



The Mole

How do we connect atoms and molecules to something we can actually measure?



Counting by mass

- ▶ How did we count the number of beans in the jar?
- ▶ Similar method for counting atoms
- ▶ Atoms combine in specific numeric ratios
 - ▶ Too small and too many to actually count
- ▶ We must count them by using their average mass – just like the beans

Average Atomic Mass

- Where can we find information about the average mass of atoms?

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
1	H Hydrogen 1.008																		2	He Helium 4.003
2	Li Lithium 6.941	Be Beryllium 9.012											B Boron 10.81	C Carbon 12.01	N Nitrogen 14.01	O Oxygen 16.00	F Fluorine 19.00	Ne Neon 20.18		
3	Na Sodium 22.99	Mg Magnesium 24.31											Al Aluminum 26.98	Si Silicon 28.09	P Phosphorus 30.97	S Sulfur 32.07	Cl Chlorine 35.45	Ar Argon 39.95		
4	K Potassium 39.10	Ca Calcium 40.08	Sc Scandium 44.96	Ti Titanium 47.88	V Vanadium 50.94	Cr Chromium 52.00	Mn Manganese 54.94	Fe Iron 55.85	Co Cobalt 58.93	Ni Nickel 58.69	Cu Copper 63.55	Zn Zinc 65.38	Ga Gallium 69.72	Ge Germanium 72.59	As Arsenic 74.92	Se Selenium 78.96	Br Bromine 79.90	Kr Krypton 83.8		
5	Rb Rubidium 85.47	Sr Strontium 87.62	Y Yttrium 88.91	Zr Zirconium 91.22	Nb Niobium 92.91	Mo Molybdenum 95.94	Tc Technetium (98)	Ru Ruthenium 101.07	Rh Rhodium 102.9	Pd Palladium 106.4	Ag Silver 107.87	Cd Cadmium 112.41	In Indium 114.82	Sn Tin 118.71	Sb Antimony 121.78	Te Tellurium 127.6	I Iodine 126.90	Xe Xenon 131.29		
6	Cs Cesium 132.91	Ba Barium 137.33	La Lanthanum 138.91	Hf Hafnium 178.49	Ta Tantalum 180.95	W Tungsten 183.85	Re Rhenium 186.21	Os Osmium 190.2	Ir Iridium 192.22	Pt Platinum 195.08	Au Gold 196.97	Hg Mercury 200.59	Tl Thallium 204.83	Pb Lead 207.2	Bi Bismuth 209	Po Polonium (209)	At Astatine (210)	Rn Radon (222)		
7	Fr Francium (223)	Ra Radium 226.0	Lr Lawrencium (260)	Rf Rutherfordium (261)	Db Dubnium (262)	Sg Seaborgium (263)	Bh Bohrium (264)	Hs Hassium (265)	Mt Meitnerium (266)	Ds Darmstadtium (281)	Rg Roentgenium (272)	Uub Ununbium (277)	Uut Ununtrium (284)	Uuq Ununquadium (289)	Uup Ununpentium (288)					
	◇	La Lanthanum 138.91	Ce Cerium 140.12	Pr Praseodymium 140.91	Nd Neodymium 144.24	Pm Promethium (145)	Sm Samarium 150.36	Eu Europium 151.96	Gd Gadolinium 157.25	Tb Terbium 158.93	Dy Dysprosium 162.50	Ho Holmium 164.93	Er Erbium 167.26	Tm Thulium 168.93	Yb Ytterbium 173.04					
	◆	Ac Actinium (227)	Th Thorium 232.04	Pa Protactinium (231)	U Uranium 238.03	Np Neptunium (237)	Pu Plutonium (244)	Am Americium (243)	Cm Curium (247)	Bk Berkelium (247)	Cf Californium (251)	Es Einsteinium (252)	Fm Fermium (257)	Md Mendelevium (258)	No Nobelium (259)					



Average Atomic Mass

- ▶ Periodic table gives average mass of an atom
 - ▶ Weighted by percent of each stable isotope
 - ▶ Average atomic masses are given in AMU
 - ▶ Atomic Mass Unit (AMU) = $1/12$ the mass of a Carbon-12 atom or 1.6605×10^{-27} kg
 - ▶ What's the problem with using AMU?
 - ▶ We need a way to ramp up the numbers to something we can actually measure.
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What do they have in common?

- ▶ What do the items I handed out have in common with each other?
- ▶ 1 dozen = 12 items
- ▶ 1 mole = 6.022×10^{23} items
 - ▶ Avagadro's number
- ▶ What is special about this number?
- ▶ Allows us to use the same numbers on the periodic table for single atoms or moles of atoms
 - ▶ Ex, 1 carbon atom \rightarrow average mass = 12.01 AMU
1 mole of carbon atoms \rightarrow average mass = 12.01 grams



The Mole

- ▶ 1 atom H = 1.01 AMU
- ▶ 10 atoms H = 10.10 AMU
- ▶ 1000 atoms H = 1010 AMU
- ▶ 1,000,000 atoms H = 1010000 AMU
- ▶ 6.022×10^{23} atoms = 1.01 grams
- ▶ 6.022×10^{23} = Avagadro's Number = 1 mole
- ▶ This number allows us to use the average atomic masses from the PT with a unit that we can actually measure (grams)



Equivalence Statements

- ▶ 1 mole = 6.022×10^{23} particles
 - ▶ Particles = atoms, molecules, formula units
- ▶ 1 mole = 1 molar mass
 - ▶ Molar mass depends on formula
 - ▶ Elements → average atomic mass from periodic table
 - ▶ Compounds → sum of all elements in formula (x subscript)

Conversion Factors

- Using these equivalence statements, we can make conversion factors
- 1 mole = 6.022×10^{23} particles

$$\frac{1 \text{ mole}}{6.022 \times 10^{23} \text{ particles}}$$

$$\frac{6.022 \times 10^{23} \text{ particles}}{1 \text{ mole}}$$

- 1 mole = 1 molar mass

$$\frac{1 \text{ mole}}{\text{molar mass}}$$

$$\frac{\text{molar mass}}{1 \text{ mole}}$$

Mole Conversions

- ▶ Converting between moles, grams, and # of particles can be done using these conversion factors
 - ▶ Same method as converting units
- ▶ How many atoms are there in 2.54 moles of Aluminum?

$$\frac{2.54 \text{ moles Al}}{1} \times \frac{6.022 \times 10^{23} \text{ atoms Al}}{1 \text{ mole Al}}$$

- ▶ What is the mass of 2.54 moles of Aluminum?

$$\frac{2.54 \text{ moles Al}}{1} \times \frac{26.98 \text{ g Al}}{1 \text{ mole Al}}$$



Mole Conversions

- ▶ How would the conversion problems change if I substitute sodium for aluminum?



Mole Conversions

- ▶ 17.95 grams of potassium oxide is how many moles?
- ▶ If you have 3.825×10^{24} molecules of carbon dioxide, how many moles do you have?



Mole Conversions

- ▶ What is the mass of 4.112×10^{22} atoms of zinc?
- ▶ How many molecules of dinitrogen pentoxide are there in 1.074 grams?