

7. Determine the percent error of Dulong and Petit's method of approximating a metal's atomic mass for aluminum ($0.903 \text{ J/g}^\circ\text{C}$), magnesium ($1.05 \text{ J/g}^\circ\text{C}$) and silver ($0.23772 \text{ J/g}^\circ\text{C}$).

8. In 1811 Amedeo Avogadro proposed that equal volumes of any gas at the same temperature and pressure contain *the same number of particles*. Cannizzaro realized this allows scientists to weigh equal numbers of atoms of different gaseous elements and determine their relative atomic masses. Complete the following data table showing the mass of equal volumes of two different gases at the same temperature and pressure.

Element	Mass of Gas (g)	Relative Atomic Mass (u)
H	0.210	1.0
	7.455	

9. Potassium has an atomic mass of 39.1 u. What does this mean?

10. Look up the following elements in the periodic table and report each element's atomic mass.

(a) P _____

(b) Ca _____

(c) U _____

11. Eight identical forks have a mass of 213.1 g. Eight identical knives have a mass of 628.2 g.

(a) What is the mass of a knife relative to that of a fork?

(b) Why did you not need to divide the supplied masses by 8 to answer 10(a)?

(c) What could you conclude from this data if the utensils of each type were not identical?

12. A mint is advertising a special set of silver coins containing a 10 g coin, a 20 g coin and a 30 g coin. One of these coins is accidentally being made 1 g lighter than its advertised mass. You have two sets of these coins and have been challenged to identify the undersized coin by weighing only one pile of coins. The single pile may include any combination of the coins that you wish. What combination of the coins would you weigh? How can you use that mass to identify the undersized coin?

3.2 Review Questions

- (a) What is the definition of a mole?

(b) What is our best estimate of the number of things in a mole?

(c) What do chemists call this number?
- (a) What mass of carbon would have the same number of atoms as 1.0 g H?

(b) What mass of carbon would have the same number of atoms as 3.0 g H?

(c) What mass of sulphur would have the same number of atoms as 32.0 g O?
- (a) What does a mole of iron weigh?

(b) Chemists call this value the _____ of iron.
- (a) What is the molecular mass of propane, C_3H_8 ?

(b) What is the formula mass of calcium hydroxide, $Ca(OH)_2$?

(c) What is the molar mass of carbon tetrachloride, CCl_4 ?
- 3.2 mol C = _____ atoms C
- How many molecules are in 0.0085 mol of C_2H_6 ?
- 1.4×10^{18} Ag atoms represent how many moles of atoms?
- 2.99 g Na = _____ mol Na
- What is the mass of 5.2 mol of fluorine?
- Airline regulations prohibit lithium metal batteries that contain over 2.0 g of lithium on passenger aircraft. How many moles of lithium are in 2.0 g Li?
- What is the mass of 0.32 mol of sodium nitrite?
- A can of cola contains 58 mg of caffeine, $C_8H_{10}N_4O_2$. How many moles of caffeine are in a can of cola?

13. Carbon dioxide, produced by respiration in plants and animals, causes the slightly acidic nature of normal rain. How many molecules of CO_2 are in 0.725 mol CO_2 ?
14. The male luna moth can detect specialized chemicals known as pheromones in order to locate a mate. A moth can detect 1.70×10^9 molecules of the pheromone. How many moles of the pheromone is this?
15. Cycling enthusiasts often prefer bicycles made with titanium frames. Titanium is resistant to corrosion and fatigue, has a significantly lower density than steel, and seems to have a natural shock absorbing ability. Suppose a high-quality titanium frame contains 1300 g of titanium. How many moles of titanium does this frame contain?
16. Bluestone is an attractive mineral with the chemical name copper(II) sulphate pentahydrate. What is the mass of a 1.75-mol sample of bluestone?
17. An environmental assessment predicts that a coal plant would emit 8.18×10^6 mol of ammonia into the atmosphere annually. How many tonnes of ammonia is this?
18. Ammonium phosphate is a fertilizer containing nitrogen and phosphorus for healthy plant growth. How many moles of ammonium phosphate are in a bag containing 2.640 kg of it?
19. The movie *Erin Brockovich* dramatizes the efforts of the title character (played by Julia Roberts) to prove that the Pacific Gas and Electric Co. contaminated the water supply of Hinkley, California, with hexavalent chromium. Tin(II) dichromate is a hexavalent chromium compound. What is the mass of 5.925 mol of tin(II) dichromate?

3.3 Review Questions

- Acticoat dressings, developed in 1995 by Robert Burrell of the University of Alberta, are impregnated with crystals of silver that are only 15 nm (nanometres) in size. These nanocrystals are remarkably more effective at healing burns and other severe wounds than any treatment previously available. Acticoat bandages are credited with saving the lives and limbs of dozens of victims of the World Trade Center attack in New York City in 2001. What is the mass of a crystal containing 1.0×10^3 silver atoms?
- Diamond is one way of arranging carbon atoms. The "Star of Africa" diamond, displayed with the crown jewels in the Tower of London, weighs 106.0 g and has an estimated value of over \$400 million. How many carbon atoms compose the "Star of Africa" diamond?
- What is the mass in grams of a chlorine atom?
- How many propane molecules are in 72.6 g propane, C_3H_8 ?
- On a particular day, 31.1 g (1 troy ounce) of gold cost \$1300.
 - 31 g Au = _____ atoms of Au
 - How many atoms of gold could you buy for 1 cent on that day?
- Complete the following "axle" conversion factors by filling in the appropriate numbers:
 - $\frac{\text{_____ mol O}}{\text{_____ mol N}_2\text{O}_4}$
 - $\frac{\text{_____ mol NO}_2}{\text{_____ mol N}}$
- $2.3 \text{ mol CO}_2 = \text{_____ mol O}$
- Calcium oxalate is a poisonous compound found in rhubarb leaves. How many moles of carbon are in 52.4 mg of calcium oxalate?
- Sodium phosphate is sold as a cleaner at most hardware stores. How many moles of sodium ions are there in 6.80×10^{24} formula units of Na_3PO_4 ?
- Sulphuric acid is used to produce a tremendous number and variety of materials including fertilizers, pigments, textiles, plastics, and explosives. What mass of sulphuric acid, H_2SO_4 , contains 1.4 mol O?

11. How many carbon atoms are in 0.85 mol of the "pain-killer" acetaminophen, $C_8H_9NO_2$?
12. How many mercury(II) ions are in 100.0 g $HgCl_2$?
13. How many grams of chloride ions are in 8.3 g of copper(II) chloride?
14. What mass of carbon is present in 4.8×10^{26} molecules of ethanol, C_2H_5OH ?
15. Hydrogen fluoride, HF, can be used to etch glass. The white lines on the glassware in your lab may have been made by this acidic gas. Determine the mass in kilograms of 3.9×10^{27} molecules of HF.
16. Up to 1.44×10^5 kg of various oxides of nitrogen are emitted by a gas-burning electrical plant in one year. Assuming this entire mass to be nitrogen dioxide, how many oxygen atoms would be present in this gas sample?
17. How many molecules are in 1.000 mg of the organic solvent, carbon tetrachloride?
18. Glycerol, $C_3H_5(OH)_3$, is a viscous, colourless liquid found in cough syrup, toothpaste, soaps, and many other household products. Calculate the number of hydrogen atoms in 4.5 mol of glycerol.
19. How many atoms are in 14.56 g of sodium hydrogen sulphate, the active ingredient in some toilet cleaners?

3.4 Review Questions

- Liquid octane, C_8H_{18} , has a molar volume of 82.4 mL/mol. What is the volume of 250 millimoles of C_8H_{18} ?
- How many moles of air are there in a human lung with a volume of 2.4 L at STP?
- 2.75 L N_2 at STP = _____ mol N_2
- Air is approximately 21% oxygen. How many moles of oxygen are in 5.0 L of air at STP?
- Diphosphorus pentoxide is a gas produced each time you strike a match. What is the mass of 2.57 L of this gas at STP?
- A 525 mL flask contains 0.935 g of a noble gas at STP. Identify the gas from its molar mass.
- Acetylene gas, C_2H_2 , is used as a fuel in welding torches. How many acetylene molecules are in a cylinder that delivers 1400 L of acetylene at STP?
- 5×10^{19} molecules PH_3 = _____ mL PH_3 at STP
- Propane gas, $C_3H_8(g)$, is easily compressible to a storable liquid. A standard barbecue tank holds 9.1 kg of propane. How many litres of gas will the tank release at STP?
- Soft drinks are bottled under pressure forcing CO_2 into solution. The industry expresses the amount of carbonation in volumes of CO_2 at STP per volume of solution. The carbonation of a typical soft drink is 3.7 v/v meaning that a 355 mL can contains 3.7×355 mL CO_2 at STP. What is the mass of CO_2 in a 355 mL can?
- How many moles of hydrogen are in 83.9 L of ammonia gas, NH_3 , at STP?

12. Nitrous oxide, N_2O , is commonly called "laughing gas." It is sometimes used by dentists as a partial anaesthetic. How many grams of nitrogen are in 3.84 L of N_2O at STP?
13. Dinitrogen tetroxide is one of the most important rocket propellants ever developed. How many oxygen atoms are in 27.2 L of the gas at STP?
14. Disposable lighters often contain butane, C_4H_{10} (density = 0.601 g/mL). How many grams of butane are there in a lighter containing 15 mL of the fuel?
15. Mercury is a liquid metal with a density of 13.546 g/mL at 20°C. What is the molar volume of mercury at 20°C?
16. Gold has a density of 19.42 g/cm³. How many moles of gold are there in a 5.0 cm³ strip?
17. Liquid bromine, Br_2 , has a density of 3.53 g/mL. How many bromine molecules are in 15.0 mL of bromine?

3.5 Review Questions

- Menthol is a strong-smelling compound that is used in cough drops. It has a formula of $C_{10}H_{20}O$. Calculate its percentage composition.
- Sodium acetate trihydrate ($NaCH_3COO \cdot 3H_2O$) is a salt commonly used in pickling foods. Calculate the percentage of water by mass in this compound.
- Trinitrotoluene ($C_7H_5O_6N_3$) is an explosive commonly referred to as TNT. Calculate the percentage of nitrogen by mass in this compound.
- Complete the following table.
- Explain why the empirical formula alone is not enough to identify a compound.
 - What other piece of information will allow you to determine its molecular formula?
- A pigment on a suspected forgery is analyzed using X-ray fluorescence and found to contain 0.5068 mol Ba, 0.5075 mol C, and 1.520 mol O. Determine its empirical formula.
- A sample of caffeine is analyzed and found to contain 1.4844 g C, 0.1545 g H, 0.4947 g O and 0.8661 g N. Determine the empirical formula of caffeine.

Structural Formula	Molecular Formula	Empirical Formula
<pre> H H H H H - C - C - C - C - H H H H H </pre>		
<pre> O H H H H - O - C - C - C - H H H H </pre>		

8. (a) In a TV series, a forensic anthropologist uses X-ray fluorescence to analyze a dental filling found in skeletal remains. The results of the analysis are provided as *atomic* percentages: 2.85% Al, 87.4% Si, and 9.75% Yb. Convert these results into mass percentages.
- (b) These results identified the filling as a commercial restorative material called Heliomolar. How might identifying the material be useful in helping to identify the remains?
9. A compound has an empirical formula of NH_2 and a molar mass of 32.1 g/mol. What is the compound's molecular formula?
10. A sample of ascorbic acid, also known as vitamin C, was analyzed and found to contain 1.080 g C, 0.121 g H, and 1.439 g O. Ascorbic acid has a molar mass of 176.1 g/mol. Determine the molecular formula of ascorbic acid.
11. A hydrocarbon is a compound containing only carbon and hydrogen. One particular hydrocarbon is 92.29% carbon by mass. If the compound's molar mass is 78.0 g/mol then what is its molecular formula?
12. Cannizzaro determined that a certain compound of carbon and oxygen had a molecular mass of 44.0 u. This meant that a certain volume of this gaseous compound weighed 44.0 times as much as the same volume of hydrogen gas at the same temperature and pressure. This compound was analyzed and found to be 27.3% carbon by mass.
- (a) What is the total mass of carbon in a molecule of this compound?
- (b) Cannizzaro repeated this experiment on many carbon compounds. Because he never found a molecule with less carbon than this one, Cannizzaro assumed that this molecule had only one carbon atom. Was this assumption correct?

3.6 Review Questions

1. What does 1.5 M HCl mean?
2. A cough syrup contains 0.011 M dextromethorphan. How many moles of the cough suppressant are in one teaspoon (5.0 mL) of the cough syrup?
3. $75.0 \text{ mmol Ca}^{2+} = \text{_____ L of } 0.20 \text{ M Ca}^{2+}$
4. The fluid inside living cells is called cytosol. A human hepatocyte (a type of liver cell) with a volume of 500 fL (1 fL (femtolitre) = 10^{-15} L) contains 12 mM Na^+ . How many sodium ions are in the cytosol of this cell?
5. Consumer products express concentrations in mg/volume or g/volume because the general public isn't familiar with molarity.
 - (a) A medium-sized (296 mL) cup of Tim Horton's coffee contains 0.10 g caffeine, $\text{C}_8\text{H}_{10}\text{N}_4\text{O}_2$. Express this concentration in molarity.
 - (b) A 355 mL can of pop contains 42.6 g sugar, $\text{C}_6\text{H}_{12}\text{O}_6$. What is the sugar's molar concentration?
6. Humans have an average blood volume of 5.0 L with an average blood sugar ($\text{C}_6\text{H}_{12}\text{O}_6$) concentration of 4.0 mM. What is the average mass of glucose coursing through the human bloodstream?
7. Describe how to prepare 250 mL of 0.50 M sodium nitrate. Be sure to answer in a complete sentence.
8. As a glass of cold tap water warms up, small air bubbles will come out of solution on the inner wall of the glass. A glass of cold water contains 0.45 mM O_2 . How many millilitres of oxygen gas at STP are dissolved in 300.0 mL of this water?
9. What concentrations of ions are present in:
 - (a) 0.35 M $\text{Fe}_2(\text{Cr}_2\text{O}_7)_3$?
 - (b) 1.6 mol/L strontium cyanide?

10. In reflected light, iron(III) chloride crystals appear dark green but in transmitted light they appear maroon. What concentration of iron(III) chloride contains 0.038 M Cl^- ?

11. In a solution of $\text{Fe}_2(\text{SO}_4)_3$:

(a) if the $[\text{Fe}^{3+}] = 1.5 \text{ M}$ then what is the $[\text{SO}_4^{2-}]$?

(b) if the $[\text{SO}_4^{2-}] = 3.0 \text{ M}$ then what is the $[\text{Fe}^{3+}]$?

12. Write the relationship between the concentrations of the ions in a solution of:

(a) zinc chromate

(b) strontium hydroxide

13. Milk has a $[\text{Ca}^{2+}]$ of about 31.4 mM. What mass of Ca^{2+} ions are in a 250 mL serving of milk?

14. How many Na^+ ions are dissolved in 1.5 L of 3.0 M Na_2CO_3 ?

15. It takes 145 drops from a pipette to reach the 5.0 mL mark on a graduated cylinder. How many grams of bromide ions are in one such drop of 0.10 M iron(III) bromide?

16. Phosphoric acid, H_3PO_4 , is added to soft drinks to increase their tartness and to act as a preservative. The concentration of H_3PO_4 in Pepsi is proprietary (a company secret) but can be determined from its phosphorus content since H_3PO_4 is the only source of phosphorus in the beverage. There are 49 mg of phosphorus in a 355 mL can of Pepsi. What is the $[\text{H}_3\text{PO}_4]$ in Pepsi?

17. Draw the plot representing a 1.5 M NaCl solution on the graph provided.

Amount of NaCl vs. Volume of Solution

