The Mole Concept

(What is a mole?)

Exercises

Unless otherwise stated, calculate all mass values in grams.

1. Consider CTQ 1. A unit plan for this problem would be dozens → elephants → trunks. Since you know there are 12 elephants in 1 dozen elephants and 1 trunk per elephant, you could set up the problem using conversion factors as follows:

$$1 \text{ dozen elephants} \times \frac{12 \text{ elephants}}{1 \text{ dozen elephants}} \times \frac{1 \text{ trunk}}{1 \text{ elephant}} = 12 \text{ trunks}$$

   Complete similar unit conversions, showing all work, for CTQs 2-13.

CTQ 2: dozens → elephants → legs

$$1 \text{ dozen elephants} \times \frac{12 \text{ elephants}}{1 \text{ dozen elephants}} \times \frac{4 \text{ legs}}{1 \text{ elephant}} = 48 \text{ legs}$$

CTQ 3: score → elephants → trunks

$$1 \text{ score elephants} \times \frac{20 \text{ elephants}}{1 \text{ score elephants}} \times \frac{1 \text{ trunk}}{1 \text{ elephant}} = 20 \text{ trunks}$$

CTQ 4: myriad → elephants → leg

$$1 \text{ myriad elephants} \times \frac{10{,}000 \text{ elephants}}{1 \text{ myriad elephants}} \times \frac{4 \text{ legs}}{1 \text{ elephant}} = 40{,}000 \text{ legs}$$

CTQ 5: moles → elephants → trunks

$$1 \text{ mole elephants} \times \frac{6.022\times10^{23} \text{ elephants}}{1 \text{ mole elephants}} \times \frac{1 \text{ trunk}}{1 \text{ elephant}} = 6.022\times10^{23} \text{ trunks}$$

CTQ 6: dozens → molecules → C atoms

$$1 \text{ dozen methane molecules} \times \frac{12 \text{ methane molecules}}{1 \text{ dozen}} \times \frac{1 \text{ carbon atom}}{1 \text{ methane molecule}} = 12 \text{ carbon atoms}$$

CTQ 7: myriad → molecules → H atoms

$$1 \text{ myraid methane molecules} \times \frac{10{,}000 \text{ methane molecules}}{1 \text{ myriad}} \times \frac{4 \text{ hydrogen atoms}}{1 \text{ methane molecule}} = 40{,}000 \text{ hydrogen atoms}$$

CTQ 8: moles → elephants

$$1 \text{ mole elephants} \times \frac{6.022\times10^{23} \text{ elephants}}{1 \text{ mole elephants}} = 6.022\times10^{23} \text{ elephants}$$

CTQ 9: moles → elephants → trunks

$$0.5 \text{ mole elephants} \times \frac{6.022\times10^{23} \text{ elephants}}{1 \text{ mole elephants}} \times \frac{1 \text{ trunk}}{1 \text{ elephant}} = 3.011\times10^{23} \text{ trunks}$$

CTQ 10: moles → elephants → legs

$$1 \text{ mole elephants} \times \frac{6.022\times10^{23} \text{ elephants}}{1 \text{ mole elephants}} \times \frac{4 \text{ legs}}{1 \text{ elephant}} = 2.409\times10^{24} \text{ trunks}$$

CTQ 11: moles → molecules → C atoms

$$1 \text{ mole methane} \times \frac{6.022\times10^{23} \text{ methane molecules}}{1 \text{ mole methane}} \times \frac{1 \text{ carbon atom}}{1 \text{ methane molecule}} = 6.022\times10^{23} \text{ carbon atoms}$$

CTQ 12: moles → molecules → H atoms

$$0.5 \text{ mole methane} \times \frac{6.022\times10^{23} \text{ methane molecules}}{1 \text{ mole methane}} \times \frac{4 \text{ hydrogen atoms}}{1 \text{ methane molecule}} = 1.204\times10^{24} \text{ hydrogen atoms}$$

CTQ 13: moles → molecules

$$1 \text{ mole methane} \times \frac{6.022\times10^{23} \text{ methane molecules}}{1 \text{ mole methane}} = 6.022\times10^{23} \text{ methane molecules}$$

2. If you measure out 69.236 g of lead, how many atoms of lead do you have? Make a unit plan first. Show work.

   g lead → mol lead → atoms lead

$$69.236 \text{ g lead} \times \frac{1 \text{ mole lead}}{207.2 \text{ g lead}} \times \frac{6.022\times10^{23} \text{ atoms lead}}{1 \text{ mole lead}} = 2.012\times10^{23} \text{ atoms lead}$$

3. Consider 1.00 mole of dihydrogen gas, H_2. How many dihydrogen molecules are present? How many hydrogen atoms are present? What is the mass of this sample?

   6.022×10^{23} dihydrogen molecules are present. Twice that many, or 1.204×10^{24} atoms of hydrogen are present. The mass of the sample is calculated as follows:

$$1 \text{ mole } H_2 \times \frac{2.016 \text{ g } H_2}{1 \text{ mole } H_2} = 2.016 \text{ g hydrogen molecules}$$

4. Ethanol has a molecular formula of CH_3CH_2OH.

   a. What is the average mass of one molecule of ethanol?

      2(12.01) + 6(1.008) + 1(16.00) = $46.0\underline{6}8$ = 46.07 amu

   b. What is the mass of 1.000 moles of ethanol?

      46.07 g

   c. What is the mass of 0.5623 moles of ethanol, CH_3CH_2OH?

$$0.5623 \text{ mole ethanol} \times \frac{46.068 \text{ g ethanol}}{1 \text{ mole ethanol}} = 25.90 \text{ g ethanol}$$

   d. How many moles of ethanol are present in a 100.0 g sample of ethanol?

$$100.0 \text{ g ethanol} \times \frac{1 \text{ mole ethanol}}{46.068 \text{ g ethanol}} = 2.171 \text{ mol ethanol}$$

   e. How many moles of each element (C, H, O) are present in a 100.0 g sample of ethanol?

$$2.171 \text{ mol ethanol} \times \frac{2 \text{ mol C atoms}}{1 \text{ mol ethanol}} = 4.341 \text{ mol C atoms}$$

$$2.171 \text{ mol ethanol} \times \frac{6 \text{ mol H atoms}}{1 \text{ mol ethanol}} = 13.02 \text{ mol H atoms}$$

$$2.171 \text{ mol ethanol} \times \frac{1 \text{ mol O atoms}}{1 \text{ mol ethanol}} = 2.171 \text{ mol O atoms}$$

f. How many grams of each element (C, H, O) are present in a 100.0 g sample of ethanol?

$$4.341 \text{ mol C atoms} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} = 52.14 \text{ g C}$$

$$13.02 \text{ mol H atoms} \times \frac{1.008 \text{ g H}}{1 \text{ mol H}} = 13.12 \text{ g H}$$

$$2.171 \text{ mol O atoms} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 34.74 \text{ g O}$$

5. How many moles of carbon dioxide, CO_2, are present in a sample of carbon dioxide with a mass of 254 grams? How many moles of O atoms are present?

$$254 \text{ g } CO_2 \times \frac{1 \text{ mole } CO_2}{44.01 \text{ g } CO_2} = 5.77 \text{ mol } CO_2$$

$$5.77 \text{ mol } CO_2 \times \frac{2 \text{ mol O atoms}}{1 \text{ mol } CO_2} = 11.5 \text{ mol O atoms}$$

6. Indicate whether each of the following statements is true or false, and explain your reasoning.

a. One mole of NH_3 weighs more than one mole of H_2O.

False. A mole of NH_3 is about 17 g, and a mole of water is about 18 g.

b. There are more carbon atoms in 48 grams of CO_2 than in 12 grams of diamond (a form of pure carbon).

True. 44 grams of CO_2 is a mole, so 48 grams of CO_2 is just over a mole. 12 g of pure carbon is one mole C. So there are more C atoms in the 48 grams of CO_2.

c. There are equal numbers of nitrogen atoms in one mole of NH_3 and one mole of N_2.

False. N_2 has 2 nitrogens per mole of N_2, whereas NH_3 has only one.

d. The number of Cu atoms in 100 grams of Cu(s) is the same as the number of Cu atoms in 100 grams of copper(II) oxide, CuO.

False. There are fewer moles of copper in the CuO, since one mole CuO weighs more than one mole Cu.

e. The number of Ni atoms in 100 moles of Ni(s) is the same as the number of Ni atoms in 100 moles of nickel(II) chloride, $NiCl_2$.

True. Both formulas have one mole Ni.

f. There are more hydrogen atoms in 2 moles of NH_3 than in 2 moles of CH_4.

False. There are 6 mol H atoms in 2 moles NH_3 and 8 mol H atoms in 2 moles CH_4.