Moles of Atoms

An atom is the smallest possible unit of an element. Each atom consists of a single nucleus containing one or more protons, zero or more neutrons, and some electrons around the nucleus.

For example, a single hydrogen atom can have just one proton for a nucleus and one electron orbiting around it in some way. A single helium atom can have two protons and two neutrons in the nucleus and two electrons orbiting the nucleus.

Each proton weighs 1.007276 amu (atomic mass units). Each neutron weighs 1.008665 amu. Each electron weighs 0.000554858 amu.

So the mass of a single hydrogen atom (${}_{1}^{1}\mathrm{H}$) with one proton and one electron is 1.0 amu (to 2 significant figures). The mass of a helium atom (${}_{2}^{4}\mathrm{He}$) with 2 protons, 2 neutrons and 2 electrons is 4.0 amu. The mass of a carbon atom (${}_{6}^{12}\mathrm{C}$) with 6 protons, 6 neutrons and 6 electrons weighs 12.0000 amu. An amu is defined to be exactly one-twelfth (1/12) of the mass of one carbon-12 atom (${}_{6}^{12}\mathrm{C}$).

Individual atoms are extremely, extremely small. Even the largest atoms are way too small to be seen by the most powerful optical microscopes. Thus even tiny quantities of substances contain huge numbers of atoms. Chemists use the quantity 1 mole = 6.022×10^{23} to count atoms. 1 mole is a concept like 1 dozen. One dozen atoms = 12 atoms. Likewise 1 mole of atoms is 6.022×10^{23} atoms. The number is defined as the number of ${}_{6}^{12}\mathrm{C}$ atoms in 12.00000 g ${}_{6}^{12}\mathrm{C}$. According to the best measurements 12.00000 g of carbon-12 atoms contain $6.02214179 \times 10^{23}$ atoms. Since each ${}_{1}^{1}\mathrm{H}$ atom is about 1/12 as heavy as a ${}_{6}^{12}\mathrm{C}$, 1 mole hydrogen atoms weighs about 1/12 as much as a mole of carbon atoms. So 1 mol H = 1.0 g H. Likewise for any element on the periodic table, one mole of an element is exactly a mass in grams equal to the relative mass on the periodic table. For example, 1mole iron = 6.022×20^{23} atoms Fe = 55.847 g Fe.

These relative masses on the periodic table are called "atomic weights" or "atomic masses". The atomic weight of iron is 55.847. It is a weighted average of the different isotopes of iron. The average atom of iron has a mass of 55.847 relative to 12.000 assigned to the mass of carbon-12 atoms.

The atomic masses are extremely useful for finding amounts of different elements having the same number of atoms. For example, 20.00 grams of oxygen is

$$20.00 \text{ g O} = 20.00 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 1.250 \text{ mol O}$$

since 1mol O = 6.022×10^{23} atoms O = 16.00 g O.

Likewise, 1.25 moles of any element contains exactly the same number of atoms.

$$1.250 \text{ moles} = 1.250 \text{ moles} \times \frac{6.022 \text{x} 10^{23} \text{ atoms}}{1 \text{ mole}} = 7.528 \text{x} 10^{23} \text{ atoms}$$

Thus 1.25 moles of calcium contains $7.528 \text{x} 10^{23}$ atoms of calcium. Since for calcium
1 mole Ca = $6.022 \text{x} 10^{23}$ atoms Ca = 40.08 g Ca

$$1.250 \text{ mol Ca} = 1.250 \text{ mol Ca} \times \frac{40.08 \text{ g Ca}}{1 \text{ mol Ca}} = 50.10 \text{ g Ca}$$

So 50.10 g of calcium has exactly as many atoms as 20.00 g oxygen.

Try the following conversions:

1. 55.0 g O = ? mol O = ? atoms O
2. 1.455 mol Fe = ? g Fe = ? atoms Fe
3. 45.0 g Au = ? atoms Au = ? mol Au
4. 26.3 mg Kr = ? atoms Kr
5. $2.00 \text{x} 10^{10}$ atoms U = ? pg U

Answers:

1. 55.0 g O = 3.44 mol O = $2.07 \text{x} 10^{24}$ atoms O
2. 1.455 mol Fe = 81.26 g Fe = $8.76 \text{x} 10^{23}$ atoms Fe
3. 45.0 g Au = $1.375 \text{x} 10^{23}$ atoms Au = 0.228 mol Au
4. 26.3 mg Kr = $1.89 \text{x} 10^{20}$ atoms Kr
5. $2.00 \text{x} 10^{10}$ atoms U = 7.91 pg U