GETTING STARTED

TRY THIS ACTIVITY: THE MINERAL CONTENT OF MILK

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Observations (answers will vary):

	Whole milk	Skim milk
Mass of evaporating dish (g)	32.791	32.794
Mass of milk residue (minerals) + evaporating dish (g)	32.810	32.809
Mass of milk residue (minerals) (g)	0.019	0.018

(a) There does not seem to be a significant difference between the mineral content of whole milk and that of skim milk.
(b) Whole milk and skim milk have approximately the same mineral content by mass.

2.1 AMOUNTS IN CHEMISTRY: MASS, MOLES, AND MOLAR MASS

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Understanding Concepts

1. $m_H = ($percent abundance hydrogen-1 $\times$ atomic mass hydrogen-1$)$

    $+ ($percent abundance hydrogen-2 $\times$ atomic mass hydrogen-2$)$

    $= (0.99985 \times 1.01 \text{ u}) + (0.00015 \times 2.01 \text{ u})$

    $= 1.01 \text{ u} + 0.000302 \text{ u}$

    $m_H = 1.01 \text{ u}$

    The relative atomic mass of hydrogen is 1.01 u.
2. The atomic mass unit is the standard mass used to determine the relative masses of all elements. The atomic mass unit, u, is equal to one-twelfth the mass of a carbon-12 atom.
3. (a) $m_{HBr} = m_H + m_{Br}$

    $= 1.01 \text{ u} + 79.90 \text{ u}$

    $m_{HBr} = 80.91 \text{ u}$

    The molecular mass of hydrogen bromide is 80.91 u.

    (b) $m_{C_6H_{12}O_6} = 6(m_C) + 12(m_H) + 6(m_O)$

    $= 6(12.01 \text{ u}) + 12(1.01 \text{ u}) + 6(16.00 \text{ u})$

    $= 72.06 \text{ u} + 12.12 \text{ u} + 96.00 \text{ u}$

    $m_{C_6H_{12}O_6} = 180.18 \text{ u}$

    The molecular mass of glucose is 180.18 u.

    (c) $m_{NaHCO_3} = m_{Na} + m_H + m_C + 3(m_O)$

    $= 22.99 \text{ u} + 1.01 \text{ u} + 12.01 \text{ u} + 3(16.00 \text{ u})$

    $m_{NaHCO_3} = 84.01 \text{ u}$

    The formula unit mass of sodium hydrogen carbonate is 84.01 u.

(d) $m_{(NH_4)_3PO_4} = 3(m_N) + 12(m_H) + (m_P) + 4(m_O)$

$\quad\quad\quad = 3(14.01\ u) + 12(1.01\ u) + (30.97\ u) + 4(16.00\ u)$

$\quad\quad\quad = 42.03\ u + 12.12\ u + 30.97\ u + 64.00\ u$

$m_{(NH_4)_3PO_4} = 149.12\ u$

The formula unit mass of ammonium phosphate is 149.12 u.

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Understanding Concepts

4. (a) $M_{C_6H_6} = 6(M_C) + 6(M_H)$

$\quad\quad\quad = 6(12.01\ g) + 6(1.01\ g)$

$\quad\quad\quad = 72.06\ g + 6.06\ g$

$M_{C_6H_6} = 78.12\ g$

The molar mass of benzene is 78.12 g.

(b) $M_{Ba(NO_3)_2} = (M_{Ba}) + 2(M_N) + 6(M_O)$

$\quad\quad\quad = (137.33\ g) + 2(14.01\ g) + 6(16.00\ g)$

$\quad\quad\quad = 137.33\ g + 28.02\ g + 96.00\ g$

$M_{Ba(NO_3)_2} = 261.35\ g$

The molar mass of barium nitrate is 261.35 g.

(c) $M_{K_3PO_4} = 3(M_K) + (M_P) + 4(M_O)$

$\quad\quad\quad = 3(39.10\ g) + (30.97\ g) + 4(16.00\ g)$

$\quad\quad\quad = 117.3\ g + 30.97\ g + 64.00\ g$

$M_{K_3PO_4} = 212.27\ g$

The molar mass of potassium phosphate is 212.27 g.

(d) $M_{NH_3} = (M_N) + 3(M_H)$

$\quad\quad\quad = (14.01\ g) + 3(1.01\ g)$

$\quad\quad\quad = 14.01\ g + 3.03\ g$

$M_{NH_3} = 17.04\ g$

The molar mass of ammonia is 17.04 g.

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Understanding Concepts

5.
$$\text{molar mass} = \frac{\text{mass}}{\text{amount}}$$

$$M_{Sn} = \frac{119.88\ g}{1.010\ mol}$$

$$M_{Sn} = 118.7\ g/mol$$

The molar mass of tin is 118.7 g/mol.

6.
$$\text{molar mass} = \frac{\text{mass}}{\text{amount}}$$
$$M_{Pt} = \frac{49.74\ \text{g}}{0.2550\ \text{mol}}$$
$$M_{Pt} = 195.1\ \text{g/mol}$$

The molar mass of platinum is 195.1 g/mol.

7. $\text{molar mass} = \dfrac{\text{mass}}{\text{amount}}$
$$M = \frac{26.66\ \text{g}}{2.220\ \text{mol}}$$
$$M = 12.01\ \text{g/mol}$$

The molar mass of the element is 12.01 g/mol. From the periodic table, this element is carbon.

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Understanding Concepts

8. mass of 1 package of cotton swabs = 240 g (key value)
    mass of 1 cotton swab = 0.480 g (conversion factor equation)

$$\text{number of cotton swabs in a package} = 240\ \cancel{g} \times \frac{1\ \text{cotton swab}}{0.480\ \cancel{g}}$$

$$\text{number of cotton swabs in a package} = 500\ \text{cotton swabs}$$

There are 500 cotton swabs in a package that contains 240 g of cotton swabs.

9. mass of 1 package of rubber bands = 729 g (key value)
    mass of 1 rubber band = 0.81 (conversion factor equation)

$$\text{number of rubber bands in package} = 729\ \cancel{g} \times \frac{1\ \text{rubber band}}{0.81\ \cancel{g}}$$

$$\text{number of rubber bands in package} = 900\ \text{rubber bands}$$

There are 900 rubber bands in a package that contains 729 g of rubber bands.

10. Method 1:
    mass of 1 box of playing cards = 558 g (key value)
    mass of 1 playing card = 1.50 g
    mass of 1 dozen playing cards = 1.50 g × 12
    mass of 1 dozen playing cards = 18 g (conversion factor equation)

$$\text{dozens of playing cards in box} = 558\ \cancel{g} \times \frac{1\ \text{dozen playing cards}}{18\ \cancel{g}}$$

$$\text{dozens of playing cards in box} = 31\ \text{dozen playing cards}$$

There are 31 dozen playing cards in a box that contains 558 g of playing cards.

Method 2:
mass of 1 box of playing cards = 558 g (key value)
mass of 1 playing card = 1.50 g (conversion factor value)

$$\text{number of playing cards in box} = 558\ \cancel{g} \times \frac{1\ \text{playing card}}{1.50\ \cancel{g}} = 372\ \text{playing cards (key value)}$$

1 dozen playing cards = 12 playing cards (conversion factor equation)

$$\text{dozens of playing cards in a box} = 372\ \cancel{\text{playing cards}} \times \frac{1\ \text{dozen playing cards}}{12\ \cancel{\text{playing cards}}}$$

$$\text{dozens of playing cards in a box} = 31\ \text{dozen playing cards}$$

There are 31 dozen playing cards in a box that contains 558 g of playing cards.

PRACTICE

Understanding Concepts

11. $m_{feathers}$ = 200.4 g (key value)

6 feathers = 2.40 g (conversion factor equation)

$$N_{feathers} = 200.4 \cancel{g} \times \frac{6 \text{ feathers}}{2.40 \cancel{g}}$$

$$N_{feathers} = 501 \text{ feathers}$$

There are 501 feathers in a pillow that contains 200.4 g of feathers.

12. $m_{pennies}$ = 1.605 kg (key value)

3 pennies = 7.50 g (conversion factor equation)

Convert the key value, 1.605 kg, to a value in grams by multiplying it by the metric conversion factor $\frac{1000 \text{ g}}{1.000 \text{ kg}}$:

$$M_{pennies} = 1.605 \cancel{kg} \times \frac{1000 \text{ g}}{1.000 \cancel{kg}}$$

$$M_{pennies} = 1.605 \times 10^3 \text{ g (key value)}$$

$$N_{pennies} = 1.605 \times 10^3 \cancel{g} \times \frac{3 \text{ pennies}}{7.50 \cancel{g}}$$

$$N_{pennies} = 642 \text{ pennies}$$

There are 642 pennies in a piggybank that contains 1.605 kg of pennies.

13. m_S = 48.0 g S (key value)

6.02×10^{23} atoms S = 32.06 g S (conversion factor equation)

$$n_S = 48.0 \cancel{g S} \times \frac{6.02 \times 10^{23} \text{ atoms S}}{32.06 \cancel{g S}}$$

$$n_S = 9.01 \times 10^{23} \text{ atoms S}$$

There are 9.01×10^{23} atoms of sulfur in a 48.0-g chunk of sulfur.

14. M_{CH4} = 52.0 g CH_4

1 mol CH_4 = 52.0 g CH_4

$$n_{CH_4} = 52.0 \cancel{g CH_4} \times \frac{1 \text{ mol } CH_4}{16.05 \cancel{g CH_4}}$$

$$n_{CH_4} = 3.24 \text{ mol } CH_4$$

There are 3.24 moles of methane molecules in 52.0 g of methane.

TRY THIS ACTIVITY: COUNTING BY MASS

Observations and Calculations

Procedural Step		
1	Mass of one dozen paper clips	4.9 g
4	Mass of paper clips in cup (g)	33.0 g

Step 5: $N_{\text{paper clips in cup}} = 33.0 \ \cancel{g} \times \dfrac{12 \text{ paper clips}}{4.9 \ \cancel{g}}$

$N_{\text{paper clips in cup}} = 81 \text{ paper clips}$

According to the calculation, there should be 81 paper clips in the cup.

Step 6: There are 81 paper clips in the cup.

(a) The number of paper clips calculated in step 5 equals the number of paper clips counted in step 6. There are no differences.

(b) Steps 1 and 6 would not be possible.

(c) Step 6 empirically (visually) confirms the value obtained in the calculation performed in step 5.

(d) A chemist uses the molar masses of the elements (published in a reliable source such as a periodic table) to determine the mass of a particular number of chemical entities (step 1). A chemist cannot count the number of chemical entities in the sample (as in step 6) to verify that the number of entities calculated equals the actual number in the sample. The chemist assumes that the molar masses given in reliable sources are accurate.

(e) **Observations and Calculations**

Mass of one paper clip	0.41 g
Mass of paper clips in cup (g)	33.0 g

$N_{\text{paper clips in cup}} = 33.0 \ \cancel{g} \times \dfrac{1 \text{ paper clip}}{0.41 \ \cancel{g}}$

$N_{\text{paper clips in cup}} = 80 \text{ paper clips}$

According to the calculation, there should be 80 paper clips in the cup.

   The procedure outlined in steps 1 to 5 seems to be better than the procedure outlined in step (e) because the number of paper clips calculated in step 5 (81) equals the counted number of paper clips (81). The number of paper clips calculated in step (e) (80) does not equal the number counted (81). The procedure outlined in steps 1 to 5 is more like the work of a chemist because a chemist uses the mass (in grams) of one mole of entities (6.02×10^{23} entities) (the molar mass) when calculating the number of entities in a given sample.

SECTION 2.1 QUESTIONS

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Understanding Concepts

1. (a) The coefficients of nitrogen, hydrogen, and ammonia are 1, 3, and 2, respectively.
   (b) One molecule of nitrogen is used to produce two molecules of ammonia.
   (c) One dozen molecules of nitrogen is used to produce two dozen molecules of ammonia.
   (d) One mole of nitrogen is used to produce two moles of ammonia

2. (a) Nucleons are protons and neutrons. They are found in the nucleus of an atom.
   (b) The mass of an electron is approximately $\dfrac{1}{2000}$ of the mass of a proton or a neutron and is therefore usually ignored when determining the mass of an atom.
   (c) An atom of carbon is approximately 12 times heavier than an atom of hydrogen because hydrogen contains one nucleon (a proton), and carbon contains 12 nucleons (6 protons and 6 neutrons).

3. Student answers will vary. A sample of magnesium taken from nature contains 79% magnesium-24 by mass. The rest of the sample is composed of other isotopes of magnesium.

4. The symbol for Avogadro's constant is N_A. Its value is 6.02×10^{23}.

5. Student answers will vary. A mole is 6.02×10^{23} entities.

6. Atomic mass is the mass of one atom of an element, measured in atomic mass units. Molar mass is the mass, in grams, of one mole (6.02×10^{23}) of an element's atoms. The atomic mass and molar mass of an element have the same numerical value but different units (u for atomic mass; g/mol for molar mass).

7. (a) The term "diatomic" means "composed of two atoms."
   (b) hydrogen, nitrogen, oxygen, fluorine, chlorine, bromine, iodine, astatine
   (c) There are 6.02×10^{23} molecules in one mole of a diatomic molecule.
   (d) There are 1.2×10^{24} atoms in one mole of a diatomic molecule.

8. $m_{\text{dimes}} = 7.800 \ \cancel{kg} \times \dfrac{1000 \text{ g}}{1 \ \cancel{kg}} = 7.8 \times 10^3 \text{ g}$ (key value)

   7 dimes = 12.30 g dimes (conversion factor equation)

$$N_{\text{dimes}} = 7.800 \times 10^3 \, \cancel{g} \times \frac{7 \text{ dimes}}{12.30 \, \cancel{g}}$$

$$N_{\text{dimes}} = 4439 \text{ dimes}$$

There are 4439 dimes in a bag that contains 7.800 kg of dimes.

9. $m_{\text{HBr}} = 38.40$ g HBr (key value)

2 mol HBr = 159.8 g HBr (conversion factor equation)

$$n_{\text{HBr}} = 38.40 \, \cancel{g \, HBr} \times \frac{2 \text{ mol HBr}}{159.8 \, \cancel{g \, HBr}}$$

$$n_{\text{HBr}} = 4.81 \times 10^{-1} \text{mol HBr}$$

There are 4.81×10^{-1} mol of hydrogen bromide molecules in the cylinder.

10. (a) Molar mass is the mass in grams per mole of one mole (6.02×10^{23}) of chemical entities. The symbol for molar mass is M and its SI unit is g/mol.
    (b) $M_C = 12.01$ g/mol
    (c) The mass of 6.02×10^{23} atoms of zinc is 65.38 g. This value is equal to the molar mass of zinc (65.38 g/mol).
    (d) The element could be gold.

Applied Inquiry Skills

11. (a) 1. Measure the total mass of the coin mixture (in grams).
       2. Separate one penny, one nickel, one dime, and one quarter from the mixture.
       3. Measure the mass of one penny, one nickel, one dime, and one quarter together (in grams).
       4. To estimate the number of coins in the mixture, divide the mass of the mixture measured in step 1 by the mass of the four coins measured in step 3, and multiply the answer by 4.
    (b) To estimate the number of dimes, divide the answer in part 4 by 4.

Making Connections

12. (a) Chemists measure and mix chemicals to produce products with properties that differ from the properties of the reactants. Similarly, chefs measure and mix food ingredients to produce food products with properties that differ from the properties of the ingredients. Chemists balance the reactants and products in a chemical equation. Similarly, accountants prepare balance sheets to balance the income and expenditures of a person or a business.
    (b) Chemists work with entities and cannot see the particles. Chefs work with ingredients they can see and even count individually. Chemists balance reactants and products in a chemical equation to determine the quantities of reactants needed and the products formed in a chemical reaction. The balance between reactants and products is always equal. Accountants balance the income and expenditures for clients to determine if a profit or loss has occurred. The relationship between the income and expenditures do not always balance (i.e., one can be greater or less than the other).
13. (a) Student answers will vary. The scanning tunnelling microscope (STM) is able to display the protrusions and depressions caused by atoms on the surface of substances like metals. The shapes of atoms are detected by changes in electric current that occur when the fine tip of a piezoelectric tube moves over the material being observed.
    (b) The STM will most likely not replace our need to calculate quantities in chemistry because atoms and molecules are so small that we will always have to deal with huge numbers of a chemical entity than to count individual entities.

2.2 CALCULATIONS INVOLVING THE MOLE

PRACTICE

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Understanding Concepts

1. $n_{\text{Al}} = 1.60$ mol Al

   $M_{\text{Al}} = 26.98$ mol/Al

   1 mol Al = 26.98 g Al