

**TABLE 1** Properties of Subatomic Particles

Particle	Symbols	Relative electric charge	Mass number	Relative mass (amu*)	Actual mass (kg)
Electron	$e^{-}$ , ${}_{-1}^0e$	-1	0	0.000 5486	$9.109 \times 10^{-31}$
Proton	$p^{+}$ , ${}_{1}^1\text{H}$	+1	1	1.007 276	$1.673 \times 10^{-27}$
Neutron	$n^{\circ}$ , ${}_{0}^1n$	0	1	1.008 665	$1.675 \times 10^{-27}$

\*1 amu (atomic mass unit) =  $1.660\,540 \times 10^{-27}$  kg

protons can exist close together to help form a nucleus. A similar attraction exists when neutrons are very close to each other or when protons and neutrons are very close together. *These short-range proton-neutron, proton-proton, and neutron-neutron forces hold the nuclear particles together and are referred to as **nuclear forces**.*

## The Sizes of Atoms

It is convenient to think of the region occupied by the electrons as an electron cloud—a cloud of negative charge. The radius of an atom is the distance from the center of the nucleus to the outer portion of this electron cloud. Because atomic radii are so small, they are expressed using a unit that is more convenient for the sizes of atoms. This unit is the picometer. The abbreviation for the picometer is pm ( $1\text{ pm} = 10^{-12}\text{ m} = 10^{-10}\text{ cm}$ ). To get an idea of how small a picometer is, consider that 1 cm is the same fractional part of  $10^3\text{ km}$  (about 600 mi) as 100 pm is of 1 cm. Atomic radii range from about 40 to 270 pm. By contrast, the nuclei of atoms have much smaller radii, about 0.001 pm. Nuclei also have incredibly high densities, about  $2 \times 10^8$  metric tons/cm<sup>3</sup>.

## SECTION REVIEW

- Define each of the following:
  - atom
  - electron
  - nucleus
  - proton
  - neutron
- Describe one conclusion made by each of the following scientists that led to the development of the current atomic theory:
  - Thomson
  - Millikan
  - Rutherford

- Compare the three subatomic particles in terms of location in the atom, mass, and relative charge.
- Why is the cathode-ray tube in **Figure 4** connected to a vacuum pump?

### Critical Thinking

- EVALUATING IDEAS** Nuclear forces are said to hold protons and neutrons together. What is it about the composition of the nucleus that requires the concept of nuclear forces?