which already has a prefix as part of its name. For instance, one-millionth of a kilogram is 1 mg (one milligram), not 1 µkg (one microkilogram).

SI multiples for gram (g)

Submultiples			**Multiples**		
Value	**Symbol**	**Name**	**Value**	**Symbol**	**Name**
10^{-1} g	dg	decigram	10^{1} g	dag	decagram
10^{-2} g	cg	centigram	10^{2} g	hg	hectogram
10^{-3} g	**mg**	**milligram**	10^{3} g	**kg**	**kilogram**
10^{-6} g	**µg**	**microgram (mcg)**	10^{6} g	Mg	megagram (tonne)
10^{-9} g	**ng**	**nanogram**	10^{9} g	Gg	gigagram
10^{-12} g	**pg**	**picogram**	10^{12} g	Tg	teragram
10^{-15} g	fg	femtogram	10^{15} g	Pg	petagram
10^{-18} g	ag	attogram	10^{18} g	Eg	exagram
10^{-21} g	zg	zeptogram	10^{21} g	Zg	zettagram
10^{-24} g	yg	yoctogram	10^{24} g	Yg	yottagram

Common prefixes are in bold face.

- When the Greek lowercase “µ” (mu) in the symbol of microgram is typographically unavailable, it is occasionally—although not properly—replaced by Latin lowercase “u”.

- The microgram is often abbreviated “mcg”, particularly in pharmaceutical and nutritional supplement labeling, to avoid confusion since the “μ” prefix is not well recognized outside of technical disciplines. Note however, that the *abbreviation* “mcg”, is also the *symbol* for an obsolete CGS unit of measure known as the “millicentigram”, which is equal to 10 μg.
- The unit name “megagram” is rarely used, and even then, typically only in technical fields in contexts where especially rigorous consistency with the units of measure is desired. For most purposes, the unit “tonne” is instead used. The tonne and its symbol, t, were adopted by the CIPM in 1879. It is a non-SI unit accepted by the BIPM for use with the SI. According to the BIPM, “In English speaking countries this unit is usually called ‘metric ton’.” Note also that the unit name “megatonne” or “megaton” (Mt) is often used in general-interest literature on greenhouse gas emissions whereas the equivalent value in scientific papers on the subject is often the “teragram” (Tg).

Glossary

- **Abstracted**: Isolated and its effect changed in form, often simplified or made more accessible in the process.
- **Artifact**: A simple human-made object used directly as a comparative standard in the measurement of a physical quantity.
- **Check standard**:
    1. A standard body’s backup replica of the international prototype kilogram (IPK).
    2. A secondary kilogram mass standard used as a stand-in for the primary standard during routine calibrations.
- **Definition**: A formal, specific, and exact specification.
- **Delineation**: The physical means used to mark a boundary or express the magnitude of an entity.
- **Disseminate**: To widely distribute the magnitude of a unit of measure, typically via replicas and transfer standards.
- **IPK**: Abbreviation of “international prototype kilogram” (CG image), *the* mass artifact in France internationally recognized as having the defining mass of precisely one kilogram.
- **Magnitude**: The extent or numeric value of a property
- **National prototype**: A replica of the IPK possessed by a nation.
- **Practical realization**: A readily reproducible apparatus to conveniently delineate the magnitude of a unit of measure.
- **Primary national standard**:
    1. A replica of the IPK possessed by a nation
    2. The least used replica of the IPK when a nation possesses more than one.
- **Prototype**:
    1. A human-made object that serves as the defining comparative standard in the measurement of a physical quantity.
    2. A human-made object that serves as *the* comparative standard in the measurement of a physical quantity.

3. The IPK and any of its replicas

- **Replica**: An official copy of the IPK.
- **Sister copy**: One of six official copies of the IPK that are stored in the same safe as the IPK and are used as check standards by the BIPM.
- **Transfer standard**: An artifact or apparatus that reproduces the magnitude of a unit of measure in a different, usually more practical, form.

Chapter-2

Ton and Tonne

Ton

The **ton** is a unit of measure. It has a long history and has acquired a number of meanings and uses over the years. It is used principally as a unit of weight, and as a unit of volume. It can also be used as a measure of energy, for truck classification, or as a colloquial term.

It is derived from the *tun*, the term applied to a barrel of the largest size. This could contain a volume between 210 and 256 gallons (800 to 1000 L), which could weigh around 2,000 pounds (900 kg) and occupy some 60 cubic feet (1700 L) of space.

In the United Kingdom, the ton is a unit of measure which, when it ceased to be legal for trade in 1985, was defined in British legislation as being a weight or mass equal to 2,240 pounds (1,016 kg) (avoirdupois pounds). In the United States and Canada, however, a ton is defined to be 2,000 pounds (907 kg). To avoid confusion, the former is more specifically referred to as a "long ton" and the latter, a "short ton"; neither should be confused with the *metric ton* (tonne), which is 1,000 kilograms (2,205 lb). While they do vary, a ton is generally one of the heaviest units of weight or mass referred to in colloquial speech.

The term "ton" is also used to refer to a number of units of *volume*, ranging from 35 to 100 cu ft (around 1000 to 2800 L) in capacity.

It can also be used as a unit of *energy*, expressed as an equivalent of coal burnt, TNT detonated, or in refrigeration, ice melted.

Units of mass/weight

There are several similar units of mass or volume called the **ton**:

Full name(s)	Common name	Quantity	Notes

long ton, weight ton, gross ton	"ton" (UK)	2,240 lb (1,016.047 kg)	Used in countries such as the United Kingdom that formerly used the Imperial system
short ton, net ton	"ton" (US)	2,000 lb (907.1847 kg)	Used in North America
metric ton, tonne	"tonne" or "metric ton"	1,000 kg (2,204.623 lb)	In the UK, Canada, Australia, and other areas that had used the Imperial system, the metric ton is the form of ton legal in trade. Conveniently, it is less than 2% different from the long ton.
ton shortweight		2240 lb	Used in the iron industry in the 17th and 18th centuries.
ton longweight		2400 lb	Used in the iron industry in the 17th and 18th centuries.

Note 1: The longweight and shortweight tons were used as a means of making an allowance for wastage in an industrial process. The workman is provided with a longweight ton and is expected to return a shortweight ton of processed product. These measures were particulary used in the operation of hammering iron blooms into shape.
Note 2: In other industries, a different longweight ton might be used. Coal miners delivered coal to the surface in longweight tons but were paid only for a shortweight ton. This was supposedly to allow for "dirt" (non-coal rocks) in the output. Mine owners, however, were free to set the value of the longweight ton at a value of their own choosing, and in at least some cases, it was set to 25 cwt (2800 lb) compared to the 20 cwt shortweight ton. This was a source of discontent amongst the miners who saw the practice as unfairly in favour of the mine owners.
Others

- The long ton is used for petroleum products such as aviation fuel.
- **Deadweight ton** (abbreviation 'DWT' or 'dwt') is a measure of a ship's carrying capacity, including bunker oil, fresh water, ballast water, crew and provisions. It is expressed in tonnes (1000 kg) or long tons (2240 pounds, about 1016 kg). This measurement is also used in the U.S. tonnage of naval ships.
- Increasingly, tonnes are being used rather than long tons in measuring the displacement of ships.
- **Harbour ton** used in South Africa in the 20th century, 2000 pounds or one short ton.

Both the long ton and the short ton are composed of 20 hundredweight, being 112 and 100 pounds respectively. Prior to the 15th century in England, the ton was composed of 20 hundredweight, each of 108 lb, giving a ton of 2,160 pounds (980 kg).

Assay ton (abbreviation 'AT') is not a unit of measurement, but a standard quantity used in assaying ores of precious metals; it is $29\frac{1}{6}$ grams (short assay ton) or $32\frac{2}{3}$ grams (long assay ton), the amount which bears the same ratio to a milligram as a short or long ton bears to a troy ounce. In other words, the number of milligrams of a particular metal found in a sample of this size gives the number of troy ounces contained in a short or long ton of ore.

In documents that predate 1960 the word *ton* is sometimes spelled *tonne*, but in more recent documents *tonne* refers exclusively to the metric ton.

In nuclear power plants **tHM** and **MTHM** mean tonnes of heavy metals, and MTU means tonnes of uranium. In the steel industry, the abbreviation **THM** means 'tons/tonnes hot metal', which refers to the amount of liquid iron or steel that is produced, particularly in the context of blast furnace production or specific consumption.

A **dry ton** or **dry tonne** has the same mass value, but the material (sludge, slurries, compost, and similar mixtures in which solid material is soaked with or suspended in water) has been dried to a relatively low, consistent moisture level (dry weight). If the material is in its natural, wet state, it is called a **wet ton** or **wet tonne**.

Units of volume

The **displacement ton** is a unit of volume used for calculating the displacement of a ship. While displacement is a measure of a ships weight, being the volume of water displaced multiplied by its density and measured in long tons (**tons displacement**), the displacement ton is the standard volume of water representing one ton displacement. It equates to 35 cubic feet (0.9911 m^3) of sea water at average density, being slightly less than the 224 imperial gallons, of the **water ton** (*qv*). It is usually abbreviated as **DT**.

One **measurement ton** or **freight ton** is equal to 40 cubic feet (1.133 m^3), but historically it has had several informal definitions. It is sometimes abbreviated as "MTON". The freight ton represents the volume of a truck, train or other freight carrier. In the past it has been used for a cargo ship but the register ton is now preferred. It is correctly abbreviated as "FT" but some users are now using freight ton to represent a weight of 1 tonne (1,000 kg; 2,205 lb), thus the more common abbreviations are now **M/T**, **MT**, or **MTON** (for measurement ton), which still cause it to be confused with the tonne, or even the megatonne.

The **register ton** is a unit of volume used for the cargo capacity of a ship, defined as 100 cubic feet (2.832 m^3). It is often abbreviated **RT** or **GRT** for **gross registered ton** (The former providing confusion with the refrigeration ton). It is known as a *tonneau de mer* in Belgium, but, in France, a *tonneau de mer* is 1.44 cubic metres (50.85 cu ft).

The **Panama Canal/Universal Measurement System (PC/UMS)** is based on net tonnage, modified for Panama Canal billing purposes. PC/UMS is based on a mathematical formula to calculate a vessel's total volume; a **PC/UMS net ton** is equivalent to 100 cubic feet of capacity.

The **water ton** was formerly used in Great Britain and is equal to 224 imperial gallons (35.96 cu ft; 1.018 m^3), the volume occupied by a mass of 1 long ton (2,240 lb; 1,016 kg) under the conditions that define 1 imperial gallon (1.201 US gal; 4.546 L).

Units of energy and power

Ton of TNT

- A **ton of TNT** or *tonne of TNT* is a unit of energy equal to 10^9 (thermochemical) calories, also known as a gigacalorie (Gcal), equal to 4.184 gigajoules (GJ).
- A **kiloton of TNT** or *kilotonne of TNT* is a unit of energy equal to 10^{12} calories, also known as a teracalorie (Tcal), equal to 4.184 terajoules (TJ).
- A **megaton of TNT** (1,000,000 metric tonnes) or *megatonne of TNT* is a unit of energy equal to 10^{15} calories, also known (infrequently) as a petacalorie (Pcal), equal to 4.184 petajoules (PJ).

Note that these are small calories (cal). The dietary calorie (Cal) is distinct and equal to one kilocalorie (Kcal), and is gradually being replaced by the latter correct term.

Early values for the explosive energy released by trinitrotoluene (TNT) ranged from 900 to 1100 calories per gram. In order to standardise the use of the term *TNT* as a unit of energy, an arbitrary value was assigned based on 1000 calories (1 kcal or 4.184 kJ) per gram. Thus there is no longer a direct connection to the chemical TNT itself. It is now merely a unit of energy that happens to be expressed using words normally associated with mass (e.g., kilogram, tonne, pound). The definition applies for both spellings: *ton of TNT* and *tonne of TNT*.

Measurements in tons of TNT have been used primarily to express nuclear weapon yields, though they have also been used since in seismology as well.

Ton of coal equivalent

- A **ton of coal equivalent** or *tonne of coal equivalent* (TCE), a conventional value of 7 Gcal (IT) = 29.3076 GJ.

Refrigeration

The unit *ton* is used in refrigeration and air conditioning to measure heat absorption. Prior to the introduction of mechanical refrigeration, cooling was accomplished by delivering ice. Installing one ton of refrigeration replaced the daily delivery of one ton of ice.

- In North America, a **standard ton of refrigeration** is 12,000 BTU/h (3,517 W). "The heat absorption per day is approximately the heat of fusion of 1 *ton* of ice at 32 °F (0 °C)." This is approximately the power required to melt one short ton (2,000 lb or 907 kg) of ice at 0 °C (32 °F) in 24 hours, thus representing the delivery of 1 ton of ice per day.

- A less common usage is the power required to cool 1 long ton (2,240 lb or 1,016 kg) of water by 1 °F (0.556 °C) every 10 minutes = 13,440 BTU/h ≈ 3939 W.

A Refrigeration Ton should be regarded as power produced by a chiller when operating in standard ARI conditions, which are typically 44 °F (7 °C) for chilled water unit, and 95 °F (35 °C) air entering the condenser. This is commonly referred to as "true ton". Manufacturers can also provide tables for chillers operating at other chilled water temperature conditions (as 65 °F or 18 °C) which can show more favorable data, which are not valid when making performance comparisons among units unless conversion rates are applied.

The refrigeration ton is commonly abbreviated as **RT**.

Informal tons

- **Ton** is also used informally, often as slang, to mean a large amount of something (material or not), for example, "Man, I just ate a ton of french fries back there".
- In Britain, a ton is colloquially used to refer to 100 of a given unit. Ton can thus refer to a speed of 100 miles per hour, and in this instance is always prefixed by the definite article, e.g. "Lee was doing the ton down the motorway"; to money e.g. "How much did you pay for that?" "A ton" (£100); to 100 points in a game e.g. "Eric just threw a ton in our darts game" (in some games, e.g. cricket, more commonly called a century); or to a hundred of pretty much anything else.

Tonne

The **tonne** (unit symbol **t**) or **metric ton** (U.S.), often written tautologously as **metric tonne**, is a unit of mass equal to 1,000 kg (2,204.62 lb) or approximately the mass of one cubic metre of water at four degrees Celsius. It is sometimes abbreviated to *mt* in the United States, although this conflicts with other SI symbols. The tonne is not a unit in the International System of Units (SI), but is accepted for use with the SI. In SI units and prefixes, the tonne is a **megagram** (**Mg**). The spelling *tonne* pre-dates the introduction of the SI in 1960; it has been used with this meaning in France since 1842 (when there were no metric prefixes for multiples of 10^6 and above), and is now used as the standard spelling for the metric mass measurement in most English-speaking countries. In the United States, the unit was originally referred to using the French words *millier* or *tonneau*, but these terms are now obsolete. The Imperial and US customary units comparable to the tonne are both spelled *ton* in English, though they differ in mass. Pronunciation of tonne (the word used in the UK) and ton is usually identical.

Derived units

Multiple	Name	Symbol	Multiple (SI)	Name	Symbol
10^0	tonne	t	10^6	megagram	Mg
10^3	kilotonne	kt	10^9	gigagram	Gg
10^6	megatonne	Mt	10^{12}	teragram	Tg
10^9	gigatonne	Gt	10^{15}	petagram	Pg
10^{12}	teratonne	Tt	10^{18}	exagram	Eg
10^{15}	petatonne	Pt	10^{21}	zettagram	Zg
10^{18}	exatonne	Et	10^{24}	yottagram	Yg

Origin

Ton and *tonne* are both derived from a Germanic word in general use in the North Sea area since the Middle Ages (cf. Old English and Old Frisian *tunne*, Old High German and Medieval Latin *tunna*, German and French *tonne*) to designate a large cask, or *tun*. A full tun, standing about a metre high, could easily weigh a tonne. The old English wine cask volume measurement known as a tun is close to a metric tonne in weight as it defines about 954 litres which for many commonly used liquids (aqueous solutions) approximates to as many kilograms.

Conversions

One tonne is equivalent to:

- One megagram (exactly);
    - This is the official SI term, but generally not used in industry or shipping, nor colloquially
- $^{1000}/_{0.453\ 592\ 37}$ pounds (exactly by definition), giving approximately
    - 2205 lb (to four significant digits)
- 98.42% of a long ton
    - One long ton (2,240 lb) is 101.605% of a tonne
- 110.23% of a short ton
    - One short ton (2,000 lb) is 90.72% of a tonne

Explanation

The unit symbol for the tonne is *t*. *T* and *mT* and *mt* (especially in the combination *mmt* for *million metric tons* compare to Mt for megatonne) are also occasionally used, but all of these are deprecated since they conflict with internationally agreed SI symbols. (T is the SI symbol for the tesla and m is SI prefix 'milli', meaning 0.001.) *Te* is also sometimes used, particularly in the offshore and nuclear industries.

In France and the English-speaking countries that are predominantly metric, the spelling *tonne* is widespread. This is generally true in Britain; however, the ton used prior to metrication was the long ton of 2,240 pounds (1,016 kg) and this is so close to the tonne that some people draw little distinction and continue to use the old spelling. For example, even the Guinness Book of World Records accepts metrication without marking this by changing the spelling. For the United States, *metric ton* is the name for this unit used and recommended by NIST. In the U.S. an unqualified mention of a ton almost invariably refers to a short ton of 2,000 pounds (907 kg).

Like the gram and the kilogram, the tonne gave rise to a (now obsolete) force unit of the same name, the tonne-force, equivalent to about 9.8 kilonewtons: a unit also often called simply "tonne" or "metric ton" without identifying it as a unit of force. Note that it is only the tonne as a unit of mass (an exact decimal multiple of the SI unit of mass, the kilogram) which is accepted for use with SI: the tonne-force or metric ton-force is not acceptable for use with SI, partly because it is not an exact multiple of the SI unit of force, the newton.

Use of mass as proxy for energy

The *tonne of trinitrotoluene (TNT)* is used as a proxy for energy, usually of explosions (TNT is a common high explosive). Prefixes are used: kiloton(ne), megaton(ne), gigaton(ne), especially for expressing nuclear weapon yield, based on a specific combustion energy of TNT of about 4.2 MJ/kg (or one thermochemical calorie per milligram). Hence, 1 kt TNT = 4.2 TJ, 1 Mt TNT = 4.2 PJ.

The SI unit of energy is the joule. Assuming that a TNT explosion releases 1,000 small (thermochemical) calories per gram (4.2 kJ/g), one tonne of TNT is equivalent to 4.2 gigajoules.

Alternate usage

A metric ton unit (MTU) can mean 10 kilograms (22 lb) within metal (e.g. tungsten, manganese) trading, particularly within the USA. It traditionally referred to a metric ton of ore containing 1% (i.e. 10 kg) of metal.

In the case of uranium, the acronym *MTU* is sometimes considered to be *metric ton of uranium*, meaning 1,000 kg.

Chapter-3

Ounce and Grain

Ounce

The **ounce** (abbreviated: **oz**, the old Italian word *onza*, now spelled *oncia*; apothecary symbol: ℥) is a unit of mass with several definitions, the most commonly used of which are equal to approximately 28 grams. The ounce is used in a number of different systems, including various systems of mass that form part of the imperial and United States customary systems. Its size can vary from system to system. The most commonly used ounces today are the international avoirdupois ounce and the international troy ounce.

Etymology

Ounce derives from Latin *uncia*, a unit that was one twelfth (1/12) of the Roman pound (*libra*). *Ounce* was borrowed twice: first into Old English as *ynsan* or *yndsan* from an unattested Vulgar Latin form with *ts* for *c* before *i* (palatalization) and second into Middle English through Anglo-Norman and Middle French (*unce*, *once*, *ounce*).

Inch comes from the same Latin word, but is different because it was borrowed into Old English and underwent i-mutation or umlaut (*u* → *y*) and palatalization (*k* → *ch*).

Definitions

Historically, in different parts of the world, at different points in time, and for different, the ounce (or its translation) has referred to broadly similar but different standards of mass.

Summary of ounce units

ounce variant	equivalent in grams	equivalent in grains
International avoirdupois ounce	28.3495231	437.5
International troy ounce Apothecaries' ounce	31.1034768	480

Maria Theresa ounce	28.0668
Spanish ounce	28.75
Dutch metric ounce	100
Chinese metric ounce	50

International avoirdupois ounce

The avoirdupois ounce is the most commonly used ounce today. It is defined to be one sixteenth of an avoirdupois pound. The avoirdupois pound is defined as 7000 grains; one ounce is therefore equal to 437.5 grains.

In 1958 the United States and countries of the Commonwealth of Nations agreed to define the international avoirdupois ounce to be exactly $^{0.45359237}/_{16}$ kg (28.349523125 g) by definition.

The ounce is commonly used as a unit of mass in the United States.

On January 1, 2000, it ceased to be a legal unit of measure within the United Kingdom for economic, health, safety or administrative purposes but remains a familiar unit, especially amongst older people.

International troy ounce

A troy ounce (abbreviated as t oz) is equal to 480 grains. Consequently, the **international troy ounce** is equal to exactly 31.1034768 grams. There are 12 troy ounces in the now obsolete troy pound.

Today, the troy ounce is used only to express the mass of precious metals such as gold, platinum, palladium or silver. Bullion coins are the most common products produced and marketed in troy ounces, but precious metal bars also exist in gram and kilogram(kg) sizes. (A kilogram bullion bar contains 32.15074657 troy ounces.)

For historical measurement of gold,

- a **fine ounce** is a troy ounce of 99.5% (".995") pure gold
- a **standard ounce** is a troy ounce of 22 carat gold, 91.66% pure (11 "fine ounces" plus one ounce of alloy material)
- in modern day, an **ounce of gold** (1 troy ounce) is referred as a 99.99% pure gold piece or gold grains (gold shot)

Apothecaries' ounce

The obsolete apothecaries' ounce (abbreviated ℥) equivalent to the troy ounce, was formerly used by apothecaries (now called pharmacists or chemists).

Maria Theresa ounce

"Maria Theresa ounce" was once introduced in Ethiopia and some European countries, which was equal to the weight of one Maria Theresa thaler, or 28.0668 g. Both the weight and the value are the definition of one "Birr", still in use in present-day Ethiopia and formerly in Eritrea.

Spanish ounce

The Spanish pound (Spanish *libra*) was 460 g. The Spanish ounce (Spanish *onza*) was $^1⁄_{16}$ of a pound, i.e. 28.75 g.

Metric ounces

Some countries have redefined their ounces in the metric system.

In 1820, the Dutch have redefined their ounce (in Dutch, *ons*) as 100 grams. Dutch amendments to the metric system, such as an *ons* of 100 grams, has been inherited, adopted, and taught in Indonesia beginning in elementary school. It is also listed as standard usage in Indonesia's national dictionary, the *Kamus Besar Bahasa Indonesia*, and the government's official elementary - school curriculum.

East Asia has a traditional ounce, known as a tael, of varying value. In China, it has been given a metric value of 50 grams.

Ounce-force

An ounce force is 1/16 of a pound-force, or 0.2780139 newton. It is not necessary to identify it as an avoirdupois ounce; there is no troy ounce-force.

Fluid Ounce

A fluid ounce (abbreviated fl oz, fl. oz. or oz. fl.) is a unit of volume equal to about 28 ml in the imperial system or 30 ml in the US system. The fluid ounce is sometimes referred to simply as an "ounce" in applications where its use is implicit. The imperial fluid ounce is also equivalent to the volume occupied by 1 imperial ounce of water weighed in air at 62°F.

Other uses

Fabric weight

Ounces are also used to express the "weight", or more accurately density, of a textile fabric in North America, Asia or the UK, as in "*16 oz denim*". The number refers to the weight in ounces of a given amount of fabric, either a yard of a given width, or a square yard.

Grain

The small golden disk close to the 5cm marker is a piece of pure gold weighing one troy grain. Shown for comparison are a tape measure and coins of major world currencies.

A **grain** is a unit of measurement of mass that is based upon the mass of a single seed of a cereal. In medieval times the average masses of wheat and barley grain were used to define units of mass, with the troy grain based on barley. The grain is the only unit of mass measure common to the three traditional English mass and weight systems (avoirdupois, Apothecaries', troy); the obsolete Tower grain was lighter than the troy grain.

Since 1958, the **grain** or **troy grain** (Symbol: **gr**) measure has been defined in terms of units of mass in the International System of Units as precisely 64.79891 milligrams. However, the measure for pearls and diamonds - the **pearl grain** and the **metric grain** - are equal to $\frac{1}{4}$ of a (metric) carat, i.e. 50 mg (0.77 gr).

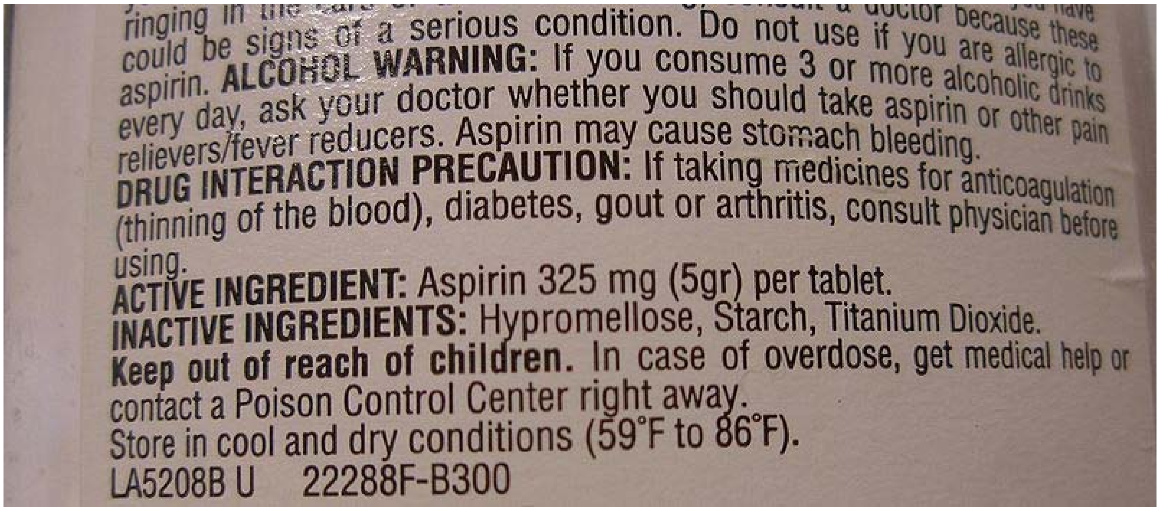
There are precisely 7,000 grains per avoirdupois pound in the Imperial and U.S. customary units, and 5,760 grains in the Troy pound.

Usage in North America

A box of .38 Special cartridges that have 148-grain bullets

The grain is used to measure the mass of bullets, gunpowder, smokeless powder, and preformed gold foil; it is the measure used by the balances used in handloading; bullets are measured in increments of one grain, gunpowder in increments of 0.1 grains. Moreover, the grain is used to weigh fencing equipment, including the foil. In archery, the grain is used to weigh arrows and arrow parts.

The grain is the most common unit used to measure the hardness of water. In particular it is used to quantitively describe the abundance of calcium Ca^{2+} and magnesium Mg^{2+} minerals in water. Typically, the measure is noted in Grains per Gallon (GPG). Water, untreated, typically can measure up to 100 gpg. This measure is critical to setting accurately the resin cation bead regeneration cycle periodicity of both sodium chloride brine and potassium chloride brine flushed water softeners.



The 5-grain aspirin. The back of a bottle of aspirin indicates that the dosage is "325 mg (5 gr)".

Grains are still used occasionally in medicine in the United States, especially in medical prescriptions, usually via the abbreviation "gr." For example, a regular tablet of aspirin is sometimes referred to as "five grain aspirin," or 325 mg. Grains are commonly used for medications that have been included in the United States Pharmacopeia for many decades, such as codeine, opium and phenobarbital combinations. For example, a prescription for tablets containing 325 mg of aspirin and 30 mg of codeine (brand name is Empirin with codeine), is written thus: "ASA gr. v c cod. gr. ss tablets," where "ASA" is short for aspirin (**A**cetyl**S**alicylic **A**cid), "v" is the roman numeral for five, "c" is the abbreviation for "with" and "ss" stands for one-half. Likewise, a prescription for B&O Supprettes #15A, which is a compound medication containing belladonna alkaloids and opium, may be written: "Belladonna gr. 1/4 c opium gr ss", as B&O Supprettes #15A contain 16.2 mg (1/4 grain) of powdered belladonna and 30 mg (1/2 grain) of opium. Similarly, a prescription for 60 mg (1 grain) of phenobarbital is often written: "Phenobarb. gr. i". Formulations of these older medications (e.g., Donnatal, Phenobarbital, etc.), often use grains on the product label along with the metric equivalent. For example, Extended-Release Donnatal tablets contain ¾ grain (approximately 48.6 mg) of phenobarbital. Given the potential error in mistaking the abbreviations for "grains" and "grams" (gr and g, respectively), and for consistency with other medical orders, metric units are preferred to avoirdupois or apothecary units; hence, the use of grains in the medical profession is rapidly becoming outmoded.

Bottle of 1/4 grain phenobarbital tablets

Grains are also used in environmental permitting to quantify particulate emissions. Grains are used to measure the amount of moisture per cubic foot of air, a measure of absolute humidity.

History

carob seed	~200 mg
barley grain	~65 mg
wheat grain	~50 mg

At least since antiquity, grains of wheat or barley were used by Mediterranean traders to define units of mass; along with other seeds, especially those of the carob tree. According to a longstanding tradition, 1 carat (the mass of a carob seed) was equivalent to the weight of 4 wheat grains or 3 barleycorns. But since the weights of these seeds are highly variable, especially that of the cereals as a function of moisture, this is a convention more than an absolute law.

The history of the modern troy grain can be traced back to a royal decree in 13th century England:

By consent of the whole Realm the King's Measure was made, so that an English Penny, which is called the Sterling, round without clipping, shall weigh Thirty-two Grains of Wheat dry in the midst of the Ear; Twenty-pence make an Ounce; and Twelve Ounces make a Pound.
—Henry III of England

The traditional reading of this text is that it refers to the troy pound, and that the reference to sterling pennies is purely symbolic. According to a more recent reading, however, the pound in question is the Tower pound, and it talks about the actual mass of real sterling pennies. The Tower pound, abolished in 1527, consisted of 12 ounces like the troy pound, but was $^{1}/_{16}$ lighter. In any case, with both readings one needs to substitute 24 barley grains for the 32 wheat grains of the text, according to the general convention of a 4:3 equivalence, for it to make sense. The weight of the original sterling pennies was 22½ troy grains, or 24 "Tower grains" if the Tower pound was divided in the same way as the troy pound. Regardless of which pound this text originally referred to, a (troy) ounce still equals 20×24 = 480(troy) grains, and a pound consists of 12×20×24 = 5760 grains.

Originally the troy pound was only "the pound of Pence, Spices, Confections, as of Electuaries", and the merchants used different standards, which had to be compatible with those used abroad. One such standard, the avoirdupois pound, was later fixed officially at exactly 7000 troy grains. It consists of 16 avoirdupois ounces of 437½ troy grains each.

Chapter-4

Pound

The **pound** or **pound-mass** (abbreviations:**lb**, **lb**$_m$, **lbm**) is a unit of mass used in the imperial, United States customary and other systems of measurement. A number of different definitions have been used, the most common today being the international avoirdupois pound which is legally defined as exactly 0.45359237 kilograms.

The unit is descended from the Roman *libra* (hence the abbreviation "lb"); the name *pound* is a Germanic adaptation of the Latin phrase *libra pondo*, 'a pound weight'.

Usage of the unqualified term *pound* reflects the historical conflation of mass and weight resulting from the near uniformity of gravity on Earth. This accounts for the modern distinguishing terms *pound-mass* and *pound-force*.

Definitions

Historically, in different parts of the world, at different points in time, and for different applications, the pound (or its translation) has referred to broadly similar but not identical standards of mass or force.

British pounds

A number of different definitions of the pound have been used in Britain. Amongst these are the avoirdupois pound and the obsolete tower, merchant's and London pounds. The weight of precious metals when given in pounds and/or ounces usually assumes Troy pounds and ounces; these units are not otherwise used today.

Historically the pound sterling was a tower pound of silver. In 1528 the standard was changed to the Troy pound.

English pounds

Unit	Pounds						Ounces			Grains	Metric	
	avdp.	troy	tower	merc.	lond.	metric	avdp.	troy	tower		g	kg
Avoirdupois	1	$\frac{175}{144}$	$\frac{35}{27}$	$\frac{28}{27}$	$\frac{35}{36}$	$\frac{10}{11}$	**16**	$14\frac{7}{12}$	$15\frac{5}{9}$	7000	454	$\frac{9}{20}$
Troy	$\frac{144}{175}$	1	$\frac{16}{15}$	$\frac{64}{75}$	$\frac{4}{5}$	$\frac{3}{4}$	$13\frac{29}{175}$	**12**	$12\frac{4}{5}$	5760	373	$\frac{3}{8}$
Tower	$\frac{27}{35}$	$\frac{15}{16}$	1	$\frac{4}{5}$	$\frac{3}{4}$	$\frac{7}{10}$	$12\frac{12}{35}$	$11\frac{1}{4}$	**12**	5400	350	$\frac{7}{20}$
Merchant	$\frac{27}{28}$	$\frac{75}{64}$	$\frac{5}{4}$	1	$\frac{15}{16}$	$\frac{7}{8}$	$15\frac{3}{7}$	$14\frac{1}{16}$	15	6750	437	$\frac{7}{16}$
London	$\frac{36}{35}$	$\frac{5}{4}$	$\frac{4}{3}$	$\frac{16}{15}$	1	$\frac{14}{15}$	$16\frac{16}{35}$	15	16	7200	467	$\frac{7}{15}$
Metric	$\frac{11}{10}$	$\frac{4}{3}$	$\frac{10}{7}$	$\frac{8}{7}$	$\frac{15}{14}$	1	$17\frac{3}{5}$	16	$17\frac{1}{7}$	7716	500	$\frac{1}{2}$

1. ^ English-metric ratios (in grey) are approximate.

Avoirdupois pound

The avoirdupois pound was invented by London merchants in 1303. Originally it was based on independent standards. During the reign of Henry VIII of England, the avoirdupois pound was redefined as 7,000 troy grains. Since then, the grain has often been considered as a part of the avoirdupois system. By 1758, two standard weights for the avoirdupois pound existed, and when measured in troy grains they were found to be of 7,002 grains and 6,999 grains.

Imperial Standard Pound

In the United Kingdom, weights and measures have been defined by a long series of Acts of Parliament, the intention of which has been to regulate the sale of commodities. Materials traded in the marketplace must be quantified according to accepted units and standards in order to avoid fraud; the standards themselves must be legally defined so as to facilitate the resolution of disputes brought to the courts; only legally defined measures will be recognised by the courts. Quantifying devices used by traders (weights, weighing machines, containers of volumes, measures of length) are subject to official inspection, and penalties apply if they are fraudulent. The Weights and Measures Act of 1878 marked a major overhaul of the British system, and the definition of the Pound given there remained in force until modern times. The Pound was defined thus (Paragraph 4) 'The … platinum weight … deposited in the Standards department of the Board of Trade … shall continue to be the imperial standard of ..weight… and the said platinum weight shall continue to be the imperial standard for determining the imperial standard pound for the United Kingdom'. Para 13 states that the weight 'in vacuo' of this standard shall be called the imperial standard pound, and that all other weights mentioned in the act and permissible for commerce shall be ascertained from it alone. The First Schedule of the Act gives more details of the standard pound:- It is a platinum cylinder nearly 1.35 inches high, and 1.15 inches diameter, and the edges are carefully rounded off. It has a groove about 0.34 inches from the top, to allow the cylinder to be lifted using an ivory fork. It was constructed following the destruction of the Houses of Parliament by fire in 1834, and is stamped P.S. 1844, 1 lb (P.S. stands for 'Parliamentary Standard'). This definition of the imperial pound remains unchanged.

Relationship to the kilogram

The 1878 Act says that contracts worded in terms of metric units will be deemed by the courts to be made according to the imperial units defined in the Act, and a table of metric equivalents is supplied whereby, in such cases, the imperial equivalents may be legally calculated. This effectively defines, for the UK courts and for commerce, the metric units in terms of imperial ones. The equivalence for the pound is given as 1 lb = 453.59265 g or 0.45359 kg, which would make the kilogram weigh approximately 2.2046213 lb. In 1883, it was determined jointly by the Standards Department of the Board of Trade and the Bureau International that 0.4535924277 kg was a better approximation, and this figure, rounded to 0.45359243 kg was given legal status by an Order in Council in May 1898. The Weights and Measures Acts (WMAs) of 1939 and 1958 defined the pound by reference to the WMA of 1878, so as late as 1963 the legal definition of the pound was the same as that given in 1878 (*i.e.* the platinum standard of 1844).

However, in the WMA of 1963 the pound was redefined for the first time as a mass (not a weight) equal to 0.45359237 kg (to match the definition of the International pound agreed in 1959), and 'For the purposes of any measurement of weight, ... the weight of any thing may be expressed... in the same terms as its mass'. The definition of the Pound mass in terms of the imperial standard pound of 1844 was also ratified. This is its present status in the United Kingdom, the same dimension and value having been ratified in the Weights and Measures Act 1985.

United States usage

In the United States, the (avoirdupois) pound as a unit of mass has been officially defined in terms of the kilogram since the Mendenhall Order of 1893. In 1893, the relationship was specified to be 2.20462 pounds per kilogram. In 1894, the relationship was specified to be 2.20462234 pounds per kilogram. This change followed a determination of the British pound.

According to a 1959 NIST publication, the international pound differed from the United States 1894 pound by approximately one part in 10 million. The difference is so insignificant that it can be ignored for almost all practical purposes.

International pound

The United States and countries of the Commonwealth of Nations agreed upon common definitions for the pound and the yard. Since 1 July 1959, the international avoirdupois pound has been defined as exactly 0.45359237 kg.

In the United Kingdom, the use of the international pound was implemented in the Weights and Measures Act 1963.

The yard or the metre shall be the unit of measurement of length and the pound or the kilogram shall be the unit of measurement of mass by reference to which any measurement involving a measurement of length or mass shall be made in the United Kingdom; and- (a) the yard shall be 0.9144 metre exactly; (b) the pound shall be 0.45359237 kilogram exactly.
—*Weights and Measures Act*, 1963, Section 1(1)

An avoirdupois pound is equal to 16 avoirdupois ounces and to exactly 7,000 grains. The conversion factor between the kilogram and the international pound was therefore chosen to be divisible by 7, and an (international) grain is thus equal to exactly 64.79891 milligrams.

Troy pound

The troy pound takes its name from the French market town of Troyes in France where English merchants traded at least as early as the time of Charlemagne (early 9th century). The system of Troy weights was used in England by apothecaries and jewellers.

A troy pound is equal to 12 troy ounces and to 5,760 grains. Today, the grain is common to the avoirdupois and troy systems of units of mass making an international troy pound equal to 373.2417216 grams.

The troy pound is no longer in general use. In Canada, Australia, the United Kingdom, and other places the troy pound is no longer a legal unit for trade (WMA 1878). In the United Kingdom, the use of the troy pound was abolished on 6 January 1879 in accordance with the WMA of 1878, though the troy ounce was retained. The troy ounce is still used for measurements of precious metals such as gold, silver, and platinum, and sometimes gems such as opals.

Most measurements of the mass of precious metals using pounds refer to troy pounds, even though it is not always explicitly stated that this is the case. Some notable exceptions are:

- Encyclopædia Britannica which uses either avoirdupois pounds or troy ounces, likely never both in the same article, and
- the mass of Tutankhamun's sarcophagus lid. This is 110 kilograms. It is often stated to have been 242 or 243 (avoirdupois) pounds but sometimes, much less commonly, it is stated as 296 (troy) pounds.

Tower pound

The system called tower weight was the more general name for King Offa's pound. This dates to 757 AD and was based on the silver penny. This in turn was struck over Arabic dirhams (2d). The pound was based on the weight of 120 Arabic silver dirhams, which have been found in Offa's Dyke. The same coin weight was used throughout the Hanseatic League.

The mercantile pound (1304) of 6750 troy grains, or 9600 tower grains, derives from this pound, as 25 shilling-weights or 15 tower ounces, for general commercial use. Multiple pounds based on the same ounce were quite common. In much of Europe, the apothecaries' and commercial pounds were different numbers of the same ounce.

The tower system was referenced to a standard prototype found in the Tower of London and ran concurrently with the avoirdupois and troy systems, until it fell out of use and was abolished in 1527.

The tower pound is equivalent to about 350 grams.

1 mercantile pound (15 oz)	=	9,600 tower grains	=	6,750 troy grains
1 tower pound (12 oz)	=	7,680 tower grains	=	5,400 troy grains
1 tower ounce (20 dwt)	=	640 tower grains	=	450 troy grains
1 tower pennyweight (dwt)	=	32 tower grains	=	22½ troy grains

Merchants' pound

The merchants' pound (*mercantile pound*, *libra mercantoria* or *commercial pound*) was equal to 9,600 wheat grains (15 tower ounces or 6,750 grains). It was used in England until the 14th century for most goods (other than money, spices and electuaries).

London pound

The London pound is that of the Hansa, as used in their various trading places. This is based on 16 of tower ounces, each ounce divided as the tower ounce. It never became a legal standard in England; the use of this pound waxed and waned with the influence of the Hansa itself.

A London pound was equal to 7,200 troy grains (16 tower ounces or, equivalently, 15 troy ounces).

1 London pound	=	1⅓ tower pounds	=	7,200 troy grains
1 London ounce	=	1 tower ounce	=	450 troy grains
1 London pennyweight	=	1 tower pennyweight	=	22½ troy grains

Wool pound

The wool pound was equal to 6,992 grains. It was a unit of mass used to measure the weight of wool.

Roman libra

§. 108.

V. Gewicht.

Das Wiener Pfund Handelsgewicht, worauf hier Rücksicht genommen wird, hat 0,560012 Kilogramm.

Nahmen der Örter und ihrer Handelsgewichte	Gewicht in Wien. Handelspfunden	Gewicht in franz. Kilogramm
Ägypten, Rotolo	0,757	0,424
Cantaro = 100 Rotoli		
Amsterdam, Pfund à 16 Unzen à 2 Lth.	0,822	0,460
Zentner = 100 ℔		
Athen, Oka à 400 Drachmen	2,730	1,529
Cantaro = 44 Oke		
Baden, Pfund	0,893	0,500
Zentner = 100 ℔		
Baiern, Pfund von 32 Lth	1,000	0,560
Zentner = 100 ℔		
Belgien, Livre (Kilogramm)	1,786	1,000
Bremen, Pfund	0,890	0,498
Zentner = 116 ℔		
Dänemark, Pfund von 32 Loth	0,892	0,499
Zentner = 100 ℔		
England, Handelspfund à 16 Unzen à 16 Drachmen	0,810	0,454
Zentner = 112 ℔		
Troy Pfund von 12 Unzen	0,666	0,373
Frankfurt a. M., Pfund à 32 Loth	0,865	0,484
Zentner = 112 ℔		
Frankreich, Kilogramm von 1000 Gramm	1,786	1,000
altes Pfund Markgewicht	0.875	0.490
Genua, Libbra peso grosso	0,623	0.349
Libra peso sottile	0,566	0,317
Cantaro = 150 Libbre		
Hamburg, Pfund à 32 Loth à 4 Quentchen	0,865	0,484
Zentner = 112 ℔		
Hannover, Pfund à 32 Loth à 4 Quentchen	0,835	0,468
Zentner = 100 ℔		
Holland, Pond (Kilogramm)	1,786	1,000
Köln, Pfund à 2 Mark à 16 Loth	0,835	0,468
Zentner = 106 ℔		
Konstantinopel, Rotolo	1,007	0,564
Oka	2,291	1,283
Cantaro = 100 Rotoli = 44 Oke		
Lemberg, Pfund à 32 Loth à 4 Quentchen	0,750	0,420
Lissabon, Libra	0,820	0,459
Quintal = 4 Arobas à 32 Libras		
Lübeck, Pfund à 32 Loth	0,863	0,483
Zentner = 112 ℔		
Mailand, Libbra peso grosso à 12 once	1,362	0,763
Libbra peso sottile	0,584	0,327
Libbra metrica (Kilogramm)	1,786	1,000
Neapel, Libbra à 12 once	0,573	0,321
Rotolo à 33⅓ once	1,591	0,891
cantaro = 100 Rotoli		
Nordamerik. Freystaaten, Londner Handelspfund	0,810	0 451
Posen, Pfund	0,724	0,406
Prag, böhmisches Pfund von 32 Loth	0,918	0,514
Preußen, Berliner Pfund à 32 Loth à 4 Quentchen	0,835	0,468
Zentner = 110 ℔		
Rom, Libra à 12 Oncе	0,606	0,339
Cantaro grosso = 10 Cantari sottili à 100 Libre		
Rußland, Pfund von 32 Loth à 3 Solotnik	0,731	0,410
Pud von 40 ℔	29,251	16,381
Sachsen, Pfund von 32 Loth	0,834	0,467
Zentner = 110 ℔		
Sardinien, Libbra (Kilogramm) à 10 Once	1,786	1,000
Schweden, Victualien- oder Schalpfund	0,760	0,425
Zentner = 120 ℔		
Schweiz, in den meisten Kantonen Pfund à 32 Loth	0,893	0,500
Smyrna, Oka à 400 Drachmen	2,172	1,216
Cantaro = 45 Oke		
Spanien, Pfund oder Libra	0,822	0,460
Quintal = 4 Arobas à 25 Libras		
Toscana, Libbra von 12 Once	0,606	0,340
Triest, wie Wien; beym Einkaufe fremder Waaren braucht man auch das venetianische Gewicht		
Venedig, Libbra grossa	0,852	0,477
Libbra sottile	0,538	0,301
Würtemberg, leichtes Pfund à 32 Loth	0,835	0,468
Zentner = 104 ℔		
Zollverein, Zollpfund	0.893	0,500
Zollzentner = 100 ℔		

Various historic pounds from a German textbook dated 1848

The libra (Latin for "scales / balance") is an ancient Roman unit of mass that was equivalent to approximately 327 grams. It was divided into 12 *uncia*, or ounces. The libra is the origin of the abbreviation for pound, lb. The commonly used abbreviation *lbs* to indicate the plural unit of measurement does not reflect Latin usage, in which *lb* is both the singular and plural abbreviation.

French livre

Since the Middle Ages, various pounds (*livre*) have been used in France. Since the 19th century, a *livre* has referred to the *metric pound*, 500g.

The *livre esterlin* was equivalent to about 367.1 grams (5,665 gr) and was used between the late 9th century and the mid-14th century.

The *livre poids de marc* or *livre de Paris* was equivalent to about 489.5 grams (7,555 gr) and was used between the 1350s and the late 18th century. It was introduced by the government of John II.

The *livre métrique* was set equal to the kilogram by the decree of *13 Brumaire an IX* between 1800 and 1812. This was a form of official metric pound.

The *livre usuelle* was defined as 500 grams, by the decree of 28 March 1812. It was abolished as a unit of mass effective 1 January 1840 by a decree of 4 July 1837, but is still used informally.

German and Austrian Pfund

Originally derived from the Roman libra, the definition varied throughout Germany in the Middle Ages and onward. The measures and weights of the Habsburg monarchy were reformed in 1761 by Empress Maria Theresia of Austria. The unusually heavy Habsburg (civil) pound of 16 ounces was later (after the kilogram was defined) found to be 560.012 g. Bavarian reforms in 1809 and 1811 adopted essentially the same standard pound. In Prussia, a reform in 1816 defined a uniform civil pound in terms of the Prussian foot and distilled water, resulting in a Prussian pound of 467.711 g.

Between 1803 and 1815 all German regions west of the River Rhine were French, organised in the *départements* Roer, Sarre, Rhin-et-Moselle, and Mont-Tonnerre. As a result of the Congress of Vienna these became part of various German states. However, many of these regions retained the metric system and the French *système usuel* with the metric pound of precisely 500 g. In 1854 the pound of 500 g also became the official mass standard of the German Customs Union, but states differed in the way they subdivided it (decimally, in 30 parts or in 32 parts), and local pounds continued to co-exist with the Zollverein pound for some time in some German states. Nowadays, the term *Pfund* is still in common use and universally refers to a pound of 500 g.

Russian funt

The Russian pound (Фунт, funt) is an obsolete Russian unit of measurement of mass. It is equal to 409.51718 grams.

Skålpund

The Skålpund was a Scandinavian measurement that varied in weight between regions. From the 17th century onward, it was equal to 425.076 grams in Sweden. It was abandoned in 1889 when Sweden switched to the metric system.

In Norway the same name was used for a weight of 498.1 grams, and in Denmark it equalled 471 grams.

In the 19th century Denmark followed Germany's lead and redefined the pound as 500 grams.

20 skålpund = 1 lispund

Jersey pound

A Jersey pound is an obsolete unit of mass used on the island of Jersey from the 14th century to the 19th century. It was equivalent to about 7,561 grains (490 grams). It may have been derived from the French livre poids de marc.

Trone pound

The trone pound is one of a number of obsolete Scottish units of measurement. It was equivalent to between 21 and 28 avoirdupois ounces (about 600-800 grams).

Metric pounds

In many countries upon the introduction of a metric system, the pound (or its translation) became an informal term for 500 grams,

The Dutch *pond* is an exception. It was officially redefined as 1 kilogram, with an ounce of 100 grams, but people seldom use it this way. In daily life *pond* is exclusively used for amounts of 500 grams, and to a lesser extent, *ons* for 100 grams.

In German the term is *Pfund*, in French *livre*, in Dutch *pond*, in Spanish and Portuguese *libra*, in Italian *libbra*, and in Danish and Swedish *pund*.

Though not from the same linguistic origin, the Chinese *jin* (also known a "catty") has a modern definition of exactly 500 grams, divided into ten *cun*. Traditionally about 605 grams, the *jin* has been in use for more than two thousand years, serving the same purpose as "pound" for the common-use measure of weight.

Hundreds of older pounds were replaced in this way. Examples of the older pounds are one of around 459 to 460 grams in Spain, Portugal, and Latin America; one of 498.1 grams in Norway; and several different ones in what is now Germany.

Although the use of the pound as an informal term persists in these countries to a varying degree, scales and measuring devices are denominated only in grams and kilograms. A pound of product must be determined by weighing the product in grams as the use of the *pound* is not sanctioned for trade within the European Union.

Use in commerce

In the United States of America the United States Department of Commerce, the Technology Administration, and the National Institute of Standards and Technology (NIST) have defined the use of mass and weight in the exchange of goods under the Uniform Laws and Regulations in the areas of legal metrology and engine fuel quality in NIST Handbook 130.

NIST Handbook 130 states:

V. "Mass" and "Weight."
The mass of an object is a measure of the object's inertial property, or the amount of matter it contains. The weight of an object is a measure of the force exerted on the object by gravity, or the force needed to support it. The pull of gravity on the earth gives an object a downward acceleration of about 9.8 m/s^2. In trade and commerce and everyday use, the term "weight" is often used as a synonym for "mass." The "net mass" or "net weight" declared on a label indicates that the package contains a specific amount of commodity exclusive of wrapping materials. The use of the term "mass" is predominant throughout the world, and is becoming increasingly common in the United States. (Added 1993)
W. Use of the Terms "Mass" and "Weight."
When used in this handbook, the term "weight" means "mass". The term "weight" appears when inch-pound units are cited, or when both inch-pound and SI units are included in a requirement. The terms "mass" or "masses" are used when only SI units are cited in a requirement. The following note appears where the term "weight" is first used in a law or regulation.
NOTE 1: When used in this law (or regulation), the term "weight" means "mass."

U.S. federal law, which supersedes this handbook, also defines weight, particularly Net Weight, in terms of the avoirdupois pound or mass pound. From 21CFR101 Part 101.105 – Declaration of net quantity of contents when exempt:

(a) The principal display panel of a food in package form shall bear a declaration of the net quantity of contents. This shall be expressed in the terms of weight, measure, numerical count, or a combination of numerical count and weight or measure. The statement shall be in terms of fluid measure if the food is liquid, or in terms of weight if the food is solid, semisolid, or viscous, or a mixture of solid and liquid; except that such

statement may be in terms of dry measure if the food is a fresh fruit, fresh vegetable, or other dry commodity that is customarily sold by dry measure. If there is a firmly established general consumer usage and trade custom of declaring the contents of a liquid by weight, or a solid, semisolid, or viscous product by fluid measure, it may be used. Whenever the Commissioner determines that an existing practice of declaring net quantity of contents by weight, measure, numerical count, or a combination in the case of a specific packaged food does not facilitate value comparisons by consumers and offers opportunity for consumer confusion, he will by regulation designate the appropriate term or terms to be used for such commodity.
(b)(1) Statements of weight shall be in terms of avoirdupois pound and ounce.

From paragraph "a" above, although the avoirdupois pound is a measure of mass, in commerce it is used with the term "Net Weight", because "there is a firmly established general consumer usage and trade custom of declaring the contents of a liquid by weight, or a solid..."

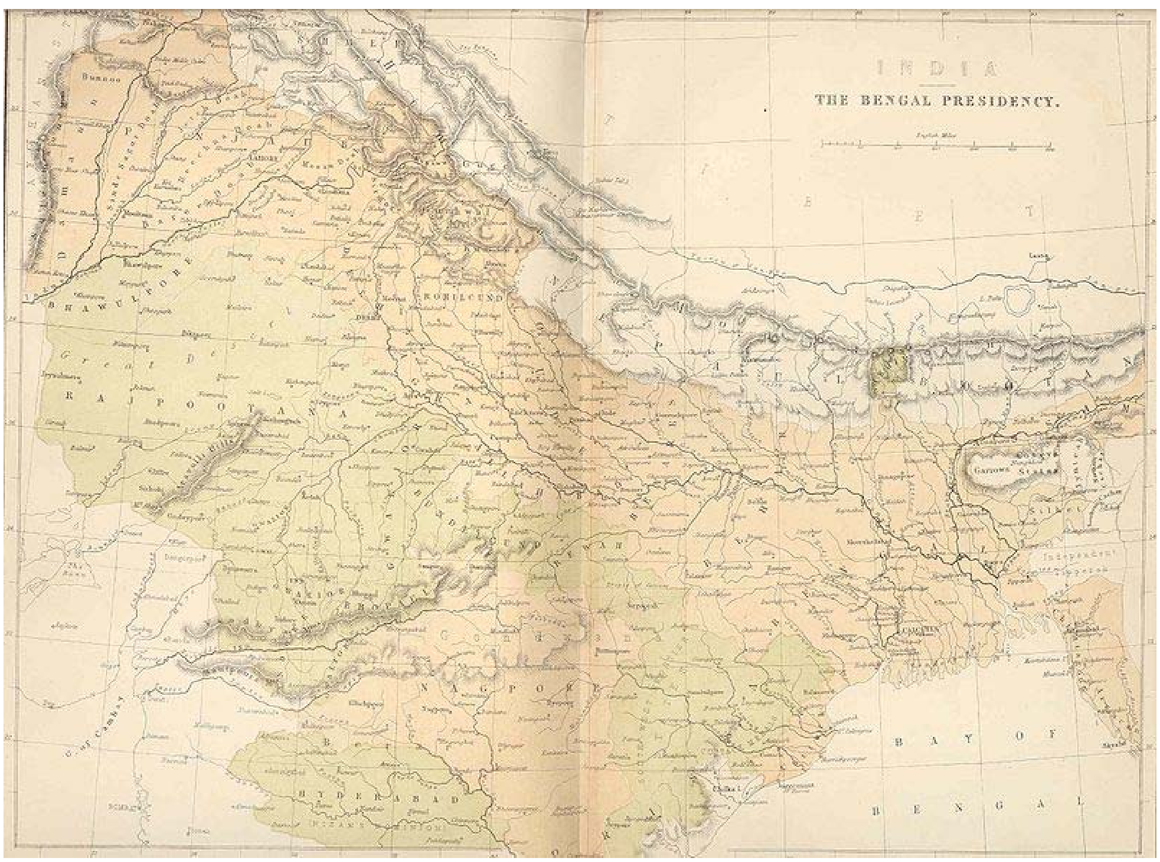
Use in weaponry

Smoothbore cannon and carronades are designated by the weight in imperial pounds of round solid iron shot of diameter to fit the barrel. A cannon that fires a six-pound ball, for example, is called a *six-pounder*. Standard sizes are 6, 12, 18, 24, 32 and 42 pounds; 68-pounders also exist, and other nonstandard weapons use the same scheme.

Chapter-5

Maund and Candy

Maund



The vast extent of the Bengal Presidency (shown here in 1858) facilitated the adoption of the standard of 100 Troy pounds for the maund throughout British India.

The **maund** is the anglicized name for a traditional unit of mass used in British India, and also in Afghanistan, Persia and Arabia: the same unit in the Moghul Empire was sometimes written as ***mun*** in English, while the equivalent unit in the Ottoman Empire and Central Asia was called the *batman*. At different times, and in different South Asian localities, the mass of the maund has varied, from as low as 25 pounds (11 kg) to as high as 160 pounds (72½ kg): even greater variation is seen in Persia and Arabia.

In British India, the maund was first standardized in the Bengal Presidency in 1833, where it was set equal to 100 Troy pounds (82.28 lbs. av.). This standard spread throughout the British Raj. After the independence of India and Pakistan, the definition formed the basis for metrication, one maund becoming exactly 37.3242 kilograms. A similar metric definition is used in Nepal.

Origins

Anglicized as "maund", the *man* as a unit of weight is thought to be of at least Chaldean origin, with Sir Henry Yule attributing Akkadian origins to the word. The Hebrew *maneh* (מנה) and the Ancient Greek *mina* (μνᾶ) are thought to be cognate. It was originally equal to one-ninth of the weight of an *artaba* of water, or approximately four to seven kilograms in modern units.

The modification of the vowel in the anglicized name is thought to be an indication that the word came into English via Portuguese.

South Asia

British Indian units of mass

Mughal Empire	
1 **maund**	= 40 seers
1 seer	= 30 dams
1 dam	= 5 tanks
1 tank	= 3 mashas
1 masha	= 8 ruttees

Bengal Presidency		
1 **maund**	=	8 passerees
1 passeree	=	5 seers
1 seer	=	16 chitaks
1 chitak	=	5 tolas
1 tola	=	12 mashas
1 masha	=	8 rattis
1 ratti	=	4 dhans

Regulation VII 1833 fixed the mass of one tola as 180 troy grains (11.663 8038 grams)

Bombay Presidency		
1 candy	=	20 **maunds**
1 **maund**	=	40 seers
1 seer	=	72 tanks

The maund was fixed at 28 pounds avoirdupois (¼ hundredweight) (12.700 586 36 kilograms)

Madras Presidency		
1 candy	=	20 **maunds**
1 **maund**	=	8 vis
1 vis	=	5 seers
1 seer	=	8 pollums
1 pollum	=	10 pagodas

The maund was fixed at 25 pounds avoirdupois (11.339 809 25 kilograms)

Mughal Empire

Prinsep (1840) summarizes the evidence as to the weight of the *mun* (later "maund") during the reign (1556–1605) of Akbar the Great, which comes from the *Ain-i-Akbari* written by the vizier Abu'l-Fazl ibn Mubarak (anglicized as "Abul Fuzl"). The principal definition is that the *mun* is forty *seers*; and that each *seer* is thirty *dams*.

1 *mun* = 40 *seers* = 1200 *dams*

The problem arises in assigning the values of the smaller units.

The section of the *Ain-i-Akbari* that defines the *mun* also defines the *dam* as five *tanks*. A separate section defines the *tank* as twenty-four *ruttees*. However, by the 19th century, the *tank* was no longer a uniform unit across the former Mughal territories: Prinsep quotes values of 50 grains (3.24 g) in Darwar, 72 grains (4.67 g) in Bombay and 268 grains (17.37 g) in Ahmednugur.

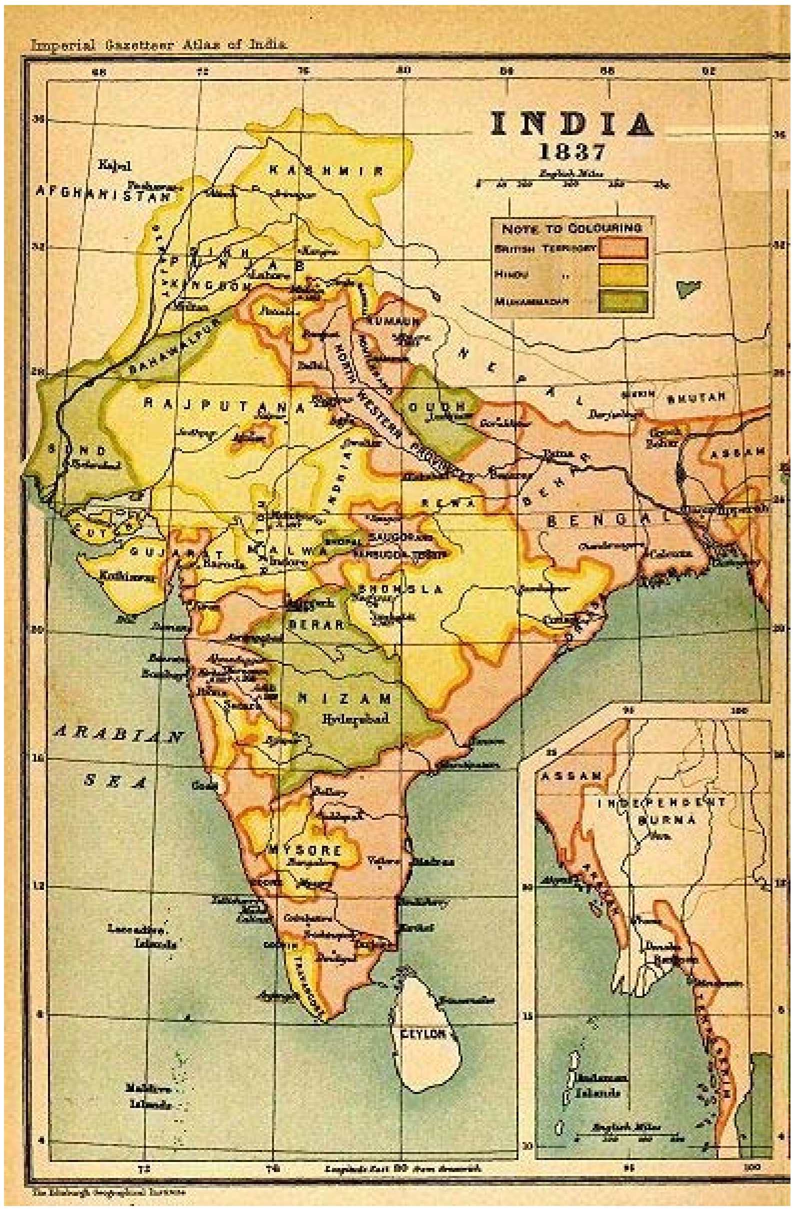
The *jilály*, a square silver rupee coin issued by Akbar, was said by the *Ain-i-Akbari* to be 11¼ *mashas* in weight: surviving *jilály* and other Mughal rupee coins weigh 170–175 Troy grains (11.02–11.34 g), so the *masha*, defined as eight *ruttees*, would be about 15½ grains (1 g). *Masha* weights sent back to London in 1819 agree with this value. This basis gives a *mun* of 34¾ lb. av. (15¾ kg).

However, in yet another section of the *Ain-i-Akbari*, the *dam* is said to be "twenty *mashas* seven *ruttees*": using this definition would imply an Imperial mass of about 47 lb. av.

(21⅓ kg) for the *mun*. Between these two values, the maund in Central India was often found to be around 40 lb. av. (18 kg) in the East India Company survey of 1821.

A Maund was 55.5 British pounds under Akbar.

Nineteenth century



British India is shown in pink on this 1837 map. The Madras Presidency is in the southeast, the Bombay Presidency is in the west and the Bengal Presidency is in the northeast.

The maund of India may as a *genus* be divided into four different *species*:

1. That of Bengal, containing 40 seers, and averaging about 80 lbs. avoir.
2. That of Central India (Malwa, Ajmeer, &c.) generally equal to 40 lbs. avoir. and containing 20 seers (so that the seer of this large portion of the continent assimilates to that of Bengal.)
3. The maund of Guzerat and Bombay, equal to ¼ cwt. or 28 pounds and divided into 40 seers of smaller grade.
4. The maund of Southern India, fixed by the Madras government at 25 lbs. avoir.

There are, however many other varieties of maund, from 15 to 64 seers in weight; which it is unnecessary to particularize.

– Prinsep (1840), p. 77

Prinsep's values for the maund come from a survey organized by the East India Company in 1821. The Company's agents were asked to send back examples of the standard weights and measures used in the places they were stationed, and these were compared with the English standards in London by Patrick Kelly, the leading British metrologist of the time. The results were published as an appendix to the second edition of Kelly's *Universal Cambist* (1831), and later as a separate book entitled *Oriental Metrology* (1832).

It will be seen from Kelly's results below that Prinsep's generalizations are only partially correct. The Gujarat maund is more closely related to the Central Indian maund than to the standardized Bombay maund, except in the town of Anjar, except that it is divided into 40 seers instead of 20 as was found in Malwa.

Central India and Gujarat

Place	Sub-division	Imperial lb.	oz.	dr.	Metric kg
Ahmadābād, in Gujarat	40 seers	42	4	13	19.817
Amod, in Broach	40 seers	40	8	12	
Anjar, in Cutch	40 seers	27	3	8	
Bairseah, in Malwa	40 seers	77	1	12	
Bārdoli, in Surat	39¾ seers, 2 pice	37	4	4¾	
Broach, in Gujarat	40 seers	40	8	12	
Baroda, in Gujarat	42 seers	44	9	10	
Cambay, in Gujarat	40 seers	37	8	0	
Chanadore, Central Provinces	64 seers	149	12	0	
Dewas, in Malwa	64 seers	137	8	2	
Doongurpoor, in Rajputana	40 seers	50	1	14	
Hānsot, in Broach	40 seers, "market"	38	9	9	

	42 seers, for oil	40	8	6
	40 *pergunna* seers	39	3	10
Indore, in Malwa	20 seers, for grain	40	8	6
	40 seers, for opium	81	0	12
Jambusar, in Broach	40 seers, "market"	40	6	4
	42 seers, for cotton	42	6	9
Kota, in Rajputana	40 seers	30	0	0
Kumbharia, in Surat	40 seers 8 pice	37	13	10
Kurod, in Surat	40 seers 15 pice	37	15	8½
Malwa	20 seers	40	7	8
Mundissor, in Malwa	15 seers	34	4	4½
Okalesur, in Broach	40 seers	38	8	13
	40 seers, "*pergunna*"	40	6	13
Omutwara, in Malwa	28 seers	54	10	8
Oujein, in Malwa	16⅞ seers	33	5	13
Pertabgurh, in Ajmer	20 seers	38	8	14
Rutlam, in Malwa	20 seers	40	7	8
Surat, in Gujarat	40 seers	37	8	0

Bombay Presidency

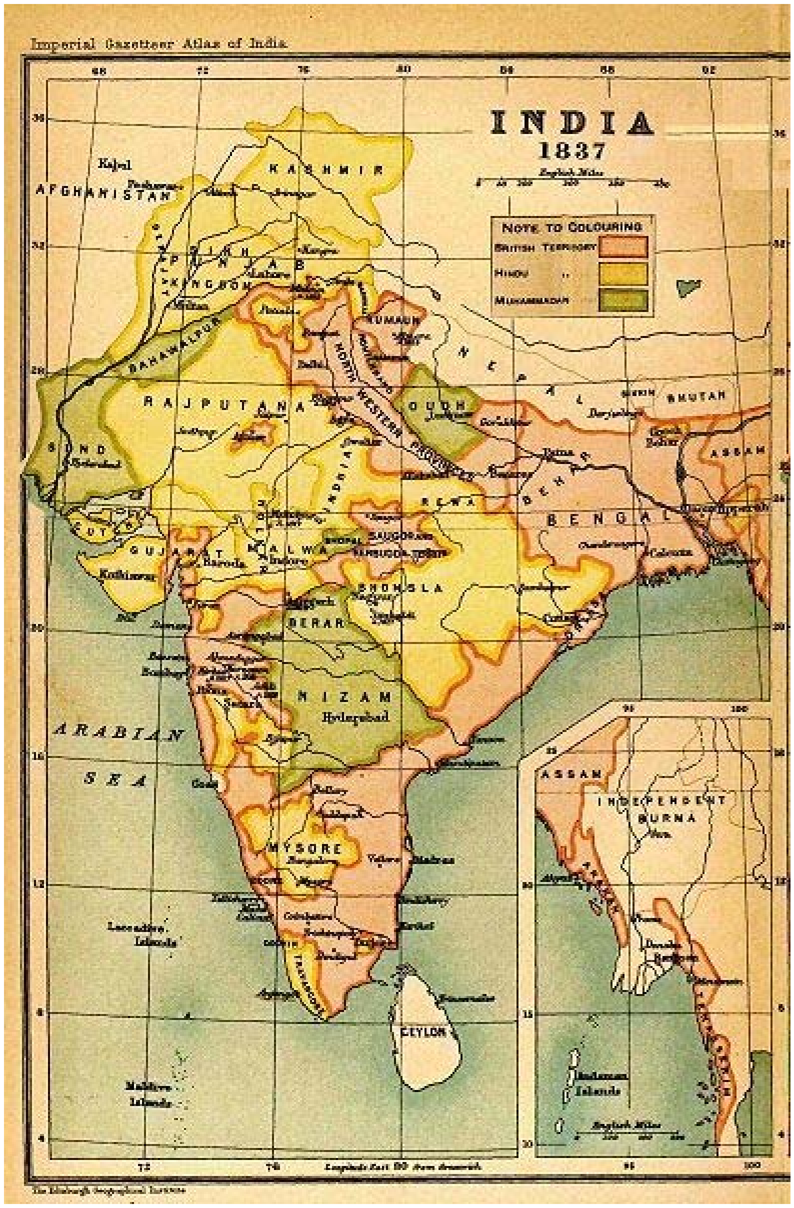
Place	Sub-division	Imperial			Metric
		lb.	oz.	dr.	kg
Ahmadnagar	40 seers	78	15	12	
Aurangabad	40 seers	74	10	10	
Belgaum	44 seers	26	3	15	
Bombay	40 seers	28	0	0	
Carwar, in Kanara	42 seers	26	0	0	
Dindoor	64 seers	157	10	10	
	12½ seers, for ghee, etc.	24	10	4⅓	
Dukhun Poona	14 seers, for metals	27	9	9⅔	
	48 seers, for grain	94	9	8	
Goa (Portuguese)	—	24	12	0	
Jamkhair, in Ahmednagar	64 seers	147	10	0	
Jaulnah, in Hyderabad	40 seers	80	2	8	
Onore, in Kanara	40–44 seers	25	0	0	
Poona	12½ seers, for ghee, etc.	24	10	4⅓	

	14 seers, for metals	27	9	9⅔
	48 seers, for grain	94	9	8
Roombharee, in Ahmednagar	64 seers	160	13	8

Madras Presidency

Place	Sub-division	Imperial lb.	oz.	dr.	Metric kg
Anjengo, in Travancore	—	28	0	0	
Bangalore, in Mysore	40 seers	25	0	0	
Bellary, in Madras	48 seers	25	6	0	
Calicut, in Malabar	68 seers	34	11	11	
Cochin, in Malabar	42½ seers	27	2	11	
Coimbatoor, in Mysore	40 seers	24	1	0	
Colachy, in Travancore	125 pollums	18	12	13	
Hyderabad, in Madras	12 seers, "*kucha*"	23	13	0	
	40 seers, "*pucka*"	79	6	0	
Madras	40 seers, or 8 vis	25	0	0	
Madura, in Carnatic	39.244 seers	25	0	0	
	46 seers, "market"	28	2	4	
Mangalore	46 seers, "Company's"	28	8	13	
	40 seers, for sugar	24	7	8	
Masulipatam, in Madras	"*kucha*"	35	10	0	
	"*pucka*"	80	0	0	
Negapatam, in Carnatic	41.558 seers	25	0	0	
Pondicherry	8 vis	25	14	5½	
Quilon, in Travancore	25 old Dutch pounds	27	5	8	
Sankeridroog, in Carnatic	41.256 seers	25	0	0	
Seringapatam	40 seers, "*kucha*"	24	4	8	
Tellicherry, in Malabar	64 seers	32	11	0	
Tranquebar, in Coromandel	68 Danish pounds	74	12	9.6	
Travancore, in Madras	—	25	0	6½	
Trichinopoly, in Carnatic	13.114 seers	25	0	0	
Vizagapatam, in Madras	"*kucha*"	35	10	0	
	"*pucka*"	80	0	0	

Candy



British India is shown in pink on this 1837 map. The Madras Presidency is in the southeast, the Bombay Presidency is in the west and the Bengal Presidency is in the northeast.

The **candy** or **candee** , also known as the **maunee**, was a traditional South Asian unit of mass, equal to 20 maunds and roughly equivalent to 500 pounds avoirdupois (227 kilograms). It was most used in southern India, to the south of Akbar's empire, but has been recorded elsewhere in South Asia. In Marathi, the same word was also used for a unit of area of 120 bighas (25 hectares, very approximately), and it is also recorded as a unit of dry volume.

The candy was generally one of the largest (if not *the* largest) unit in a given system of measurement. The word was adopted into several South Asian languages before the compilation of dictionaries, presumably through trade as several Dravidian languages have local synonyms.

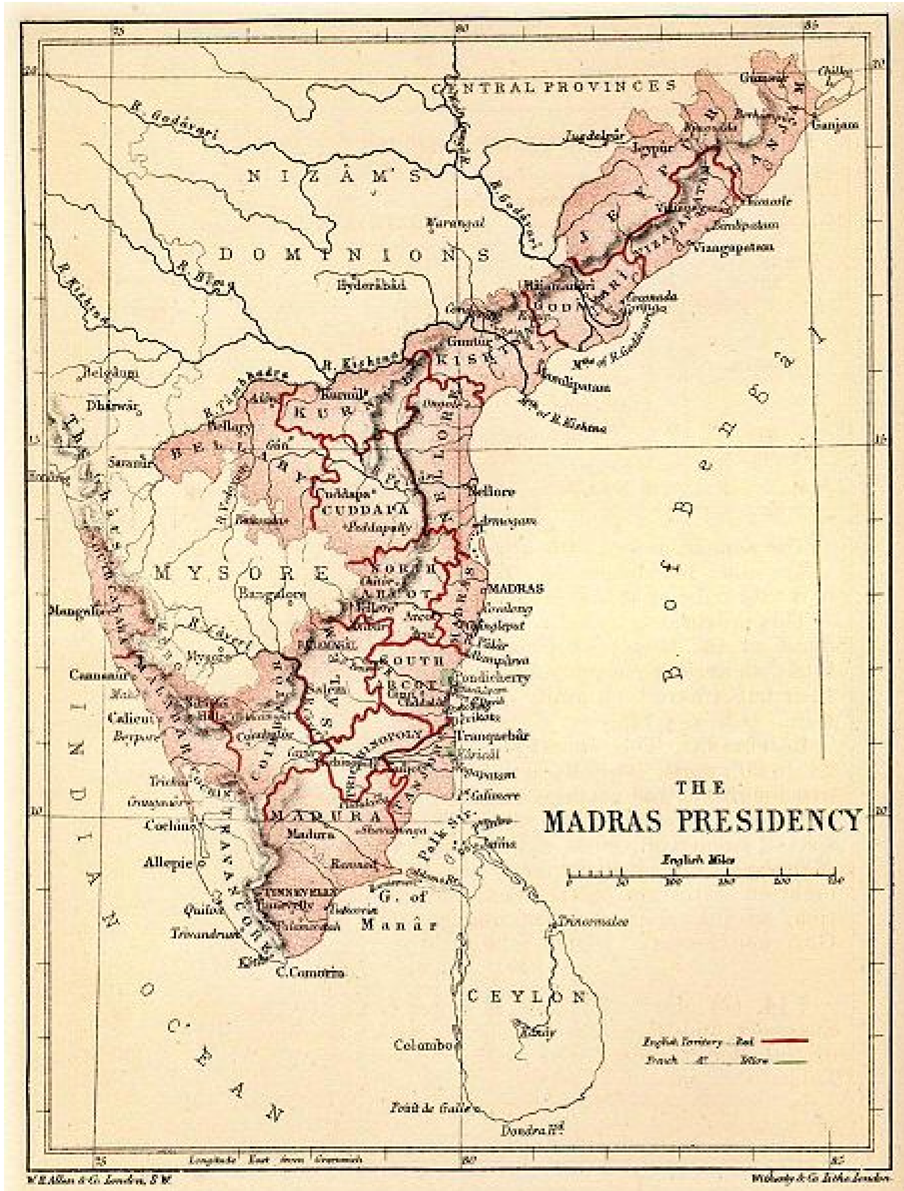
Unit of mass

The candy was equal to twenty maunds, but the value of the maund was not standardised across South Asia. There were at least three different approximate values for maund in early nineteenth century India, ranging from 11.34 kg to 37.32 kg, and values from outside India varied even wider. Much of our knowledge of the values of South Asian mass units comes from an 1821 study ordered by the British East India Company and subsequently published as *Kelly's Oriental Metrology*, although the approximate value of 500 pounds for the candy is attested as early as 1618. The earliest European reference to the candy (1563) puts its mass at 522 arráteis (239.6 kg, 528.2 lbs.).

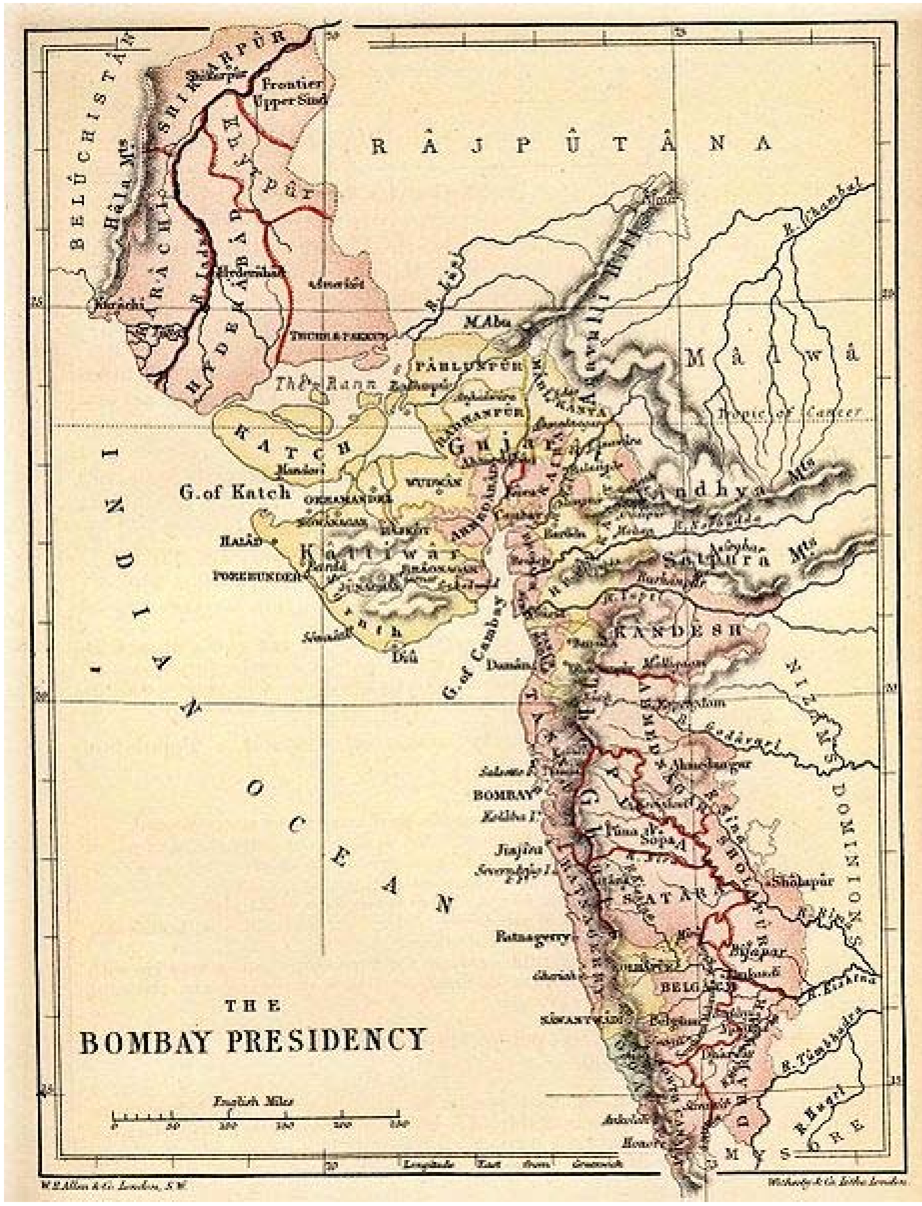
The three Presidencies of British India had already undertaken a fair degree of standardisation of weights and measures by the time of Kelly's study. In the Madras Presidency, the maund was fixed at 25 lbs. av. (11.340 kg), making the candy equal to 500 lbs. av. (226.796 kg). In the Bombay Presidency, the maund was fixed at 28 lbs. av. (12.701 kg), making the candy exactly equal to 5 hundredweight (560 lbs. av., 254.012 kg). In Bombay itself (present-day Mumbai), a separate value of the candy was recorded for "grain", equal to 8 parahs or 358 lbs. 6 oz. 4 dr. (162.563 kg). In the Bengal Presidency, where the candy was not traditionally used, the maund (or *mun*) was a much larger unit, 100 troy pounds (37.324 kg, equivalent to a candy of 746.5 kg).

The effects of this standardisation can also be seen in other territories under direct British control. In Ceylon, the candy (also known as the bahar) was 500 lbs (226.796 kg) as on the Continent. Use of the candy is also recorded in British Burma, where it was the equivalent of 150 vis: its equivalent in Imperial units was measured as 500 lbs. (226.796 kg) in Pegu and 550 lbs. (249.476 kg) in Rangoon.

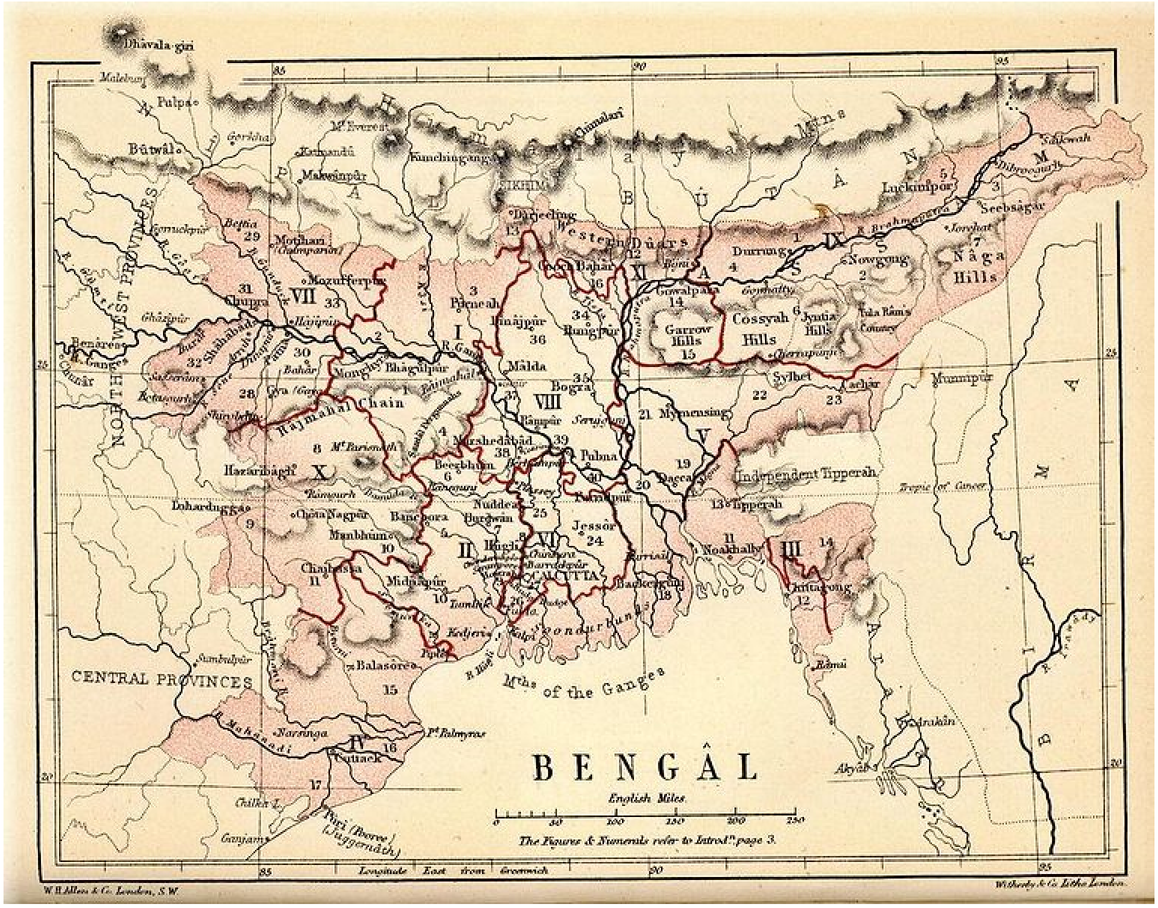
Perhaps the most striking example is from the princely state of Travancore in southwest India. At the British East India Company trading station of Anjengo, (near modern-day Kadakkavoor), the candy was equal to 35 telong and fixed at 560 lbs. (254.012 kg), as in Bombay. At Colachy (modern-day Kolachal) however, less than 50 miles (80 km) to the south, the candy was measured at only 376 lbs. 1 oz. 2 dr. (170.583 kg).



Madras Presidency shown in an 1880 map.



Bombay Presidency in an 1880 map.



Bengal Presidency in 1880.

In the region of the Central Provinces, the maund was roughly 40 lbs., which is probably about the value it had under the Mughal Empire. The candy was not recorded as being in use as a unit of measurement in this region in 1821. Although not a part of the Central Provinces region, the unusually high value recorded for the candy in Baroda, Gujarat (modern-day Vadodara) – 892 lbs. 1 oz. 4 dr. (404.640 kg) – can be explained by this higher value of the Mughal maund. The candy in Surat, the main port of Gujerat, is also consistently quoted as being much larger than the same unit further south.

Unit of area

The candy is also recorded as a unit of area in Marathi, equal to 120 bighas. It is impossible to accurately convert this to modern units given the huge variability in the different values of the bigha in different locations. In particular, Kelly's 1821 study of South Asian metrology is completely silent on land measures in the Bombay Presidency. Molesworth defines the Marathi bigha as equal to twenty pandas or to 400 square kathys but also notes that it varies in different districts. The same author defines the kathy as "a land measure,—five cubits and five handbreadths […] also the measuring rod": other authors are silent on the unit. A cubit is roughly equal to five handbreadths, so the kathy can be taken to be roughly 25 square cubits: that is, 8100 square inches or 6.25 square yards. This would make the bigha roughly 2500 square yards, or half an acre, in agreement with measurements in other areas of India. The candy, therefore, can be taken to be approximately 60 acres or 25 hectares.

The celebrated Scottish orientalist Sir Henry Yule gives a slightly larger value for the candy as a unit of area ("approximately 75 acres"), and describes it as the area of land which will produce one candy of grain. The Telegu unit of the putty is also used in the same way: one putty of land is that area which will produce one putty of rice.

Unit of dry volume

Several sources also describe the candy as a unit of dry measure. Again, it is difficult to give an accurate conversion to modern units, as most sources quote conversions to mass units for specific goods, and the few specific conversion factors that exist range from 8 to 25 bushels. More plausible is that one candy of dry measure was the volume that would have been occupied by one candy (in mass) of water, that is about 254 litres (7 bushels) in Bombay (present-day Mumbai).

- One candy of "grain" (unspecified) in Bombay was recorded by Kelly as 8 parahs or 358 lbs. 6 oz. 4 dr. (162.563 kg), compared to a standard Bombay candy of 560 lbs. (254.012 kg), a factor of 0.640. This factor is lower than the relative density of modern hulled rice (0.753) but higher than the that of rough rice (0.577).
- One parah for salt measure for Bombay was reported as 1607.6 cubic inches (26.344 litres), implying a candy for dry measure of salt as 210.8 litres: the factor (1.20, based on 254 litres for one candy of water) is identical to the relative density of caked salt.
- The Ceylonese standard parah was a cube of sides 11.57 inches, that is 25.41 litres.
- Molesworth defines the Marathi palah as 120 seers, implying a candy of 960 seers and a maund of 48 seers. The Bombay seer is given by Kelly as 11 oz. 3 dr. (317.2 g) for both grain and other commercial goods.

Not all grain measures in candies should be taken as dry measures. The United Nations Statistical Office reported that the candy was in use in the 20th century:

- in east India for measuring rice, with a value of approximately 210.636 kg compared to the old Madras standard candy of 226.796 kg;
- in Ceylon (later Sri Lanka) for measuring copra, with a value of 560 lbs.

Both of these are obviously related to the candy as a unit of mass.

Chapter-6

Carat, Tael, Batman (unit) and Kendrick Mass

Carat (mass)

The **carat** is a unit of mass equal to 200 mg (0.007055 *oz*), and it is used for measuring gemstones and pearls.

The current definition, sometimes known as the **metric carat**, was adopted in 1907 at the Fourth General Conference on Weights and Measures, and soon afterwards in many countries around the world. The carat is divisible into one hundred *points* of two milligrams each. Other subdivisions, and slightly different mass values, have been used in the past in different locations.

In terms of diamonds, a *paragon* is a flawless stone of at least 100 carats (20 g).

The ANSI X.12 EDI standard abbreviation for the carat is **CD**.

Etymology

First attested in English in the middle 15th century, the word *carat* came to English from Middle French *carat*, in turn from Italian *carato*, which came from Arabic *qīrāṭ* (قيراط), a term for a very small unit of weight defined by reference to a small seed, which in turn comes from Greek κεράτιον (*kerátion*), literally meaning "small horn" (diminutive of κέρας - *keras*, "horn") but also "carob seed" which was used as a unit of weight. The Latin word for carat is *siliqua*. The carob tree is Ceratonia siliqua.

In past centuries, different countries each had their own carat unit, all roughly equivalent to the mass of a carob seed, though the carob seed itself was not used as the standard reference point for the weight. These units were often used for weighing gold.

Historical definitions in the United Kingdom

Board of Trade carat

In the United Kingdom, before 1888, the **Board of Trade carat** was exactly $3\,\frac{1647}{9691}$(≈ 3.170) grains; after 1887, the Board of Trade carat was exactly $3\,\frac{17}{101}$(≈ 3.168) grains. Despite it being a non-metric unit, a number of metric countries used this unit for its limited range of application.

The Board of Trade carat was divisible into four *diamond grains*, but measurements were typically made in multiples of $\frac{1}{64}$carat.

Pound carat and ounce carat

There were also two varieties of *refiners' carats* once used in the United Kingdom — the **pound carat** and the **ounce carat**. The pound troy was divisible into 24 *pound carats* of 240 grains troy each; the pound carat was divisible into four *pound grains* of 60 grains troy each; and the pound grain was divisible into four *pound quarters* of 15 grains troy each. Similarly, the ounce troy was divisible into 24 *ounce carats* of 20 grains troy each; the ounce carat was divisible into four *ounce grains* of 5 grains troy each; and the ounce grain was divisible into four *ounce quarters* of 1¼ grains troy each.

The carat of the Romans and Greeks

The *solidus* was also a Roman weight unit. There is literary evidence that the weight of 72 coins of the type called *solidus* was exactly a Roman pound, and that the weight of a *solidus* was 24 *siliquae*. The weight of a Roman pound is generally believed to have been 327.45 *g* or possibly up to 5 *g* less. Therefore the metric equivalent of 1 *siliqua* was approximately 189 *mg*. The Greeks had a similar unit of the same value.

Gold fineness in carats, comes from carats and grains of gold in a solidus of coin. One solidus = 24 carats, 1 carat = 4 grains, is preserved right up to this day. A book gives gold fineness in carats of 4 grains, and silver in (pound) of 12 ounces each 20 dwt.

The carat in Byzantine Egypt

A carob based weight unit was also used in Egypt in the Byzantine and early Arab periods. In this region, glass weights were used for weighing coins. From these the weight of the Egypt carat has been reconstructed as 196 *mg*. This is consistent with the average weights of carob seeds in the region.

The Syrian and Arabic carat in the First Millennium CE

According to literary sources, the Arabic carat was only 2% less than the Syrian carat. Based on coins and glass weights their weight was reconstructed as approximately

212 *mg*. This is consistent with literary information that a solidus weighed slightly less than 22 carats.

Tael

Tael can refer to any one of several weight measures of the Far East. Most commonly, it refers to the Chinese tael, a part of the Chinese system of weights and currency.

In Taiwan, Hong Kong, and Southeast Asia it is equivalent to 10 mace (*qián* 錢) or $^{1}/_{16}$ catty, albeit with slightly different equivalents in metric in these two places. These Chinese units of measurement are usually used in the Chinese herbal medicine stores as well as gold and silver exchange.

Names and etymology

The English word *tael* comes through Portuguese from the Malay word *tahil*, meaning "weight". Early English forms of the name such as "tay" or "taes" derive from the Portuguese plural of tael, *taeis*.

Tahil in Singaporean English) is used in Malay *and* English today when referring to the weight in Malaysia, Singapore, and Brunei where it is still used in some contexts especially related to the significant Overseas Chinese population.

In Chinese, tael is written 兩 (simplified Chinese: 两) and pronounced *liǎng* in Mandarin Chinese. In Chinese and Vietnamese, the phrase "half a catty, eight taels" (半斤八兩 and *kẻ tám lạng người nửa cân*, respectively), meaning two different presentations of the same thing (similar to the English phrase "Six of one and half-a-dozen of the other"), is still often used today.

In Thai, the tael is called *tamlueng*. The Thai expression roughly equivalent to "speech is silver; silence is golden", *Phūt pai sǭng phai bīa, ning sīa tamlưng thǭng* is literally, "if you talk, (you'll get) 2 *phai* [i.e., a small sum] of money; if you remain silent, (you'll get) a *tamlueng* [i.e., a lot] of gold".

Historical usage

Japanese Edo era tael sycees. In descending size, 30, 20, 10, 5, 4, 3, and 2 tael sycees.

In China, there were many different weighting standards of tael depending on the region or type of trade. In general the silver tael weighed around 40 grams. The most common government measure was the *Kùpíng* (庫平 "treasury standard") tael, weighing 1.2 Troy ounces (37.3 g). A common commercial weight, the *Cáopíng* (漕平 "canal shipping standard") tael weighed 1.18 Troy ounces (36.7 g) of marginally less pure silver.

As in China, Japan used the tael (両 *ryō*) as both a unit of weight and, by extension, a currency.

The Siamese (Thai) tael or *tamlueng* was a unit of weight and was equal to four ticals.

Tael currency

Traditional Chinese silver sycees and other currencies of fine metals were not denominated or made by a central mint and their value was determined by their weight in taels. They were made by individual silversmiths for local exchange, and as such the shape and amount of extra detail on each ingot were highly variable; square and oval shapes were common but "boat", flower, tortoise and others are known. The local tael also took precedence over any central measure, so the Canton tael weighed 37.5g, the Convention or Shanghai tael was 33.9 g (1.09 oz troy), and the Customs or *Hǎiguān* (海關) tael 37.8 g (defined as $1\frac{1}{3}$ oz avoirdupois, about 1.22 oz troy). The conversion rates between various common taels were well known. The tael was still the basis of the silver currency and sycee remained in use until the end of the Qing Dynasty in 1911. Common weights were 50 tael, 10 tael, and 5 down to 1.

Modern studies suggest that, on purchasing power parity basis, one tael of silver was worth about 4130 modern Chinese yuan in the early Tang Dynasty, 2065 in the late Tang Dynasty, and 660.8 in the mid Ming Dynasty.

In Siam (now Thailand), the tael or *tamlueng* was a currency subdivision equal to $\frac{1}{32}$ of a tical, the base currency which became the Thai baht.

Contemporary usage

The tael is still in use as a weight measurement in a number of countries though usually only in limited contexts.

China

The Republic of China's standardised **market tael** (市两 *shìliǎng*) of 31.25 g was modified by the People's Republic of China in 1959. The new market tael was 50 g or $\frac{1}{10}$ catty (500 g) to make it compatible with metric measures. In Shanghai, silver is still traded in taels.

Some foodstuffs in China are sold in units also called "taels", but which do not necessarily weigh one tael. For cooked rice, the weight of the tael is approximated using special tael-sized ladels. Other items sold in taels include the shengjian mantou and the xiaolongbao, both small buns commonly found in Shanghai. In these cases, one tael is traditionally four and eight buns respectively.

Hong Kong

The tael is a legal weight measure in Hong Kong, and is still in active use. In Hong Kong, one tael is 37.79936375 g, and in ordinance 22 of 1884 is $1\frac{1}{3}$ oz. avoir. Similar to Hong Kong, in Singapore, one tael is defined as $1\frac{1}{3}$ ounce and is approximated as 37.7994 g

Taiwan

The Taiwan tael is 37.5 g and is still used in some contexts. Taiwan never adopted the Republic of China's market tael of 31.25 g; its tael is derived from the tael or *ryō* of the Japanese system (equal to 10 *momme*) which was 37.5 g. Although the catty is still frequently used in Taiwan, the tael is only used for precious metals and medicines.

Vietnam

In French Indochina, the colonial administration standardised the tael *(lạng)* as 100 g but this unit is no longer used in Vietnam. However, a different tael (called *cây*, *lạng*, or *lượng*) unit of 37.5 g is used for domestic transactions in gold. Real estate prices are often quoted in taels of gold rather than the local currency over concerns over monetary inflation.

Batman (unit)

The **batman** was a unit of mass used in the Ottoman Empire and among Turkic peoples of the Russian Empire. It has also been recorded as a unit of area in Uyghur-speaking regions of Central Asia. The name is Turkic (Ottoman Turkish *baṭmān*; Chagatai *bātmān*), but was also sometimes used for the equivalent unit in Persia (من , *man*). The equivalent unit in British India was anglicized as the maund. The value of the batman (or maund) varied considerably from place to place.

Origins

The *man* as a unit of weight is thought to be of at least Chaldean origin, with Sir Henry Yule attributing Akkadian origins to the word. The Hebrew *maneh* (הנמ) and the Ancient Greek *mina* (μνᾶ) are thought to be cognate. It was originally equal to one-ninth of the weight of an *artaba* of water, or approximately four kilograms in modern units. İnalcık believes the ancient Persian *patimāna* may have come from the late Assyrian word for "mana of the king". The *man* or *batman* spread throughout Arabia and Persia: it was adopted by the Ottoman Empire, and brought to India by the Mughal Empire. The first attestation which gives a comparison to European weights was by Pegolotti in his *Pratica della mercatura*, written about 1340. He reported the *batman* as the main unit of mass in Ayasluğ ("Altoluogo di Turchia" to Pegolotti; modern Selçuk, in western Turkey), equivalent to 32 Genoese pounds (*libbre*).

Ottoman Empire

The batman (or bateman) was first recorded in English in 1599, in Babylon (probably modern Baghdad), where it was said to be equal to "7 pound and 5 ounces English weight". In the central Ottoman system of weights, the batman was equal to six okas, as is attested in 1811 in Aleppo, 1821 in Baghdad and in 1850 in Constantinople. At this point, the batman was equal to 16 lb. 8 oz. avoirdupois (7.484 kg).

Arabia

Place	Local	Imperial lb.	oz.	dr.	Metric kg
Bayt al-Faqih	$^1/_{10}$ frazil	2	0	10	0.9249
Jeddah	30 uqiyyas	2	3	9 $^3/_5$	1.0092
Mocha	40 uqiyyas	3	5	0	1.5025

Source: Kelly's *Oriental Metrology* (1832)

The *mann* (مَنّ) had doubtless formed a part of the Arabian system of weights before the arrival of the Ottomans. It was divided into *uqiyyas* (the number varying with the location), while ten *mann* made one *frazil*. A still larger unit of mass was the *bahar*, of ten to forty *frazils*. The Arabic *mann* was smaller than the Ottoman *batman* at about 2–3 lb. av. (1–1½ kg), except in Basra where there were two maunds in use, both much larger than either the Arabic *mann* or the Ottoman *batman*.

Turkey

The Turkish system of weights and measures was metrified in 1931. The *oka* was redefined as exactly one kilogram, while the *batman* became ten *okas* (10 kg).

Central Asia

The batman was used in Central Asia up until at least the 18th century. In Khiva in 1740, there were said to be two batmans (as in Persia): the "great batman" of 18 Russian pounds (фунт, *funt*; approx. 7.4 kg) and the "lesser batman" of 9¼ Russian pounds (approx. 3.8 kg).

In Uyghur, the batman was also a measure of land area, the area that could be sown with one batman (in mass) of seed.

Idel-Ural

The Tatar batman is an equivalent to 1000 pood or 16.4 tonnes.

Persia

Place	Local	Imperial lb.	oz.	dr.	Metric kg
Bandar-Abbas	*tabrézy*	6	12	0	3.0617
("Gamron")	*sháhy*	13	8	0	6.1235
Bushehr	720 mithqals	7	10	15	3.4852
Shiraz	600 mithqals	12	10	14.4	5.7521
Tabriz	300 mithqals	6	5	7.2	2.8761

The two main commercial weights in Persia were the *tabrézy man* (زیربت نم), literally the *man* of Tabriz, and the *sháhy man* (ءاش نم), literally the Shah's *man*, which was twice as large. The *sháhy man* was particularly used in Shiraz and Isfahan. Kelly also distinguishes a *man* used for copra and "provisions" at Gamron (modern Bandar-Abbas) of 7 lb. 12 oz. av. (3.5153 kg).

The United Nations Statistical Office found a wide range of values for the *man* in Iran in 1966, from 3 kg to 53 kg. The *man* was divided into *mithqals* (the number depending on the locality): larger subdivisions included the *abbassi* and the *ratl*. The term *batman* appears to be reserved for the *tabrézy man*, approximately 2.969 kg in 1966.

Afghanistan

The *mann* (Pashto: نم) was also used as a unit of mass in Afghanistan, but varied widely between different localities. In Kandahar is was about 8 lb. av. (3½ kg), while in Peshawar it was 80 lb. av. (35 kg).

Kendrick mass

The **Kendrick mass** is a mass obtained by multiplying the measured mass by a numeric factor. The Kendrick mass is used to aid in the identification of molecules of similar chemical structure from peaks in mass spectra. The method of stating mass was suggested in 1963 by the chemist Edward Kendrick.

Definition

According to the procedure outlined by Kendrick, the mass of CH_2 is defined as 14.000 Da, instead of the IUPAC mass of 14.01565 Da.

To convert an IUPAC mass to the Kendrick mass, the equation

$$Kendrick\ mass = IUPAC\ mass \times \frac{14.00000}{14.01565}.$$

is used. The mass in dalton units (*Da*) can be converted to the Kendrick scale by dividing by 1.0011178.

Other groups of atoms in addition to CH_2 can be used to obtain the Kendrick mass, for example COO, H_2, H_2O, and O. In this case, the Kendrick mass for a family of compounds F is given by

$$Kendrick\ mass\ (F) = (observed\ mass) \times \frac{nominal\ mass\ F}{exact\ mass\ F}.$$

For hydrocarbon analysis, F=CH_2.

A recent publication has suggested that Kendrick mass be expressed in Kendrick units with symbol *Ke*.

Kendrick mass defect

The Kendrick mass defect is defined as the exact Kendrick mass subtracted from the nominal (integer) Kendrick mass:

$$Kendrick\ mass\ defect = nominal\ Kendrick\ mass - Kendrick\ mass$$

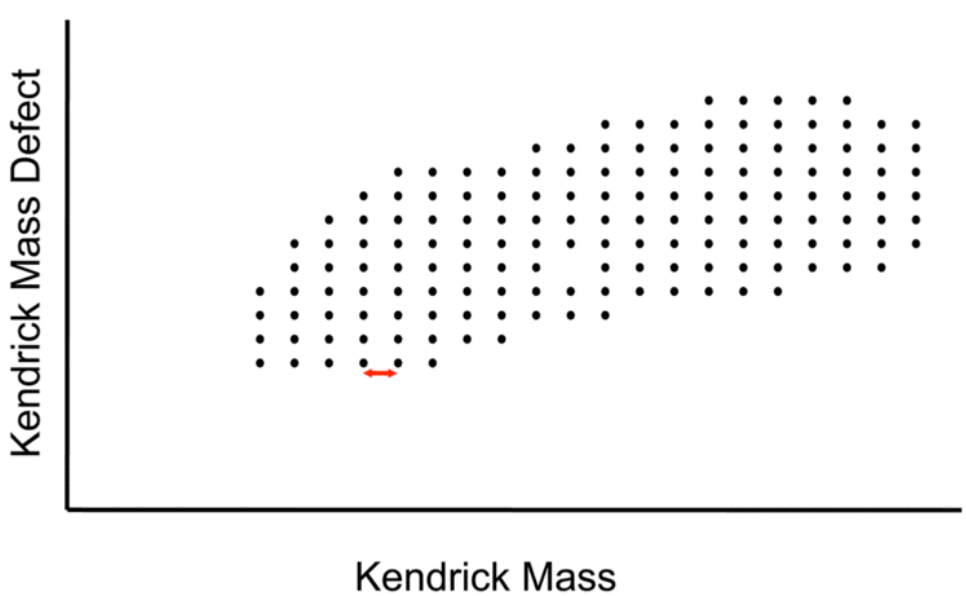
An alkylation series have the same degree of saturation and number of heteroatoms (nitrogen, oxygen and sulfur) but differ by the number of CH_2 units. Members of an alkylation series have the same Kendrick mass defect.

The Kendrick mass defect has also been defined as

$$Kendrick\ mass\ defect = nominal\ Kendrick\ mass - Kendrick\ mass \times 1,000.$$

The abbreviations *KM* and *KMD* have been used for Kendrick mass and Kendrick mass defect, respectively. In some definitions, the KMD

Kendrick mass analysis



Plot of Kendrick mass defect as function of Kendrick mass; horizontal lines indicate common repeat units. Each dot in the plot corresponds to a peak measured in a mass spectrum.

In a Kendrick mass analysis, the Kendrick mass defect is plotted as function of nominal Kendrick mass for ions observed in a mass spectrum. Ions of the same family, for example the members of an alkylation series, have the same Kendrick mass defect but different nominal Kendrick mass and are positioned along a horizontal line on the plot. If the composition of one ion in the family can be determined, the composition of the other ions can be inferred. Horizontal lines of different Kendrick mass defect correspond to ions of different composition, for example degree of saturation or heteroatom content.

A Kendrick mass analysis is often used in conjunction with a Van Krevelen diagram, a two- or three- dimensional graphical analysis in which the elemental composition of the compounds are plotted according to the atomic ratios H/C, O/C, or N/C.

Chapter-7

Apothecaries' System

The **apothecaries' system** of weights is a historical system of mass units that were used by physicians and apothecaries for medical recipes, and also sometimes by scientists. The English version of the system is closely related with the English troy system of weights, the pound and grain being exactly the same in both. It divides a pound into 12 ounces, an ounce into 8 drachms, and a drachm into 3 scruples or 60 grains. This exact form of the system was used in the United Kingdom; in some of its former colonies it survived well into the 20th century. The apothecaries' system of measures is a similar system of volume units based on the fluid ounce. For a long time, medical recipes were written in Latin, often using special symbols to denote weights and measures.

The use of different measure and weight systems depending on the purpose was an almost universal phenomenon in Europe between the decline of the Roman Empire and metrication. This was connected with international commerce, especially with the need to use the standards of the target market and to compensate for a common weighing practice that caused a difference between actual and nominal weight. In the 19th century, most European countries or cities still had at least a "commercial" or "civil" system (such as the English avoirdupois system) for general trading, and a second system (such as the troy system) for precious metals such as gold and silver. The system for precious metals was usually divided in a different way from the commercial system, often using special units such as the carat. More significantly, it was often based on different weight standards.

The apothecaries' system often used the same ounces as the precious metals system, although even then the number of ounces in a pound could be different. The apothecaries' pound was divided into its own special units, which were inherited (via influential treatises of Greek physicians such as Dioscorides and Galen, 1st and 2nd century) from the general-purpose weight system of the Romans. Where the apothecaries' weights and the normal commercial weights were different, it was not always clear which of the two systems was used in trade between merchants and apothecaries, or by which system apothecaries weighed medicine when they actually sold it. In old merchants' handbooks the former system is sometimes referred to as the **pharmaceutical system**, and distinguished from the apothecaries' system.

English-speaking countries

Weights: UK (Imperial) and US					
Weight (abbreviation)	**pound (℔)**	**ounce (℥)**	**dra(ch)m (ʒ)**	**scruple (℈)**	**grain (gr.)**
	1 ℔	12 ℥	96 ʒ	288 ℈	5,760 gr.
		1 ℥	8 ʒ	24 ℈	480 gr.
			1 ʒ	3 ℈	60 gr.
				1 ℈	20 gr.
metric equivalent	**373 g**	**31.1 g**	**3.89 g**	**1.296 g**	**64.8 mg**

The traditional English apothecaries' system of weights is as shown in the table, the pound, ounce and grain being identical to the troy pound, ounce and grain. In the United Kingdom, a reform in 1824 made the troy pound the primary weight unit (a role in which it was superseded half a century later by the Avoirdupois pound), but this had no effect on apothecaries' weights. However, the Medicinals Act of 1858 completely abolished the apothecaries' system in favour of the standard Avoirdupois system. In the United States, the apothecaries' system remained official until it was abolished in 1971 in favour of the metric system.

From the pound down to the scruple, the English apothecaries' system was a subset of the Roman weight system except that the troy pound and its subdivisions were slightly heavier than the Roman pound and its subdivisions. Similar systems were used all over Europe, but with considerable local variation described below under Variants.

The English-speaking countries also used a system of measure units, or in modern terminology volume units, based on the apothecaries' system. A volume of liquid that was approximately that of an apothecaries' ounce of water was called a fluid ounce, and was divided into fluid drachms and sometimes also fluid scruples. The analogue of the grain was called a minim. The Imperial and US systems differ in the size of the basic unit (the gallon or the pint, one gallon being equal to eight pints), and in the number of fluid ounces per pint. Apothecaries' systems for volumes were internationally much less common than those for weights. Before introduction of the Imperial Units in the UK, all apothecaries' measures were based on the wine gallon, which survived in the US under the name *liquid gallon* or *wet gallon*.

The wine gallon was abolished in Britain in 1824, and this system was replaced by a new one based on the newly introduced Imperial gallon. Since the Imperial gallon is 20% more than the liquid gallon, the same is true for the Imperial pint in relation to the liquid pint. This explains why the number of fluid ounces per gallon had to be adjusted in the new system so that the fluid ounce was not changed too much by the reform. Even so, the modern UK fluid ounce is 4% *less* than the US fluid ounce, and the same is true for the smaller units. For some years both systems were used concurrently in the UK.

Measures: US (and UK before 1824)

liquid pt	fl. ounce	fl. dram	fl. scruple	minim
1 liq pt	16 f℥	128 fʒ	384 f℈	7,680 ♏
	1 f℥	8 fʒ	24 f℈	480 ♏
		1 fʒ	3 f℈	60 ♏
			1 f℈	20 ♏
473 ml	**29.6 ml**	**3.70 ml**	**1.23 ml**	**0.062 ml**

Key: pt = pint, fl. = fluid

Measures: UK (Imperial)

pint	fl. ounce	fl. drachm	fl. scruple	minim
1 pt	20 f℥	160 fʒ	480 f℈	9,600 ♏
	1 f℥	8 fʒ	24 f℈	480 ♏
		1 fʒ	3 f℈	60 ♏
			1 f℈	20 ♏
568 ml	**28.4 ml**	**3.55 ml**	**1.18 ml**	**0.059 ml**

Key: fl. = fluid

Apothecaries' measures eventually fell out of use in the UK and were officially abolished in 1971. In the US, they are still occasionally used, for example with prescribed medicine being sold in four ounce (℥ iv) bottles.

Medical recipes

Until around 1900, medical recipes and most European pharmacopoeias were written in Latin. Here is a typical example from the middle of the 19th century.

Infusion of Dandelion, &c.

℞ Infusi Taraxaci, f℥iv.	4 fluid ounces of dandelion infusion
Extracti Taraxaci, fʒij.	2 fluid drachms of dandelion extract
Sodæ Carbonatis, ʒß.	½ drachm of sodium carbonate
Potasse Tartratis, ʒiij.	3 drachms of potassium tartrate
Tincturæ Rhei, fʒiij.	3 fluid drachms of rhubarb tincture

———— Hyoscyami, gtt. xx.	20 drops of henbane tincture
Fiat mistura. *Signa.*—One third part to be taken three times a day. In dropsical and visceral affections.	Make mixture. *Write:* "One third part to be taken three times a day. In dropsical and visceral affections."

The use of Latin ensured that the recipes could be read by an international audience. There was a technical reason why *3 ℥* was written *℥iij,* and $^1/_2$ *℥* as *℥ß* or *℥ss*: Since only the units of the apothecaries' system were used in this way, this made it clear that the civil weight system was not meant.

Variants

Diversity of local standards

Variation in standards for apothecaries' weights

12 ounces	1 ounce	Standard
300 g	25 g	Venice
325 g	27 g	Roman Empire
340 g	28 g	Modern Rome
345 g	29 g	Iberian peninsula
350 g	29 g	Prussia
360 g	30 g	Nuremberg
370 g	31 g	Troy
420 g	35 g	Habsburg monarchy

The basic form of the apothecaries' system is essentially a subset of the Roman weight system. An apothecaries' pound normally consisted of 12 ounces. (In France this was changed to 16 ounces, and in Spain the customary unit was the *marco*, a mark of 8 ounces.) In the south of Europe and in France, the scruple was generally divided into 24 grains, so that one ounce consisted of 576 grains. Nevertheless, the subdivision of an ounce was somewhat more uniform than that of a pound, and a common feature of all variants is that 12 ounces are roughly 100 drachms (96–128 drachms) and a grain is roughly the weight of a physical grain.

Map showing examples of the weight of 1 apothecaries' ounce in grammes around 1800, before metrication and the Prussian weight reform. The dashed lines indicate three different ways to subdivide the ounce.

It is most convenient to compare the various local weight standards by the metric weights of their ounces. The actual mass of an ounce varied by ±17% (5 g) around the typical value of 30 g. The table only shows approximate values for the most important standards; even the same nominal standard could vary slightly between one city and its neighbour. The range from 25 g to 31 g is filled with numerous variants, especially the Italian range up to 28 g. But there is a relatively large gap between the troy ounces of 31 g and the Habsburg ounce of 35 g. The latter is the product of an 18th century weight reform.

Even in Turkey a system of weights similar to the European apothecaries' system was used for the same purpose. For medical purposes the tcheky (approx. 320 g) was divided in 100 drachms, and the drachm in (16 killos or) 64 grains. This is close to the classical Greek weight system, where a *mina* (corresponding roughly to a Roman *libra*) was also divided into 100 drachms.

With the beginning of metrication, some countries standardized their apothecaries' pound to an easily remembered multiple of the French gramme. E.g. in the Netherlands the Dutch troy pound of 369.1 g was standardized in 1820 to 375.000 g, to match a similar reform in France. The British troy pound retained its value of 373.202 g until in 2000 it was legally defined in metric terms, as 373.2417216 g. (At this time its use was already illegal for all purposes except trading precious metals.)

Basic variants

In the Romance speaking part of Europe the scruple was divided in 24 grains, in the rest of Europe in 20 grains. Notable exceptions were Venice and Sicily, where the scruple was also divided in 20 grains.+

Non-Romance variant					Romance variant				
Libra	***Uncia***	***Drachma***	***Scrupulum***	***Grana***	***Libra***	***Uncia***	***Drachma***	***Scrupulum***	***Grana***
1 *Lb.*	12 *Unc.*	96 *Dr.*	288 *Scr.*	5,760 *Gr.*	1 *Lb.*	12 *Unc.*	96 *Dr.*	288 *Scr.*	6,912 *Gr.*
	1 *Unc.*	8 *Dr.*	24 *Scr.*	480 *Gr.*		1 *Unc.*	8 *Dr.*	24 *Scr.*	576 *Gr.*
		1 *Dr.*	3 *Scr.*	60 *Gr.*			1 *Dr.*	3 *Scr.*	72 *Gr.*
			1 *Scr.*	20 *Gr.*				1 *Scr.*	24 *Gr.*
360 g	**30 g**	**4 g**	**1.3 g**	**60 mg**	**360 g**	**30 g**	**4 g**	**1.3 g**	**50 mg**

The Sicilian apothecaries' ounce was divided in 10 drachms. Since the scruple was divided in only 20 grains, like in the northern countries, an ounce consisted of 600 grains. This was not too different from the situation in most of the other mediterranean countries, where an ounce consisted of 576 grains.

In France, at some stage the apothecaries' pound of 12 ounces was replaced by the larger civil pound of 16 ounces. The subdivisions of the apothecaries' ounce were the same as in the other Romance countries, however, and were different from the subdivisions of the otherwise identical civil ounce.

Origins

Roman weight system

Roman weights

libra	***uncia***	***drachma***	***scrupulum***	***obolus***	***siliqua***	***chalcus***
1 pound	12 ounces	96 drachms	288 scruples	576 oboli	1,728 siliquas	4,608 chalci
	1 ounce	8 drachms	24 scruples	48 oboli	144 siliquas	384 chalci
		1 drachm	3 scruples	6 oboli	18 siliquas	48 chalci
			1 scruple	2 oboli	6 siliquas	16 chalci
327 g	**27.3 g**	**3.41 g**	**1.14 g**	**568 mg**	**189 mg**	**71 mg**

The basic apothecaries' system consists of the units pound, ounce and scruple from the classical Roman weight system, together with the originally Greek drachm and a new subdivision of the scruple into either 20 ("barley") or 24 ("wheat") grains (Latin: *grana*). In some countries other units of the original system remained in use, for example in Spain the *obolo* and *siliqua*. In some cases the apothecaries' and civil weight systems had the same ounces ("an ounce is an ounce"), but the civil pound consisted of 16 ounces. *Siliqua* is Latin for the seed of the carob tree.

Many attempts were made to reconstruct the exact mass of the Roman pound. One method for doing this consists in weighing old coins; another uses the fact that Roman weight units were derived from Roman units of length similarly to the way the kilogramme was originally derived from the metre, i.e. by weighing a known volume of water. Nowadays the Roman pound is often given as 327.45 g, but one should keep in mind that (apart from the other uncertainties that come with such a reconstruction) the Roman weight standard is unlikely to have remained constant to such a precision over the centuries, and that the provinces often had somewhat inexact copies of the standard. The weight and subdivision of the pound in the Holy Roman Empire was reformed by Charlemagne, but in the Byzantine Empire it remained essentially the same. Since Byzantine coins circulated up to Scandinavia, the old Roman standard continued to be influential through the Middle Ages.

Weight system of Salerno

		Doctors of Salerno		
Libra	***Uncia***	***Drachma***	***Scrupulum***	***Granum***
1 *Lb.*	12 *Unc.*	108 *Dr.*	324 *Scr.*	6480 *Gr.*
	1 *Unc.*	9 *Dr.*	27 *Scr.*	540 *Gr.*
		1 *Dr.*	3 *Scr.*	60 *Gr.*
			1 *Scr.*	20 *Gr.*
360 g	**30 g**	**3.3 g**	**1.1 g**	**56 mg**

The history of mediaeval medicine started roughly around the year 1000 with the school of medicine in Salerno, which combined elements of Latin, Greek, Arabic and Jewish medicine. Galen and Dioscorides (who had used the Graeco-Roman weight system) were among the most important authorities, but also Arabic physicians, whose works were systematically translated into Latin.

According to *De ponderibus et mensuris*, a famous 13th century text that exists in numerous variations and is often ascribed to Dino di Garbo, the system of weights used in Salerno was different from the systems used in Padua and Bologna. As can be seen from the table, it was also different from the Roman weight system used by Galenus and Dioscorides and from all modern apothecaries' systems: The ounce was divided into 9 drachms, rather than 8 drachms.

Centuries later, the region around Salerno was the only exception to the rule that (except for skipping units that had regionally fallen out of use) the apothecaries' ounce was subdivided down to the scruple in exactly the same way as in the Roman system: It divided the ounce into 10 drachms.

Romance countries

While there will naturally have been some changes throughout the centuries, here we, only tries to give a general overview over the situation that was recorded in detail in numerous 19th century merchants' handbooks.

Some Romance apothecaries' weight standards in the 19th century

1 pound	1 ounce	state or city
301.2 g	25.1 g	Venice
320.8 g	26.7 g	Kingdom of the Two Sicilies (1816–1861)
325.7 g	27.1 g	Bologna
326.8 g	27.2 g	Milan (–1815)
328.0 g	27.3 g	Parma
332.0 g	27.7 g	Sardinia
334.5 g	27.9 g	Duchy of Lucca (1815–1847)
339.2 g	28.3 g	Rome
339.5 g	28.3 g	Florence
339.5 g	28.3 g	Grand Duchy of Tuscany (–1859)
340.5 g	28.4 g	Duchy of Modena (1814–1859)
344.2 g	28.7 g	Kingdom of Portugal
344.8 g 345.1 g	28.7 g 28.8 g	Kingdom of Spain

Iberian Peninsula

On the Iberian Peninsula, apothecaries' weights in the 19th century were relatively uniform, with 24 grains per scruple (576 grains per ounce), the standard in Romance countries. The weight of an apothecaries' pound was 345.1 g in Spain and 344.2 g in Portugal. As in Italy, some of the additional subdivisions of the Roman system, such as the *obolo*, were still in use there. It was standard to use the *marco*, defined as 8 ounces, instead of the pound.

France

In 18th century France, there was a national weight standard, the *marc de Paris* of 8 ounces. The civil pound of 16 ounces was equivalent to 2 marks, and it was also used as the apothecaries' pound. With 30.6 g, the ounces were considerably heavier than other apothecaries' ounces in Romance countries, but otherwise the French system was not remarkable. Its history and connections to the English and Flemish standards are discussed below under Weight standards named after Troyes.

Italy

Due in part to the political conditions in what would become a united Kingdom of Italy only in 1861, the variation of apothecaries' systems and standard weights in this region was enormous. The *libbra* (pound) generally consisted of the standard twelve ounces, however.

The civil weight systems were generally very similar to the apothecaries' system, and since the *libbra* (or the *libbra sottile*, where different systems were in use for light and heavy goods) generally had a suitable weight for an apothecaries' pound it was often used for this purpose. Extreme cases were Rome and Genoa, where the same system was used for everything, including medicine. On the other hand there were relatively large differences even between two cities in the same state. E.g. Bologna (in the Papal States) had an apothecaries' pound that was less than the local civil pound, and 4% lighter than the pound used in Rome.

The weight of an apothecaries' pound ranged generally between 300 g and 320 g, slightly less than that of a pound in the Roman Empire. An important exception to this rule is that the Kingdom of Lombardy–Venetia was under rule of the Habsburg monarchy 1814–1859 and therefore had the extremely large Habsburg apothecaries' pound of 420 g. E.g. in the large city of Milan the apothecaries' system based on a pound of 326.8 g was officially replaced by the metric system as early as 1803, because Milan was part of the Napoleonic Italian Republic. Since the successor of this little state, the Napoleonic Kingdom of Italy, fell to Habsburg in 1814 (at a time when even in France the *système usuel* had been introduced because the metric system was not accepted by the population), an apothecaries' system was officially introduced again, but now based on the Habsburg apothecaries' pound, which weighed almost 30% more.

Sicilian variant

Libra	***Uncia***	***Drachma***	***Scrupulum***	***Grana***
1 *Lb.*	12 *Unc.*	120 *Dr.*	360 *Scr.*	7,200 *Gr.*
	1 *Unc.*	10 *Dr.*	30 *Scr.*	600 *Gr.*
		1 *Dr.*	3 *Scr.*	60 *Gr.*
			1 *Scr.*	20 *Gr.*
360 g	**30 g**	**3 g**	**1 g**	**50 mg**

The apothecaries' pound in Venice had exactly the same subdivisions as those in the non-Romance countries, but its total weight of 301 g was at the bottom of the range. During the Habsburg reign of 1814–1859 an exception was made for Venice; as a result the extreme weights of 301 g and 420 g coexisted within one state and in immediate proximity. The Venice standard was also used elsewhere, for example in Udine. In Dubrovnik (called "Ragusa" until 1909) its use was partially continued for a long time in spite of the official Habsburg weight reform.

The measure and weight systems for the large mainland part of the Kingdom of the Two Sicilies were unified in 1840. The area consisted of the southern half of the Italian Peninsula and included Naples and Salerno. The subdivision of apothecaries' weight in the unified system was essentially the same as that for gold, silver, coins and silk. It was the most excentric variant in that the ounce was divided in 10 drachms, rather than the usual 8. The scruple, like in Venice but unlike in the rest of the Romance region, was divided into 20 grains. The existence of a unit called *aureo*, the equivalent of 1½ *dramme*, is interesting because 6 *aurei* were 9 *dramme*. In the original Salerno weight system an ounce was divided into 9 drachms, and so an *aureo* would have been ⅙ of an ounce.

Troyes, Nuremberg and Habsburg

Weight standards named after Troyes

Late French variant

Libra	***Uncia***	***Drachma***	***Scrupulum***	***Grana***
1 *Lb.*	16 *Unc.*	128 *Dr.*	384 *Scr.*	9,216 *Gr.*
	1 *Unc.*	8 *Dr.*	24 *Scr.*	576 *Gr.*
		1 *Dr.*	3 *Scr.*	72 *Gr.*
			1 *Scr.*	24 *Gr.*
480 g	**30 g**	**4 g**	**1.3 g**	**50 mg**

As early as 1147 in Troyes in Champagne (in the Middle Ages an important trading town) a unit of weight called *marc de Troyes* was used.

The national French standard until 1799 was based on a famous artefact called the *Pile de Charlemagne*, which probably dates back to the second half of the 15th century. It is an elaborate set of nesting weight pieces, with a total metric weight of 12.238 *kg*. The set is now shown in the Musée des Arts et Métiers in Paris. The total nominal value of the set is 50 *marcs de Troyes* or *marcs de Paris*, a mark being 8 ounces. The ounce *poids de marc* had therefore a metric equivalent of 30.59 g. The *poids de marc* was used as a national French standard for trading, for gold, silver and jewels, and for weighing medicine. It was also used in international communications between scientists. In the time before the French Revolution, the civil pound also played the role of the apothecaries' pound in the French apothecaries' system, which otherwise remained a standard system of the Romance (24 grains per scruple) type.

1 ounce	**Standard**	**12 ounces**
?	*marc de Troyes* (Troyes)	?
30.60 g	*poids de marc* (Paris)	367 g
30.76 g	trooisch pond (Flanders)	369 g
31.10 g	troy pound (London)	373 g

In Bruges, Amsterdam, Antwerpen and other Flemish cities, a "troy" unit ("trooisch pond") was also in use as a standard for valuable materials and medicine. As in France, the way in which the Flemish troy ounce was subdivided depended on what was weighed. Unlike the French, the Flemish apothecaries divided the scruple in 20 grains. The Flemish troy pound became the standard for the gold and apothecaries' system in the United Kingdom of the Netherlands; it was also used in this way in Lübeck. (The London troy pound was referred to as the 'trooisch pond', after metrification.)

The Dutch troy mark consisted of 8 Flemish troy ounces, with each ounce of 20 engels, and each engel divided into 32 assen. The Amsterdam Pound of two marks, used in commerce, weighed 10,280 assen, while the Amsterdam Troy pound weighed 10,240 assen, i.e. exactly two troy marks.

In 1414, six years before the Treaty of Troyes, a statute of Henry V of England gave directions to the goldsmiths in terms of the troy pound. (In 1304 it had apparently not yet been introduced, since it did not appear in the statute of weights and measures.) There is evidence from the 15th century that the troy pound was used for weighing metals and spices. After the abolishment of the Tower pound in 1527 by Henry VIII of England, the troy pound was the official basis for English coin weights. The British apothecaries' system was based on the troy pound until metrication, and it survived in the United States and Australia well into the 20th century.

Since the modern (English, American and Imperial) troy ounces are roughly 1.5% heavier than the late Paris ounce, the exact historical relations between the original *marc de Troyes*, the French *poids de marc*, the Flemish trooisch pond and the English troy pound are unclear. It is known, however, that the numerical relation between the English and French troy ounces was *exactly* 64:63 in the 14th century.

Nuremberg standard

Nuremberg standard (regional variation, c. 1800)

1 ounce	Standard	1 pound
29.69 g	Sweden	356.2 g
29.82 g	Nuremberg	357.8 g
29.83 g	Lucerne	358.0 g
29.86 g	Russia	358.3 g
29.88 g	Poland	358.5 g

In the Middle Ages the Imperial Free City of Nuremberg, an important trading place in the south of Germany, produced large amounts of nesting weight pieces to various European standards. In the 1540s, the first pharmacopoeia in the modern sense was also printed there. In 1555, a weight standard for the apothecaries' pound of 12 ounces was set in Nuremberg. Under the name *Nuremberg pharmaceutical weight* (German: *Nürnberger Medizinalgewicht*) it would become the standard for most of the north-east of Europe. However, some cities kept local copies of the standard.

As of 1800 all German states and cities except Lübeck (which had the Dutch troy standard) followed the Nuremberg standard. It was also the standard for Denmark, Norway, the Russian Empire and most cantons of Switzerland. Poland and Sweden had their own variants of the standard, which differed from each other by 0.6%.

In 1811, Bavaria legally defined the apothecaries' pound as 360.00 g (an ounce of 30.00 g). In 1815, Nuremberg lost its status as a free city and became part of Bavaria. From now on the Nuremberg apothecaries' pound was no longer the official apothecaries' pound in Nuremberg; but the difference was only 0.6%. In 1836 the Greek apothecaries' pound was officially defined by this standard, four years after Otto, the son of the king of Bavaria, became the first king of Greece. But only few German states followed the example of Bavaria, and with a long delay. The apothecaries' pound of 360 g was also adopted in Lübeck, where it was official as of 1861.

Austria and the states of the Habsburg monarchy officially had a different standard since 1761, and Prussia, followed by its neighbours Anhalt, Lippe and Mecklenburg, would diverge in the opposite direction with a reform in 1816. But in both cases apothecaries continued to use the Nuremberg standard unofficially for a long time after it became illegal.

In Russia the apothecaries' system survived well into the 20th century. The Soviet Union officially abolished it only in January 1927.

Habsburg standard

Empress Maria Theresia of Austria reformed the measures and weights of the Habsburg monarchy in 1761. The weight of an apothecaries' pound of 12 ounces was increased to a value that was later (after the kilogramme was defined) found to be 420.009 g; this was called the *libra medicinalis major*. It was defined as $^{3}/_{4}$ of the unusually heavy Habsburg civil pound (defined as $^{6}/_{5}$ of the civil pound of Cologne) and corresponded to a record ounce weight of 35 g.

Before the reform, in the north of the empire the Nuremberg standard had been in effect, and in Italy the local standards had been even lighter. It is not surprising that an increase by 17% and more met with some inertia. The 1770 edition of the pharmacopoeia *Dispensatorium Austriaco-Viennense* still used the Nuremberg standard *libra medicinalis minor*, indicating that even in the Austrian capital Vienna it took some time for the reform to become effective. In 1774, the *Pharmacopoea Austriaco-provincialis* used the new standard, and in 1783 all old apothecaries' weight pieces that were still in use were directed to be destroyed.

Venice was not part of these reforms and kept its standard of approximately 25 g per ounce.

When Austria started producing scales and weight pieces to the new standard with an excellent quality/price ratio, these were occasionally used by German apothecaries as well.

Metrication

Early metrication

	exact	*système usuel*	
Libra	489.506 g	500.00 g	
Uncia	30.594 g	32.00 g	~~31.25 g~~
Drachma	3.824 g	4.00 g	~~3.906 g~~
Grana	0.053 g	50 mg	~~65.1 mg~~

At the time of the Industrial Revolution, the fact that each state had its own system of weights and measures became increasingly problematic. Serious work on a "scientific" system was started in France under Louis XVI, and completed in 1799 (after the French Revolution) with its implementation. The French population, however, was initially unhappy with the new system. In 1812, Napoleon Bonaparte reintroduced some of the old measures and weights, but in a modified form that was defined with respect to the metric system. This *système usuel* was finally abolished in 1837 and became illegal in 1840.

Due to the large expansion of the First French Empire under Napoleon I, French metrication also affected what would be (parts of) France's neighbour countries after the Congress of Vienna.

The Netherlands were partially metricated when they were French, in the years 1810–1813. With full metrication, effective January 1821, the Netherlands reformed the trooisch pond. The apothecaries' new pound was 375.00 g. Apart from rounding issues concerning the subdivisions, this corresponded exactly to the French *système usuel*. (The reform was not followed in the north German city of Lübeck, which continued to use the trooisch pond.) In Belgium, apothecaries' weight was metricized effective 1856.

Between 1803 and 1815 all German regions west of the River Rhine were French, organised in the *départements* Roer, Sarre, Rhin-et-Moselle, and Mont-Tonnerre. As a result of the Congress of Vienna these became part of various German states. A large part of the Palatinate fell to Bavaria, but having the metric system it was excepted from the Bavarian reform of weights and measures.

Prussia's path to metrication

Apothecaries' weight in Prussia

1 ounce	Standard	1 pound
29.82 g	Nuremberg (initially)	357.8 g
29.23 g	civil pound (from 1816)	350.8 g

31.25 g metric pound (from 1856) 375.0 g
abolished metric pound (from 1867) *abolished*

In Prussia, a reform in 1816 defined the Prussian civil pound in terms of the Prussian foot and distilled water. It also redefined the apothecaries' pound as 12 ounces, i.e. $^{3}/_{4}$, of the civil pound: 350.78 g. This reform was not popular with apothecaries, because it broke the uniformity of the apothecaries' pound in Germany at a time when a German national state was beginning to form. It seems that many apothecaries did not follow this reduction by 2%.

Another reform in 1856 increased the civil pound from 467.711 g to 500.000 g (the German civil pound defined by the Zollverein), as a first step towards metrication. As a consequence the official apothecaries' pound was now 375.000 g, i.e. it was increased by 7%, and it was now very close to the troy standards. §4 of the law that introduced this reform said: "Further, a pharmaceutical weight deviating from the civil weight does not take place." But this paragraph was suspended until further notice.

The abolishment of the apothecaries' system meant that doctors' prescriptions had to take place in terms of the current civil weight: grammes and kilograms. This was considered unfeasible by many, and the state received numerous protests and asked for expertises. Yet by 1868, §4 of the earlier reform was finally put into force.

Metrication in countries using the troy and avoirdupois systems

Proposed avoirdupois-based apothecaries' system, Dublin 1850

Libra	***Uncia***	***Drachma***	***Scrupulum***	***Grana***
1 *Lb.*	16 *Unc.*	128 *Dr.*	384 *Scr.*	7,000.00 *Gr.*
	1 *Unc.*	8 *Dr.*	24 *Scr.*	437.50 *Gr.*
		1 *Dr.*	3 *Scr.*	54.68 *Gr.*
			1 *Scr.*	18.22 *Gr.*
480 g	**30 g**	**4 g**	**1.3 g**	**70 mg**

Britain was initially involved in the development of the metric system, and the US was among the 17 initial signatories of the Metre Convention in 1875. Yet in spite of enthusiastic support for the new system by intellectuals such as Charles Dickens, these two countries were particularly slow to implement it.

To unify all weight systems used by apothecaries, the Irish pharmacopœia of 1850 introduced a new variant of the apothecaries' system which subdivided a new apothecaries' pound of 12 avoirdupois ounces instead of the troy pound. To allow effective use of the new system, new weight pieces were produced. Since an avoirdupois ounce corresponds to 28.35 g, the proposed system was very similar to that in use in Portugal and Spain, and in some locations in Italy. But it would have doubled the value of the avoirdupois drachm (an existing unit, but by then only used for weighing silk).

Therefore it conflicted with other non-standard variations that were based on that nearly obsolete unit.

The Irish proposal was not widely adopted, but British legislation, in the form of the Medicinals Act 1858, was more radical: It prescribed the use of the avoirdupois system for the United Kingdom (then including Ireland), with none of the traditional subdivisions. This innovation was first used in the united British pharmacopœia of 1864. In practice the old apothecaries' system based on the troy pound was still widely used, however, until it was abolished by the Weights and Measures Act of 1976. Since then it can only be used to measure precious metals and stones. (The troy pound was already declared illegal for most other uses by the Weights and Measures Act of 1878.)

In the US, the metric system replaced the apothecaries' system in the US Pharmacopoeia of 1971.