# Chapter 12

## Answers to Questions

1. (a) nitrogen dioxide (b) hydrogen sulfide (c) hydrogen chloride

2. (a) hydrogen cyanide (b) dinitrogen oxide (c) ammonia

3. X = sulfur, Y = oxygen, Z = sulfur dioxide

4. X = carbon monoxide, Y = oxygen, Z = carbon dioxide

5.

| Strategy | Relationship |
|---|---|
| Press/mol/temp of gas → vol gas | V = nRT/P |

$$V = \frac{nRT}{P} = \frac{(1.00\ \text{mol})(8.31\ \text{kPa} \cdot \text{L} \cdot \text{mol}^{-1} \cdot \text{K}^{-1})(743\ \text{K})}{(9.3\ \times 10^3\ \text{kPa})} = 0.66\ \text{L}$$

6.

| Strategy | Relationship |
|---|---|
| Press/mol/temp of gas → vol gas | V = nRT/P |

$$V = \frac{nRT}{P} = \frac{(1.00\ \text{mol})(8.31\ \text{kPa} \cdot \text{L} \cdot \text{mol}^{-1} \cdot \text{K}^{-1})(263\ \text{K})}{(0.60\ \text{kPa})} = 3.6\ \times 10^3\ \text{L}$$

7.

| Strategy | Relationship |
|---|---|
| Press/vol/temp of $O_2$ → mol $O_2$ | n = PV/RT |
| Mol $O_2$ → mass $O_2$ | 1 mol $O_2$ ≡ 32.0 g |

$$n = \frac{PV}{RT} = \frac{(100\ \text{kPa})(25.0\ \text{L})}{(8.31\ \text{kPa} \cdot \text{L} \cdot \text{mol}^{-1} \cdot \text{K}^{-1})(298\ \text{K})} = 1.01\ \text{mol}$$

$$\text{Mass } O_2 = 1.01 \text{ mol } O_2 \times \left(\frac{32.0 \text{ g}}{1 \text{ mol}}\right) = 32.3 \text{ g } O_2$$

8.

| Strategy | Relationship |
| --- | --- |
| Mass $CO_2 \rightarrow$ mol $CO_2$ | 1 mol $CO_2 \equiv$ 44.0 g |
| Mol/press/temp $CO_2 \rightarrow$ vol $CO_2$ | V = nRT/P |

$$\text{Mol } CO_2 = 30.0 \text{ g } CO_2 \times \left(\frac{1 \text{ mol}}{44.0 \text{ g}}\right) = 0.682 \text{ mol } CO_2$$

$$V = \frac{nRT}{P} = \frac{(0.682 \text{ mol})(8.31 \text{ kPa} \cdot \text{L} \cdot \text{mol}^{-1} \cdot \text{K}^{-1})(298 \text{ K})}{(100 \text{ kPa})} = 16.9 \text{ L}$$

9.

| Strategy | Relationship |
| --- | --- |
| Press/vol/temp of $C_2H_2 \rightarrow$ mol $C_2H_2$ | n = PV/RT |
| Mol $C_2H_2 \rightarrow$ mass $C_2H_2$ | 1 mol $C_2H_2 \equiv$ 26.0 g |

$$n = \frac{PV}{RT} = \frac{(1.72 \times 10^3 \text{ kPa})(87.0 \text{ L})}{(8.31 \text{ kPa} \cdot \text{L} \cdot \text{mol}^{-1} \cdot \text{K}^{-1})(301 \text{ K})} = 59.8 \text{ mol}$$

$$\text{Mass } C_2H_2 = 59.8 \text{ mol } C_2H_2 \times \left(\frac{26.0 \text{ g}}{1 \text{ mol}}\right) = 1.56 \times 10^3 \text{ g } C_2H_2 = 1.56 \text{ kg } C_2H_2$$

10.

| Strategy | Relationship |
| --- | --- |
| Press/vol/temp of He $\rightarrow$ mol He | n = PV/RT |
| Mol He $\rightarrow$ mass He | 1 mol He $\equiv$ 4.00 g |

$$n = \frac{PV}{RT} = \frac{(102 \text{ kPa})(5.74 \times 10^6 \text{ L})}{(8.31 \text{ kPa} \cdot \text{L} \cdot \text{mol}^{-1} \cdot \text{K}^{-1})(290 \text{ K})} = 2.43 \times 10^5 \text{ mol}$$

$$\text{Mass He} = 2.43 \times 10^5 \text{ mol He} \times \left(\frac{4.00 \text{ g}}{1 \text{ mol}}\right) = 9.72 \times 10^5 \text{ g He}$$

$$= 0.972 \text{ tonne He}$$

11.

| Strategy | Relationship |
| --- | --- |
| Press/vol/temp of $X_2H_6$ → mol $X_2H_6$ | n = PV/RT |
| Mol/mass $X_2H_6$ → molar mass $X_2H_6$ | mm $X_2H_6$ = m/n |

$$n = \frac{PV}{RT} = \frac{(196\text{ kPa})(1.26\text{ L})}{(8.31\text{ kPa}\cdot\text{L}\cdot\text{mol}^{-1}\cdot\text{K}^{-1})(356\text{ K})} = 8.35\times10^{-2}\ \text{mol}$$

$$\text{molar mass} = \left(\frac{5.20\text{ g}}{8.35\times10^{-2}\ \text{mol}}\right) = 62.3\text{ g}\cdot\text{mol}^{-1}$$

$2 \times X = [62.3 - 6(1.01)]\ g{\cdot}mol^{-1} = 56.2\ g{\cdot}mol^{-1}$

$X = 28.1\ g{\cdot}mol^{-1}$

According to the Periodic Table, this molar mass corresponds to the element silicon

12.

| Strategy | Relationship |
| --- | --- |
| Press/vol/temp of $XH_3$ → mol $XH_3$ | n = PV/RT |
| Mol/mass $XH_3$ → molar mass $XH_3$ | mm $XH_3$ = m/n |

$$n = \frac{PV}{RT} = \frac{(115\text{ kPa})(0.775\text{ L})}{(8.31\text{ kPa}\cdot\text{L}\cdot\text{mol}^{-1}\cdot\text{K}^{-1})(312\text{ K})} = 3.44\times10^{-2}\ \text{mol}$$

$$\text{molar mass} = \left(\frac{2.68\text{ g}}{3.44\times10^{-2}\ \text{mol}}\right) = 77.9\text{ g}\cdot\text{mol}^{-1}$$

$X = [77.9 - 3(1.01)]\ g{\cdot}mol^{-1} = 74.9\ g{\cdot}mol^{-1}$

According to the Periodic Table, this molar mass corresponds to the element arsenic

13.

| Strategy | Relationship |
| --- | --- |
| Press/mol/temp of gas → vol gas | V = nRT/P |
| Vol/mass of gas → density of gas | d = m/V |

$$\text{Molar V} = \frac{\text{nRT}}{\text{P}} = \frac{(1.00\ \text{mol})(8.31\ \text{kPa} \cdot \text{L} \cdot \text{mol}^{-1} \cdot \text{K}^{-1})(298\ \text{K})}{(100\ \text{kPa})} = 24.8\ \ \text{L}$$

Molar mass, $H_2$ = 2.02 g

$$\text{Density} = \left(\frac{2.02\ \text{g}}{24.8\ \text{L}}\right) = 8.15 \times 10^{-2}\ \text{g} \cdot \text{L}^{-1}$$

14.

| Strategy | Relationship |
|---|---|
| Press/mol/temp of gas → vol gas | V = nRT/P |
| Vol/mass of gas → density of gas | d = m/V |

$$\text{Molar V} = \frac{\text{nRT}}{\text{P}} = \frac{(1.00\ \text{mol})(8.31\ \text{kPa} \cdot \text{L} \cdot \text{mol}^{-1} \cdot \text{K}^{-1})(298\ \text{K})}{(100\ \text{kPa})} = 24.8\ \ \text{L}$$

Molar mass, $UF_6$ = 352.0 g

$$\text{Density} = \left(\frac{352.0\ \text{g}}{24.8\ \text{L}}\right) = 14.2\ \text{g} \cdot \text{L}^{-1}$$

15. Part 1: Find Empirical Formula

Assume 100.0 g of compound. This will contain 92.3 g of carbon and 7.7 g of hydrogen.

$$\text{Mol of C} = 92.3\ \text{g C} \times \left(\frac{1\ \text{mol}}{12.0\ \text{g}}\right) = 7.69\ \text{mol C}$$

$$\text{Mol of H} = 7.7\ \text{g H} \times \left(\frac{1\ \text{mol}}{1.01\ \text{g}}\right) = 7.7\ \text{mol H}$$

$$\text{Ratio} = \frac{7.69\ \text{mol C}}{7.69\ \text{mol}} : \frac{7.7\ \text{mol H}}{7.69\ \text{mol}} = 1\ \text{C} : 1.0\ \text{H}$$

Rounding to the nearest whole number of 1:1, gives the empirical formula of CH.

Part 2: Find molar mass of Compound

| Strategy | Relationship |
|---|---|

Press/vol/temp → mol n = PV/RT
Mol/mass → molar mass mm = m/n

$$n = \frac{PV}{RT} = \frac{(101\ \text{kPa})(0.226\ \text{L})}{(8.31\ \text{kPa} \cdot \text{L} \cdot \text{mol}^{-1} \cdot \text{K}^{-1})(373\ \text{K})} = 7.36 \times 10^{-3}\ \text{mol}$$

$$\text{molar mass} = \left(\frac{0.573\ \text{g}}{7.36 \times 10^{-3}\ \text{mol}}\right) = 77.8\ \text{g} \cdot \text{mol}^{-1}$$

Part 3: Find Molar Mass and Molecular Formula

The molecular formula will be some multiple of the empirical formula: $(CH)_n$. To find *n*, the ratio of the molar mass (77.8 g) and the empirical formula mass (1 × 12.0 g + 1 × 1.01 g = 13.0 g) is found. The value *n* is always an integer.

$$\text{Mass ratio}, n = \frac{77.8\ \text{g}}{13.0\ \text{g}} = 6$$

The molecular formula is $(CH)_6$ or more correctly, $C_6H_6$

16. Part 1: Find Empirical Formula

Assume 100.0 g of compound. This will contain 64.56 g of carbon, 10.86 g of hydrogen, and 24.58 g of oxygen.

$$\text{Mol of C} = 64.56\ \text{g C} \times \left(\frac{1\ \text{mol}}{12.01\ \text{g}}\right) = 5.376\ \text{mol C}$$

$$\text{Mol of H} = 10.86\ \text{g H} \times \left(\frac{1\ \text{mol}}{1.008\ \text{g}}\right) = 10.77\ \text{mol H}$$

$$\text{Mol of O} = 24.58\ \text{g H} \times \left(\frac{1\ \text{mol}}{16.00\ \text{g}}\right) = 1.536\ \text{mol O}$$

$$\text{Ratio} = \frac{5.376 \text{ mol C}}{1.536 \text{ mol}} : \frac{10.86 \text{ mol H}}{1.536 \text{ mol}} : \frac{1.536 \text{ mol O}}{1.536 \text{ mol}} = 3.500 \text{ C} : 7.070 \text{ H} : 1 \text{ O}$$

Rounding off, it is: 3.5 C : 7 H : 1 O

Multiplying through by 2 gives: 7 C : 14 H : 2 O

giving the empirical formula of $C_7H_{14}O_2$.

Part 2: Find molar mass of Compound

| Strategy | Relationship |
|---|---|
| Press/vol/temp → mol | n = PV/RT |
| Mol/mass → molar mass | mm = m/n |

$$n = \frac{PV}{RT} = \frac{(156.5 \text{ kPa})(1.880 \text{ L})}{(8.314 \text{ kPa} \cdot \text{L} \cdot \text{mol}^{-1} \cdot \text{K}^{-1})(448.1 \text{ K})} = 7.897 \times 10^{-2} \text{ mol}$$

$$\text{molar mass} = \left(\frac{10.29 \text{ g}}{7.897 \times 10^{-2} \text{ mol}}\right) = 130.3 \text{ g} \cdot \text{mol}^{-1}$$

Part 3: Find Molar Mass and Molecular Formula

The molecular formula will be some multiple of the empirical formula: $(C_7H_{14}O_2)_n$. To find *n*, the ratio of the molar mass (130.3 g) and the empirical formula mass (7 × 12.01 g + 14 × 1.008 g + 2 × 16.00 = 130.2 g) is found. The value *n* is always an integer.

$$\text{Mass ratio}, n = \frac{130.3 \text{ g}}{130.2 \text{ g}} = 1$$

The molecular formula is $(C_7H_{14}O_2)_1$ or more correctly, $C_7H_{14}O_2$