THE ERINDALE ACADEMY
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Teacher: Ms. Ella

Unit 3: Quantities in Chemical Reactions

6.1: Qualitative and Quantitative Analysis

In Section 6.1:
You will explore these Key Concepts: accurately analyze the quantities of chemicals in our **bodies**, in various **foods**, and in **daily use**; appreciate that accurate measurements and analyses are crucial to our **health and environment**, as well as to **industrial and manufacturing processes**.

Qualitative analysis: the process of **identifying or detecting** substances present in a sample; no measurements are involved

Quantitative analysis: the process of **measuring** the quantity of a substance in a sample, providing **numerical** data

Examples: Urine test strip (color change to test if glucose present in urine – diabetes)
Acid-base indicator (color change)
Drug-testing technique (test if athletes intake creatine or other drugs)
Toxic/Carcinogenic Air-borne pollutants detector
Glucometer
Carbon dioxide/carbon monoxide/smoke detector

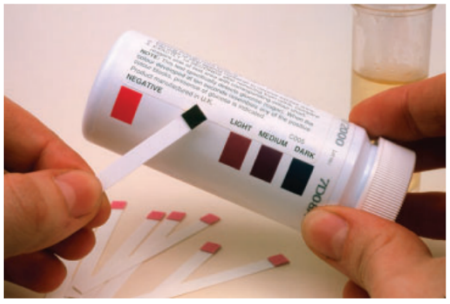

Figure 2 The dark colour of a glucose urine test strip is a positive test for excess glucose in urine. Diabetic patients have abnormally high concentrations of glucose in their urine.

Figure 3 A glucometer gives a quantitative measure of the blood glucose level. A drop of blood is required for the analysis.

Figure 4 An air quality technician measures pollutants in vehicle exhaust.

ALCOHOL TESTER
Professional Mini Police Digital LCD Screen
Breath Alkohol Alcohol Tester .

Homework: pg 263. #1 - 3

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Unit 3: Quantities in Chemical Reactions

6.3: Mole – The unit of Counting

Table 1 Counting Units

Unit	Example
1 dozen	12 golf balls
1 six-pack	6 cans of pop
1 ream	500 sheets of paper
1 h	60 min

Recall: We use one-twelfth the mass of a single ^{12}C as 1 AMU and measure the atomic mass of the rest of elements in term of that.

AMU = 1 gram / mole

So what is Mole?

- Mole is the SI base unit for the amount of substance.
- 1 Mole of any substance (molecules, atoms, electrons, protons, neutrons, etc.…) contains 602 214 199 000 000 000 000 000 entities of the substance.
- We call this number Avogadro's constant: $N_A = 6.02 \times 10^{23}$ entities / mole

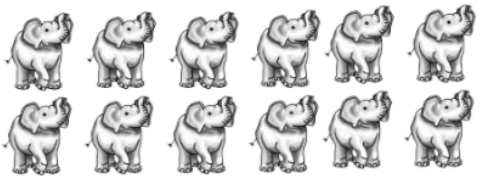
Why 6.02×10^{23}?

- Because that is how many subatomic particles (protons or neutrons or amu_s) required to make 1 actual gram which is a value that is much more understandable and user friendly.
- 1.67×10^{-24} g/subatomic particle x 6.02×10^{23} = approximately 1 gram

A mole is just quick way of summarizing a large quantities.

A pair (2) of elephants:

A dozen (12) elephants:



A **mole** (6.02×10^{23}) of elephants:

um.... never mind

Example 1: 1 mole of hydrogen gas:

- has 6.02×10^{23} of diatomic hydrogen molecules.
- has $2 \times 6.02 \times 10^{23} = 1.204 \times 10^{24}$ number of Hydrogen atoms.
- has $2 \times 6.02 \times 10^{23} = 1.204 \times 10^{24}$ number of protons.
- How many electrons?

Example 2: Commercial product that people sometimes take to settle an upset stomach contains magnesium hydroxide, a base. If a teaspoon of stomach medicine contains 4.1×10^{21} formula units of magnesium hydroxide, what amount in moles of magnesium hydroxide is in the teaspoon?

So we can take Avogadro's constant (N_A) to convert number of particles to amount in Moles:

$$n = \frac{N}{N_A} = \frac{number\ of\ individual\ particles, N}{6.02 \times 10^{23} particels/mol}$$

Homework:

Practice Problems

21. A gold coin contains 9.51×10^{22} atoms of gold. What amount in moles of gold is in the coin?

22. A patient in a dentist's office is given 1.67×10^{23} molecules of dinitrogen monoxide (laughing gas), $N_2O(g)$, during a procedure. What amount in moles of dinitrogen monoxide is the patient given?

23. A sheet of drywall contains 1.2×10^{26} formula units of gypsum (calcium sulfate dihydrate), $CaSO_4 \cdot 2H_2O(s)$. What amount in moles of gypsum is in the sheet of drywall?

24. Limewater, a weak solution of calcium hydroxide, $Ca(OH)_2(s)$, is used to detect the presence of carbon dioxide gas. Suppose that you are given a solution that contains 8.7×10^{19} formula units of calcium hydroxide. What amount in moles of calcium hydroxide is in the solution?

25. If there are a total of 7.3×10^{29} atoms in a sample of glucose, $C_6H_{12}O_6(s)$, what amount in moles of glucose is in the sample?

26. A sample of aluminum oxide, $Al_2O_3(s)$, contains 8.29×10^{25} total atoms. Calculate the amount in moles of aluminum oxide in the sample. **Hint:** This is a two-step problem. Calculate the number of formula units first.

27. Trinitrotoluene, or TNT for short, has the chemical formula $C_7H_5N_3O_6(s)$. If a stick of dynamite is pure TNT and it contains 2.5×10^{25} atoms in total, what amount in moles of TNT does it contain?

28. A sample of rubbing alcohol solution contains ethanol, $C_2H_5OH(\ell)$. If the sample contains 1.25×10^{23} atoms of hydrogen in the ethanol, what amount in moles of ethanol is in the sample?

29. A cleaning solution contains 7.9×10^{26} molecules of ammonia, $NH_3(aq)$. What amount in moles of ammonia is in the solution?

30. A muffin recipe calls for cream of tartar, or potassium hydrogen tartrate, $KHC_4H_4O_6(s)$. The amount of cream of tartar that is required contains 2.56×10^{23} atoms of carbon. What amount in moles of potassium hydrogen tartrate is required?

Review Questions

1. K/U Define "mole" in your own words. Use an example to illustrate your definition.
2. K/U Compare a mole and a dozen. Provide one similarity and one difference.
3. K/U Is the value that is presently accepted for the mole, $6.022\ 141\ 79 \times 10^{23}$ particles, an exact number? Explain.
4. T/I If the volume of one mole of water at room temperature is 18.02 mL, what is the volume of one molecule of water, in litres?
5. C Use a flowchart to show the process of converting moles of phosphorus, $P_4(s)$, to atoms of phosphorus.
6. T/I Calculate the number of formula units of sodium chloride in 0.0578 mol.
7. T/I Calculate the number of particles in each sample. Indicate the correct type of particle (atom, molecule, ion, or formula unit).
   a. 0.156 mol Au(s)
   b. 7.8 mol $MgCl_2(s)$
   c. 15.2 mol $H_2O_2(\ell)$
8. T/I Calculate the amount in moles of molecules for each substance listed.
   a. a sample of ammonia, $NH_3(g)$, containing 8.1×10^{20} atoms of hydrogen
   b. a sample of diphosphorus pentoxide, $P_2O_5(s)$, containing a total of 4.91×10^{22} atoms of phosphorus and oxygen
9. T/I A sample of ethanol, $C_2H_5OH(\ell)$, contains 2.49×10^{23} molecules of ethanol. A sample of carbon contains 1.65 mol of carbon atoms. Which sample, the ethanol or the carbon, contains the greater amount in moles of carbon?
10. T/I If there are 4.28×10^{21} atoms of hydrogen and oxygen in a sample of water, what amount in moles of water is in the sample?
11. A Aluminum oxide, $Al_2O_3(s)$, forms a thin coating on an aluminum surface, such as the body of an airplane, when aluminum is exposed to oxygen in air. This coating helps to reduce further corrosion of the aluminum. Suppose that a sample contains 2.6 mol of aluminum oxide.
    a. How many formula units are in the sample?
    b. How many atoms, in total, are in the sample?
    c. How many aluminum atoms are in the sample?

12. A Zinc chloride hexahydrate, $ZnCl_2 \cdot 6H_2O(s)$, is used in the textile industry, often to prepare fireproofing agents. In a particular fireproofing solution, 0.46 mol of zinc chloride hexahydrate is used.
    a. How many formula units of zinc chloride hexahydrate are in the solution?
    b. How many atoms of chlorine are in the solution?
13. C Draw a graphic organizer that shows the conversions between number of particles and amount in moles.
14. A Arrange the following three samples from largest to smallest in terms of their numbers of representative particles:
    - 3.92 mol of octane, $C_8H_{18}(\ell)$
    - 6.52×10^{23} atoms of copper, Cu(s)
    - 1.25×10^{24} formula units of sodium hydrogen carbonate, $NaHCO_3(s)$.
15. T/I Calculate the number of atoms in 6.0 mol of fluorine, $F_2(g)$, molecules.

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Answer key:

4. 2.992×10^{-26} L

6. 3.48×10^{22} formula units of sodium chloride

7. a. 9.39×10^{22} atoms of gold
b. 4.7×10^{24} formula units of magnesium chloride
c. 9.15×10^{24} molecules of hydrogen peroxide

8. a. 4.5×10^{-4} mol
b. 0.0117 mol

9. the sample of carbon

10. 2.37×10^{-3} mol of water

11. a. 1.6×10^{24} formula units
b. 7.8×10^{24} atoms
c. 3.1×10^{24} atoms

12. a. 2.8×10^{23} formula units
b. 5.5×10^{23} atoms of chlorine

14. octane, then sodium hydrogen carbonate, then copper

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Unit 3: Quantities in Chemical Reactions

6.4: Molar Mass

Essential question: By now we know the mass of 1 mole or 6.02×10^{23} numbers of proton or neutron is 1 g, then what is the mass of 1 mole of hydrogen, oxygen, or any other elements?

Molar mass of element: is the same as the value of its atomic mass in the periodic table. For instance, oxygen has atomic mass of 15.999 AMU which indicates there is 15.999 grams of oxygen atom in each mole.

Molar mass of compound: we find the molar mass of each element, multiply by the number of atoms of each element, and add the values.

Example: What is the molar mass of water? Aluminum sulfate?

Practice Problems

31. State the molar mass of each element.
- **a.** sodium
- **b.** tungsten
- **c.** xenon
- **d.** nickel

32. Calculate the molar mass of phosphorus, $P_4(s)$.

33. Determine the molar mass of calcium phosphate, $Ca_3(PO_4)_2(s)$.

34. Calculate the molar mass of lead(II) nitrate, $Pb(NO_3)_2(s)$.

35. Determine the molar mass of the iron(III) thiocyanate ion, $FeSCN^{2+}(aq)$.

36. Calculate the molar mass of sodium stearate, $NaC_{17}H_{35}COO(s)$.

37. Calculate the molar mass of barium hydroxide octahydrate, $Ba(OH)_2 \cdot 8H_2O(s)$. (**Hint:** The molar mass of a hydrate must include the water component.)

38. Determine the molar mass of tetraphosphorus decoxide, $P_4O_{10}(s)$.

39. Calculate the molar mass of iron(II) ammonium sulfate hexahydrate, $(NH_4)_2Fe(SO_4)_2 \cdot 6H_2O(s)$.

40. The formula for a compound that contains an unknown element, A, is A_2SO_4. If the molar mass of the compound is 361.89 g/mol, what is the atomic molar mass of A?

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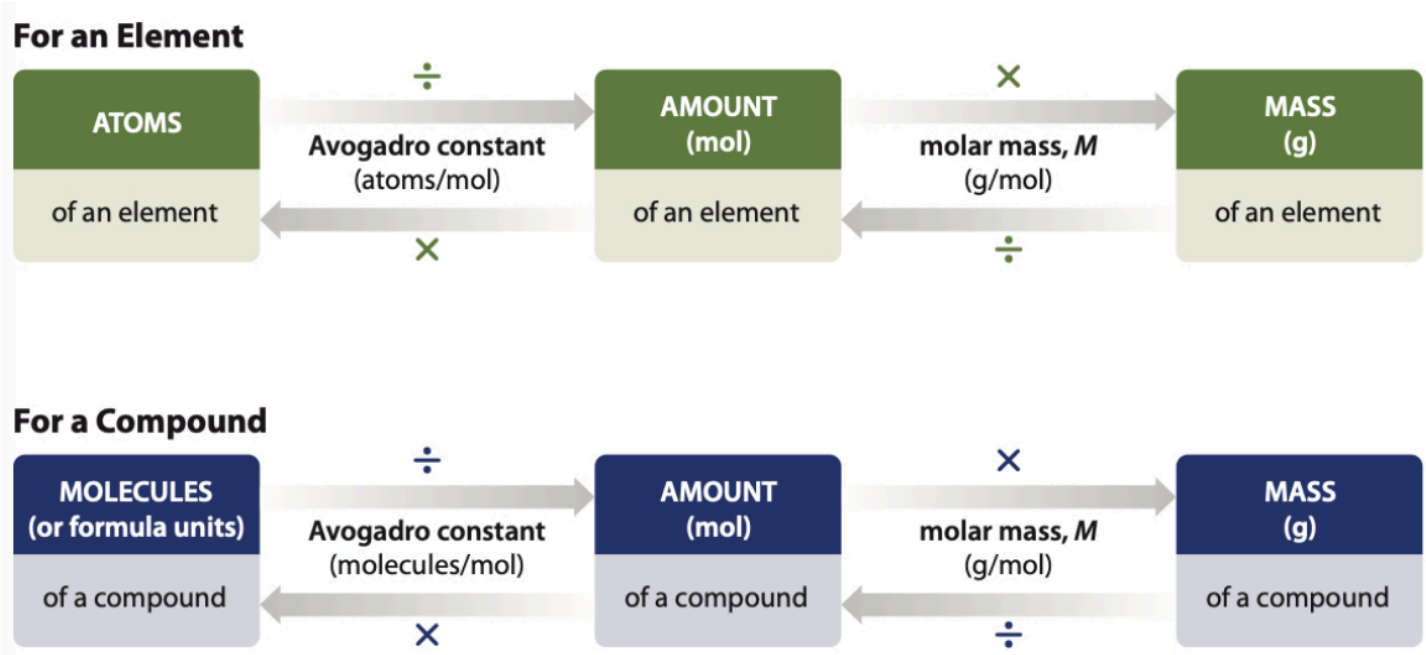
The relationship between Mole, Mass, and Number of particles



Example 1: Convert mole to mass

A chemist performs a reaction that produces 0.258 mol of silver chloride precipitate. What mass of precipitate is produced?

Example 2: Convert mass to mole

Arrange the following substances in order from largest to smallest amount in moles:

- 865 mg of $Ni(NO_3)_2(s)$
- 9.82 g of $Al(OH)_3(s)$
- 10.4 g of $AgCl(s)$

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Example 3: Convert mass to number of particles

Phosphoryl chloride, $POCl_3(\ell)$, is an important compound in the production of flame retardants. How many molecules of phosphoryl chloride are in a 25.2 g sample?

Practice:

2. C Use a flowchart to show the relationships among number of particles, amount in moles, and mass in grams.

3. C Use a flowchart to show how the atomic mass and atomic molar mass of an element are related.

4. T/I Determine the amount in moles of gallium oxide, $Ga_2O_3(s)$, in a 45.2 g sample.

5. T/I What is the mass of 3.2×10^2 mol of cerium nitrate, $Ce(NO_3)_3(s)$?

6. T/I Calculate the amount in moles of strontium chloride, $SrCl_2(s)$, in a 28.6 kg sample.

7. T/I What is the mass of 0.68 mol of iron(III) sulfate, $Fe_2(SO_4)_3(s)$?

8. T/I What is the mass of 2.9×10^{26} molecules of dinitrogen pentoxide, $N_2O_5(g)$?

9. T/I Calculate the number of oxygen atoms in 15.2 g of trinitrotoluene, $C_7H_5(NO_2)_3(s)$.

10. T/I Which has more sulfur atoms: 13.4 g of potassium thiocyanate, KSCN(s), or 0.067 mol of aluminum sulfate, $Al_2(SO_4)_3$?

11. T/I Which has a greater amount in moles: a sample of sulfur trioxide containing 4.9×10^{22} atoms of oxygen or a 4.9 g sample of carbon dioxide?

12. A Imagine that you are an environmental chemist who is testing drinking water for water hardness. A sample of water you test has 3.5×10^{-2} mg of dissolved calcium carbonate, $CaCO_3(aq)$.

a. How many formula units of calcium carbonate are in the sample?

b. How many oxygen atoms are in the calcium carbonate in the sample?

14. T/I Copy and complete the following table.

Number of Particles, Amount, and Mass of Selected Elements and Compounds

Substance	Number of Particles	Amount (mol)	Mass (g)
$P_4(s)$		13.2	
$Ba(MnO_4)_2(s)$	6.7×10^{20}		
$C_5H_9NO_4(s)$			19.62

15. A Methyl salicylate, $C_6H_4(OH)COOCH_3(s)$, is used in many consumer products, such as mouthwash, as a flavouring. A mouthwash sample contains 1.38×10^{18} molecules of methyl salicylate. What is the mass of the methyl salicylate in the sample?

16. T/I Determine the order of the following three substances, from smallest to greatest number of carbon atoms: 5.6×10^{23} molecules of benzoic acid, $C_6H_5COOH(s)$; 1.3 mol of acetic acid, $CH_3COOH(\ell)$; 0.17 kg of oxalic acid, HOOCCOOH(s).

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Answer key:

4. 0.241 mol
5. 1.0×10^5 g
6. 1.80×10^2 mol
7. 2.7×10^2 g
8. 5.2×10^4 g
9. 2.42×10^{23} atoms
10. aluminum sulfate
11. carbon dioxide
12. a. 2.1×10^{17}
b. 6.3×10^{17} atoms
13. 3.1×10^{17} lead atoms translates into 0.11 mg/L, which is about ten times greater than the allowable lead limit. Therefore, the water is not safe to drink.
14.

Substance	Number of Particles	Amount (mol)	Mass (g)
$P_4(s)$	7.95×10^{24}	13.2	1.64×10^3
$Ba(MnO_4)_2(s)$	6.7×10^{20}	1.1×10^{-3}	0.42
$C_5H_9NO_4(s)$	8.027×10^{22}	0.1333	19.62

15. 3.49×10^{-4} g
16. $CH_3COOH(\ell)$, HOOCCOOH(s), $C_6H_5COOH(s)$

SUMMARY Calculating Mass, Amounts in Moles, and Number of Entities

1. n represents the amount in moles, m the mass measured, M the molar mass, N the number of entities, and N_A Avogadro's constant (**Table 1**).
2. $n = \frac{m}{M}$
3. $m = nM$
4. $N = nN_A$

Table 1: Stoichiometry, Symbols and Units

Symbol	Quantity	Unit
n	amount in moles	mol
m	mass	mg, g, kg
M	molar mass	g/mol
N	number of entities	atoms, ions, formula units, molecules
N_A	Avogadro's constant, 6.02×10^{23}	—