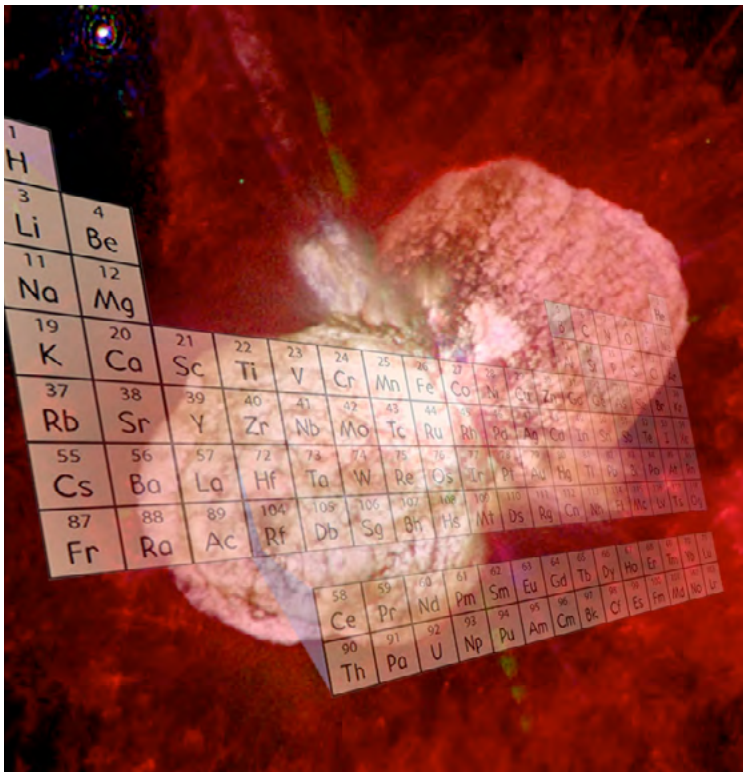


Chapter 2

Particles of Matter

THE MAIN IDEA

Matter is made of particles called atoms

2.3 Mass and Volume

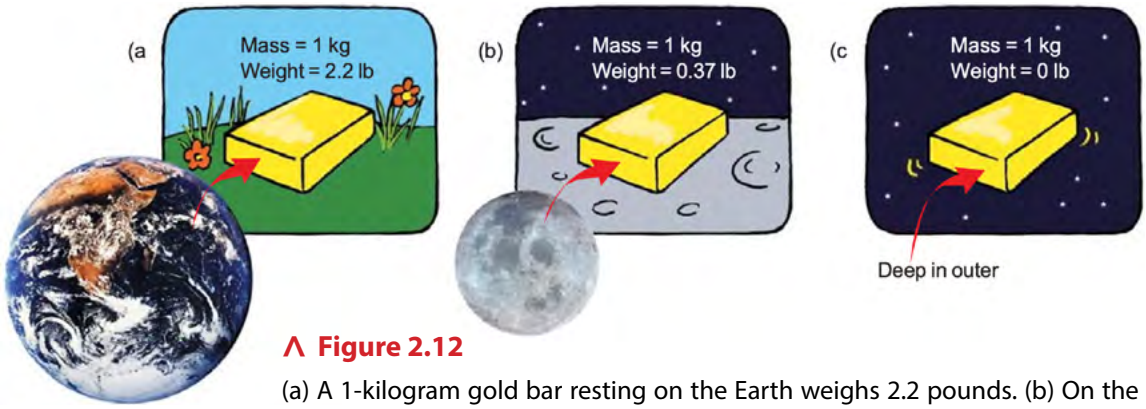
To describe a material object, we can quantify any number of properties, but perhaps the most fundamental of these is mass. **Mass** is the quantitative measure of how much matter a material object contains. The greater the mass of an object, the greater the amount of matter in it. A gold bar that is twice as massive as another gold bar, for example, contains twice as many gold atoms.

Mass is also a measure of an object's *inertia*, which is the resistance the object has to any change in its motion. A cement truck, for example, has a lot of mass (inertia), which is why it requires a powerful engine to get it moving and powerful brakes to cause it to come to a stop.

The standard unit of mass is the kilogram. A replica of the cylinder used to determine exactly what mass "1 kilogram" describes is shown in **Figure 2.11**. An average-sized adult human male has a mass of about 70 kilograms (154 pounds). For smaller quantities, we use the gram. Table 1.3 in the previous chapter tells us that the prefix kilo- means "1000," so we see that 1000 grams is equivalent to 1 kilogram (1000 grams = 1 kilogram). For even smaller quantities, the milligram is used (1000 milligrams = 1 gram).

READING CHECK
What is mass?

Figure 2.11 >
The standard kilogram is defined as the mass of a platinum-iridium cylinder kept at the International Bureau of Weights and Measures in Sèvres, France. The cylinder is removed from its very safe location only once a year for comparison with duplicates, such as the one shown here, which is housed at the National Institute of Standards and Technology in Washington, D.C.



∧ Figure 2.12

(a) A 1-kilogram gold bar resting on the Earth weighs 2.2 pounds. (b) On the Moon, this same gold bar would weigh 0.37 pound. (c) Deep in space, far from any planet, the gold bar would weigh 0 pounds, though it would still have a mass of 1 kilogram.

FOR YOUR INFORMATION

If you counted by ones at a rate of one number each second, counting to a million would take you 11.6 days (assuming no time off for sleeping). How about a billion? Is there a dramatic difference? Get this: counting to a billion would take you 31.8 years. Counting to a trillion, which is a thousand billion, would take you 31,800 years! Now you know why there are far more millionaires than billionaires, and no trillionaires yet.

Since mass is simply a measure of the amount of matter in a sample, which is a function of how many atoms the sample contains, the mass of an object remains the same no matter where it is located. A 1-kilogram gold bar, for example, has the same mass whether it is on the Earth, on the Moon, or floating "weightless" in space. This is because it contains the same number of atoms in each location.

Weight is more complicated. By definition, **weight** is the gravitational force exerted on an object by the most massive nearby body, such as Earth. The weight of an object, therefore, depends entirely upon its location, as is shown in **Figure 2.12**. On the Moon, a gold bar weighs less than it does on Earth. This is because the Moon is much less massive than Earth; hence, the gravitational force exerted by the Moon on the bar is much less. On Jupiter, the gold bar would weigh more than it does on Earth, because of the greater gravitational force exerted on the bar by this very massive planet.

The amount of space a material object occupies is its **volume**. The SI unit of volume is the liter, which is only slightly larger than the USCS unit of volume, the quart. A liter is the volume of space marked off by a cube measuring 10 centimeters by 10 centimeters by 10 centimeters, which is 1000 cubic centimeters. A smaller unit of volume is the milliliter, which is one-thousandth of a liter, or 1 cubic centimeter.

A convenient way to measure the volume of an irregular object is shown in **Figure 2.13**. The volume of water displaced is equal to the volume of the object.

< Figure 2.13

The volume of an object, no matter what its shape, can be measured by its displacement of water. When this object is immersed in the water, the rise in the water level equals the volume of the object, which in this example measures about 9 mL.

CONCEPT **CHECK**
Is there gravity on the Moon?

CHECK YOUR ANSWER Yes, absolutely! The Moon exerts a downward gravitational pull on any body near its surface, as evidenced by the fact that astronauts were able to land and walk on the Moon. This NASA photograph shows an astronaut jumping. Without gravity, this jump would have been his last, because he would never have come back down. With the Moon's weaker gravity he is able to jump relatively high.