***Chemistry***

**3: Composition of Substances and Solutions**

**3.1: Formula Mass and the Mole Concept**

1. What is the total mass (amu) of carbon in each of the following molecules?

(a) CH4

(b) CHCl3

(c) C12H10O6

(d) CH3CH2CH2CH2CH3

Solution

(a) 1 × 12.01 amu = 12.01 amu; (b) 1 × 12.01 amu = 12.01 amu; (c) 12 × 12.01 amu = 144.12 amu; (d) 5 × 12.01 amu = 60.05 amu

3. Calculate the molecular or formula mass of each of the following:

(a) P4

(b) H2O

(c) Ca(NO3)2

(d) CH3CO2H (acetic acid)

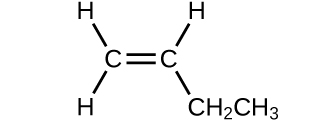
(e) C12H22O11 (sucrose, cane sugar).

Solution

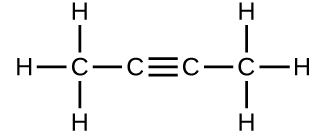
(a) 4 × 30.974 amu = 123.896 amu; (b) 2 × 1.008 amu + 15.999 amu = 18.015 amu; (c) 40.078 amu + 2 × 14.007 amu + 6 × 15.999 amu = 164.086 amu; (d) 2 × 12.011 amu + 4 × 1.008 amu + 2 × 15.999 amu = 60.052 amu; (e) 12 × 12.011 amu + 22 × 1.008 amu × 11 × 15.999 amu = 342.297 amu

5. Determine the molecular mass of the following compounds:

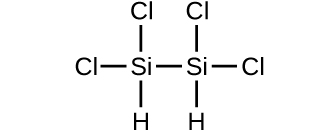
(a)



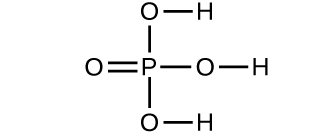
(b)



(c)



(d)



Solution

(a) C4H8

;

(b) C4H6

;

(c) H2Si2Cl4

;

(d) H3PO4



7. Write a sentence that describes how to determine the number of moles of a compound in a known mass of the compound if we know its molecular formula.

Solution

Use the molecular formula to find the molar mass; to obtain the number of moles, divide the mass of compound by the molar mass of the compound expressed in grams.

9. Which contains the greatest mass of oxygen: 0.75 mol of ethanol (C2H5OH), 0.60 mol of formic acid (HCO2H), or 1.0 mol of water (H2O)? Explain why.

Solution

Formic acid. Its formula has twice as many oxygen atoms as the other two compounds (one each). Therefore, 0.60 mol of formic acid would be equivalent to 1.20 mol of a compound containing a single oxygen atom.

11. How are the molecular mass and the molar mass of a compound similar and how are they different?

Solution

The two masses have the same numerical value, but the units are different: The molecular mass is the mass of 1 molecule while the molar mass is the mass of 6.022 × 1023 molecules.

13. Calculate the molar mass of each of the following:

(a) S8

(b) C5H12

(c) Sc2(SO4)3

(d) CH3COCH3 (acetone)

(e) C6H12O6 (glucose)

Solution

(a) S8

8S = 8 × 32.066 = 256.528 g/mol;

(b) C5H12

;

(c) Sc2(SO4)3

;

(d) CH3COCH3

;

(e) C6H12O6



15. Calculate the molar mass of each of the following:

(a) the anesthetic halothane, C2HBrClF3

(b) the herbicide paraquat, C12H14N2Cl2

(c) caffeine, C8H10N4O2

(d) urea, CO(NH2)2

(e) a typical soap, C17H35CO2Na

Solution

(a) C2HBrClF3

;

(b) C12H14N2Cl2

;

(c) C8H10N4O2

;

(d) CO(NH2)2

;

(e) C17H35CO2Na



17. Determine the mass of each of the following:

(a) 0.0146 mol KOH

(b) 10.2 mol ethane, C2H6

(c) 1.6 × 10–3 mol Na2SO4

(d) 6.854 × 103 mol glucose, C6H12O6

(e) 2.86 mol Co(NH3)6Cl3

Solution

(a) KOH:



Mass = 0.0146 mol × 56.1056 g/mol = 0.819 g;

(b) C2H6



Mass = 10.2 mol × 30.070 g/mol = 307 g;

(c) Na2SO4:



Mass = 1.6 × 10–3 mol × 142.044 g/mol = 0.23 g;

(d) C6H12O6



Mass = 6.854  103 mol × 180.158 g/mol = 1.235 × 106 g (1235 kg);

(e) Co(NH3)6Cl3



Mass = 2.86 mol × 267.5344 g/mol = 765 g

19. Determine the mass of each of the following:

(a) 2.345 mol LiCl

(b) 0.0872 mol acetylene, C2H2

(c) 3.3 × 10–2 mol Na2CO3

(d) 1.23 × 103 mol fructose, C6H12O6

(e) 0.5758 mol FeSO4(H2O)7

Solution

(a) ;

(b) ;

(c) ;

(d) ;

(e) 

21. Determine the mass in grams of each of the following:

(a) 0.600 mol of oxygen atoms

(b) 0.600 mol of oxygen molecules, O2

(c) 0.600 mol of ozone molecules, O3

Solution

(a) 0.600 ~~mol~~ × 15.9994 g/~~mol~~ = 9.60 g; (b) 0.600 ~~mol~~ × 2 × 15.994 g/~~mol~~ = 19.2 g; (c) 0.600 ~~mol~~ × 3 × 15.994 g/~~mol~~ = 28.8 g

23. Determine the number of atoms and the mass of zirconium, silicon, and oxygen found in 0.3384 mol of zircon, ZrSiO4, a semiprecious stone.

Solution

Determine the number of moles of each component. From the moles, calculate the number of atoms and the mass of the elements involved. Zirconium: 0.3384 ~~mol~~ × 6.022 × 1023 ~~mol~~~~–1~~ = 2.038 × 1023 atoms; 0.3384 ~~mol~~ × 91.224 g/~~mol~~ = 30.87 g; Silicon: 0.3384 ~~mol~~ × 6.022 × 1023 ~~mol~~~~–1~~ = 2.038 × 1023 atoms; 0.3384 ~~mol~~ × 28.0855 g/~~mol~~ = 9.504 g; Oxygen: 4 × 0.3384 ~~mol~~ × 6.022 × 1023 ~~mol~~~~–1~~ = 8.151 × 1023 atoms; 4 × 0.3384 ~~mol~~ × 15.9994 g/~~mol~~ = 21.66 g

25. Determine which of the following contains the greatest mass of aluminum: 122 g of AlPO4, 266 g of A12C16, or 225 g of A12S3.

Solution

Determine the molar mass and, from the grams present, the moles of each substance. The compound with the greatest number of moles of Al has the greatest mass of Al.

Molar mass AlPO4: 26.981539 + 30.973762 + 4(15.9994) = 121.9529 g/mol

Molar mass Al2Cl6: 2(26.981539) + 6(35.4527) = 266.6793 g/mol

Molar mass Al2S3: 2(26.981539) + 3(32.066) = 150.161 g/mol

AlPO4: 

mol Al = 1 × 1.000 mol = 1.000 mol, or 26.98 g Al

Al2Cl6: 

mol Al = 2 × 0.997 mol = 1.994 mol, or 53.74 g Al

Al2S3: 

mol Al = 2 × 1.50 mol = 3.00 mol, or 80.94 g Al

The Al2S3 sample thus contains the greatest mass of Al.

27. The Cullinan diamond was the largest natural diamond ever found (January 25, 1905). It weighed 3104 carats (1 carat = 200 mg). How many carbon atoms were present in the stone?

Solution

Determine the number of grams present in the diamond and from that the number of moles. Find the number of carbon atoms by multiplying Avogadro’s number by the number of moles:



29. A certain nut crunch cereal contains 11.0 grams of sugar (sucrose, C12H22O11) per serving size of 60.0 grams. How many servings of this cereal must be eaten to consume 0.0278 moles of sugar?

Solution

Determine the molar mass of sugar. 12(12.011) + 22(1.00794) + 11(15.9994) = 342.300 g/mol; Then 0.0278 mol × 342.300 g/mol = 9.52 g sugar. This 9.52 g of sugar represents  of one serving or 

This amount is = 0.865 servings, or about 1 serving.

31. Which of the following represents the least number of molecules?

(a) 20.0 g of H2O (18.02 g/mol)

(b) 77.0 g of CH4 (16.06 g/mol)

(c) 68.0 g of CaH2 (42.09 g/mol)

(d) 100.0 g of N2O (44.02 g/mol)

(e) 84.0 g of HF (20.01 g/mol)

Solution

Calculate the number of moles of each species, then remember that 1 mole of anything = 6.022 × 1023 species. (a) 20.0 g = 1.11 mol H2O; (b) 77.0 g CH4 = 4.79 mol CH4; (c) 68.0 g CaH2 = 1.62 mol CaH2; (d) 100.0 g N2O = 2.27 mol N2O; (e) 84.0 g HF = 4.20 mol HF. Therefore, 20.0 g H2O represents the least number of molecules since it has the least number of moles.

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