Moles

Unit: Moles

MA Curriculum Frameworks (2016): HS-PS1-2, HS-PS1-3

Mastery Objective(s): (Students will be able to…)

- Determine the molar mass of a compound.
- Convert between moles, mass, volume, and molecules/atoms.

Success Criteria:

- Conversions are set up properly so undesired units are canceled and desired units appear in the correct place.
- Algebra and rounding to appropriate number of significant figures is correct.

Tier 2 Vocabulary: mole, molar

Language Objectives:

- Explain the concept of a quantitative collective noun (such as "dozen") and apply it to the mole concept.

Notes:

mole: (working definition) the amount a compound that is the same number of grams* as the compound's formula or molecular mass in amu.

mole: (formal definition) the amount of matter that contains the same number of objects (atoms, molecules, *etc.*) as the number of atoms in exactly 12 g of ^{12}C. When the British Imperial system was more commonly used, this quantity was often called a gram-mole.

Avogadro's constant: 1 mole = 6.022×10^{23} atoms, molecules, *etc.* (*Memorize this number!*)

molar volume: the space occupied by 1 mole of ANY gas. At S.T.P. (0 °C = 273 K) and 1 bar of pressure), the molar volume is 22.7 L. (*Memorize this number!*)

molar mass (m.m.): the mass (in grams) of 1 mole of a substance. For atoms, this is the same number as the atomic mass on the periodic table, but with the unit "grams". For compounds, add up the mass of each atom in the compound.

* Technically, this is only true for moles in the S.I. system, which used to be called "gram-moles". In the British Imperial system, a "pound-mole" is the amount of a compound that is the same number of *pounds* as its formula mass. Chemists use the term "ton-mole" the same way other people might use "@#%$-ton".

Use this space for summary and/or additional notes:

How Moles are Used in Chemistry

Moles are used as a way to make sure you have the desired number of atoms or molecules for a chemical reaction.

For example, consider the reaction:

$$2\ Fe + 3\ I_2 \rightarrow 2\ FeI_3$$

Suppose you wanted to perform this reaction in a lab with exact amounts of your starting materials (for example, let's say it's because you didn't want to have anything left over). You would need a ratio of 2 atoms of Fe for every 3 molecules of I_2. The problem is that all you have to work with is a jar of iron, a jar of iodine, and a balance.

To solve this problem, we define a mole as being the same number of grams as the average atomic mass. This means that a mole is always the same number of atoms or molecules (Avogadro's constant), so if we start with exactly 2 ***moles*** of Fe and exactly 3 ***moles*** of I_2, we will end up making exactly 2 ***moles*** of FeI_3.

You can think of a mole the same way you think of a dozen (or a 12-pack). If you have 3 dozen eggs and 6 dozen slices of toast, you could serve $\frac{1}{12}$ dozen eggs (one egg) and $\frac{2}{12}$ dozen slices of toast (2 slices) to each person. Similarly, if you have 2 moles of Fe (12.04×10^{23} atoms), and 3 moles of I_2 (18.06×10^{23} molecules), you can react them to make 2 moles of FeI_3 (12.04×10^{23} molecules).

In the chapter on "Stoichiometry," starting on page 409, we will use the coëfficients in chemical equations to calculate the number of moles of reactants used and the moles of products produced in a reaction.

Use this space for summary and/or additional notes:

Molar Mass

The molar mass is the mass (in grams) of one mole of a chemical. Molar mass is used to convert between grams and moles. (Recall the "Conversions (Factor-Label Method)" section on page 88.)

The molar mass of an atom is its (average) atomic mass, but expressed in grams instead of atomic mass units (amu):

1 atom of Fe has a mass of 55.8 amu (from the periodic table), so
1 mole of Fe has a mass of 55.8 g

The molar mass of a compound is the sum of the (average) atomic masses of the elements in the compound, but again expressed in grams instead of amu:

1 molecule of I_2 has 2 atoms of I. One atom of I has a mass of 126.9 amu, so
1 molecule of I_2 has a mass of 2 × 126.9 = 253.8 amu. This means that
1 mole of I_2 has a mass of 2 × 126.9 = 253.8 g

Similarly:

1 mole of FeI_3 contains 1 mole of Fe atoms and 3 moles of I atoms, so we add up all of the atoms in the molecule:

	1 mole Fe = 1 × 55.8 =	55.8 g
+	3 moles I = 3 × 126.9 =	380.7 g
	1 mole FeI_3 =	436.5 g

Use this space for summary and/or additional notes:

Homework Problems

Calculate the mass in grams of one mole of each of the following compounds.

1. HCl

   Answer: $36.46 \frac{g}{mol}$

2. Fe_2O_3

   Answer: $36.46 \frac{g}{mol}$

3. $LiAlH_4$

   Answer: $36.46 \frac{g}{mol}$

4. $C_6H_{12}O_6$

   Answer: $36.46 \frac{g}{mol}$

5. $Ca_3(PO_4)_2$

   Answer: $36.46 \frac{g}{mol}$

Use this space for summary and/or additional notes:

6. $UOCl_2$

Answer: $36.46\frac{g}{mol}$

7. $NiCl_2$

Answer: $36.46\frac{g}{mol}$

8. $(NH_4)_2SO_4$

Answer: $36.46\frac{g}{mol}$

9. $AgNO_3$

Answer: $36.46\frac{g}{mol}$

10. CH_3COOH

Answer: $36.46\frac{g}{mol}$

Use this space for summary and/or additional notes:

Mole Conversions

1 mol = __ grams *(add up the mass of the formula)*

1 mol = 6.02 x 10^{23} atoms, molecules, *etc.*

n mol = $\frac{PV}{RT}$ (1 mol of gas @ S.T.P.* = 22.7 L)

These conversions work just like the ones from earlier in the year.

Sample Problems:

1. 2.5 mol of NH_3 gas occupies what volume at S.T.P.?

$$\frac{2.5\,\cancel{\text{mol NH}_3}}{1} \times \frac{22.7\,\text{L NH}_3}{1\,\cancel{\text{mol NH}_3}} = 57\,\text{mol NH}_3$$

2. What is the mass of 4.1 mol NH_3 gas?

   The molar mass of 1 mol NH_3 is (1 × 14) + (3 × 1) = 17 g NH_3.

$$\frac{4.1\,\cancel{\text{mol NH}_3}}{1} \times \frac{17\,\text{g NH}_3}{1\,\cancel{\text{mol NH}_3}} = 70.\,\text{g NH}_3$$

3. How many molecules are there in 0.75 mol of NH_3 gas?

$$\frac{0.75\,\cancel{\text{mol NH}_3}}{1} \times \frac{6.02\times10^{23}\ \text{molecules NH}_3}{1\,\cancel{\text{mol NH}_3}} = 4.5\times10^{23}\ \text{molecules NH}_3$$

4. What is the volume of 25.5 g of NH_3 gas at S.T.P.?

   The molar mass of 1 mol NH_3 = (1 × 14) + (3 × 1) = 17 g NH_3.

$$\frac{25.5\,\cancel{\text{g NH}_3}}{1} \times \frac{1\,\cancel{\text{mol NH}_3}}{17\,\cancel{\text{g NH}_3}} \times \frac{22.7\,\text{L NH}_3}{1\,\cancel{\text{mol NH}_3}} = 34.1\,\text{L NH}_3$$

Note: this chapter is a good time to start including the chemical formula as part of the units. This will be extremely useful when we study stoichiometry.

* S.T.P. = "Standard Temperature and Pressure". Since 1980, the official IUPAC definition of S.T.P. has been 0 °C and 100 kPa. Some texts (and the MA DESE) stubbornly insist on using the old definition of 0 °C and 1 atm. This would make the molar volume of an ideal gas 22.4 L instead of 22.7 L.

Use this space for summary and/or additional notes:

Homework Problems

1. How many moles are 65.0 grams of zinc?

   Answer: 0.99 mol Zn
2. How many moles are 1 250.5 g of lead (II) nitrate ($Pb(NO_3)_2$)?

   Answer: 3.775 mol lead (II) nitrate
3. How many moles are 2 500 g of tin (IV) chlorate ($Sn(ClO_3)_4$)?

   Answer: 5.5 mol tin (IV) chlorate
4. How many moles are 125.0 g of silver nitrate ($AgNO_3$)?

   Answer: 0.7357 mol silver nitrate
5. How many nitrogen atoms are there in 62.5 g of dinitrogen pentoxide?

   Answer: 0.579 mol dinitrogen pentoxide
6. How many oxygen atoms are there in 380 g of copper (II) phosphate?

   Answer: 1.00 mol copper (II) phosphate
7. How many hydrogen atoms in 454 g of aluminum hydroxide?

   Answer: 5.82 mol aluminum hydroxide

Use this space for summary and/or additional notes:

8. What is the mass (in grams) of 2.35 mol of S_2N_3?

   Answer: 249 g S_2N_3

9. What is the mass (in grams) of 0.25 mol of silver acetate?

   Answer: 42 g silver acetate

10. What is the mass (in grams) of a 2.00 kg bag of table sugar ($C_{12}H_{22}O_{12}$)?

    Answer: 2 000 g ☺

11. How many moles are in 123.5 L of oxygen gas at S.T.P.?

    Answer: 5.44 mol oxygen

12. How many moles are in a 40. gallon drum of chlorine gas at S.T.P.?
    (1 gal = 3.78 L)

    Answer: 6.7 mol chlorine gas

13. What is the volume (in liters) of 3.5 mol of argon gas at 1.1 atm and 20 °C?
    (*Hint: this is not at S.T.P., so you need to use PV = nRT.*)

    Answer: 76.5 L argon gas

14. What is the volume (in liters) of 4.90×10^{25} molecules of N_2 gas at S.T.P.?

    Answer: 1 850 L N_2 gas

Use this space for summary and/or additional notes: