

PROBLEMS and THEIR SOLUTIONS

- ① - Combustion analysis of a 12.01 g sample of tartaric acid - which contains only C, H, and O - produced 14.08 g CO₂ and 4.32 g H₂O. Determine the empirical formula for tartaric acid.

Solution : $\text{mol C} = 14.08 \text{ g CO}_2 \cdot \frac{1 \text{ mol CO}_2}{44 \text{ g CO}_2} \cdot \frac{1 \text{ mol C}}{1 \text{ mol CO}_2} = 0.32 \text{ mol C}$
 $\text{mol H} = 4.32 \text{ g H}_2\text{O} \cdot \frac{1 \text{ mol H}_2\text{O}}{18 \text{ g H}_2\text{O}} \cdot \frac{2 \text{ mol H}}{1 \text{ mol H}_2\text{O}} = 0.48 \text{ mol H}$

$$\text{g C} = 0.32 \text{ mol C} \cdot \frac{12 \text{ g C}}{1 \text{ mol C}} = 3.84 \text{ g C}$$

$$\text{g H} = 0.48 \text{ mol H} \cdot \frac{1 \text{ g H}}{1 \text{ mol H}} = 0.48 \text{ g H}$$

$$\text{mass of oxygen} = 12.01 - (3.84 + 0.48) = 7.69 \text{ g O}$$

$$\text{mol O} = 7.69 \text{ g O} \cdot \frac{1 \text{ mol O}}{16 \text{ g O}} = 0.48 \text{ mol O}$$

$$\text{C} \frac{0.32}{0.32} \text{ H} \frac{0.48}{0.32} \text{ O} \frac{0.48}{0.32} \quad \{ \text{C H}_{1.5} \text{O}_{1.5} \} \times 2 \equiv \text{C}_2 \text{H}_3 \text{O}_3$$

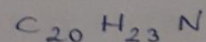
- ② - A dry active substance has the following mass composition : C 86.59%, H 8.35% and N 5.05%. Find its empirical formula.

Solution :

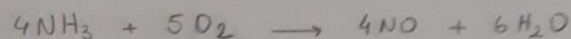
$$\text{mol C} = 86.59 \text{ g C} \cdot \frac{1 \text{ mol C}}{12.01 \text{ g C}} = 7.216 \div 0.361 = 19.99 \sim 20$$

$$\text{mol H} = 8.35 \text{ g H} \cdot \frac{1 \text{ mol H}}{1.01 \text{ g H}} = 8.267 \div 0.361 = 22.90 \sim 23$$

$$\text{mol N} = 5.05 \text{ g N} \cdot \frac{1 \text{ mol N}}{14 \text{ g N}} = 0.361 \div 0.361 = 1 \sim 1$$



- ③ - In an experiment, 3.25 g of NH_3 are allowed to react with 3.50 g of O_2



- What is the theoretical yield of NO in grams?
- What are the limiting and excess reactants?
- How much of the excess reactant remains after the reaction?
- If you ran the reaction and achieved an 84.0% yield, how much NO did you produce?

Solution:

$$\text{a) } ? \text{ g NO} = 3.25 \text{ g NH}_3 \cdot \frac{1 \text{ mol NH}_3}{17.03 \text{ g NH}_3} \cdot \frac{4 \text{ mol NO}}{4 \text{ mol NH}_3} \cdot \frac{30.01 \text{ g NO}}{1 \text{ mol NO}} = 5.73 \text{ g NO}$$

$$? \text{ g NO} = 3.50 \text{ g O}_2 \cdot \frac{1 \text{ mol O}_2}{32.0 \text{ g O}_2} \cdot \frac{4 \text{ mol NO}}{5 \text{ mol O}_2} \cdot \frac{30.01 \text{ g NO}}{1 \text{ mol NO}} = \underline{2.63 \text{ g NO}} \quad (\text{less!})$$

theoretical yield

b) limiting reactant ; O_2
excess reactant ; NH_3

$$\text{c) } ? \text{ g NH}_3 = 2.63 \text{ g NO} \cdot \frac{1 \text{ mol NO}}{30.01 \text{ g NO}} \cdot \frac{4 \text{ mol NH}_3}{4 \text{ mol NO}} \cdot \frac{17.03 \text{ g NH}_3}{1 \text{ mol NH}_3} = 1.49 \text{ g NH}_3$$

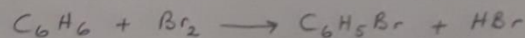
used up

$$3.25 - 1.49 = \underline{1.76} \quad \text{remain}$$

$$\text{d) } 84.0 = \frac{x}{2.63} \times 100$$

$$x = \underline{2.21 \text{ g NO produced}}$$

- ④ - Consider the reaction below:



- What is the theoretical yield of $\text{C}_6\text{H}_5\text{Br}$ if 42.1 g of C_6H_6 react with 73.0 g of Br_2 ?
- If the actual yield of $\text{C}_6\text{H}_5\text{Br}$ is 63.6 g, what is the percent yield?

Solution:

$$\begin{aligned} \text{a) } ? \text{ g C}_6\text{H}_5\text{Br} &= 42.1 \text{ g C}_6\text{H}_6 \cdot \frac{1 \text{ mol C}_6\text{H}_6}{78.11 \text{ g C}_6\text{H}_6} \cdot \frac{1 \text{ mol C}_6\text{H}_5\text{Br}}{1 \text{ mol C}_6\text{H}_6} \cdot \frac{157.0 \text{ g C}_6\text{H}_5\text{Br}}{1 \text{ mol C}_6\text{H}_5\text{Br}} \\ &= 84.6 \text{ g C}_6\text{H}_5\text{Br} \end{aligned}$$

$$\begin{aligned} ? \text{ g C}_6\text{H}_5\text{Br} &= 73.0 \text{ g Br}_2 \cdot \frac{1 \text{ mol Br}_2}{159.80 \text{ g Br}_2} \cdot \frac{1 \text{ mol C}_6\text{H}_5\text{Br}}{1 \text{ mol Br}_2} \cdot \frac{157.0 \text{ g C}_6\text{H}_5\text{Br}}{1 \text{ mol C}_6\text{H}_5\text{Br}} \\ &= 71.7 \text{ g C}_6\text{H}_5\text{Br} \quad (\text{less!}) \\ &\quad \rightarrow \text{theoretical yield} \end{aligned}$$

$$\begin{aligned} \text{b) } \% &= \frac{63.6}{71.7} \times 100 = 88.7 \% \\ &\quad \rightarrow \text{percent yield.} \end{aligned}$$

- ⑤ - A light with a wavelength of 630 nm and a frequency of $6.50 \times 10^{14} \text{ s}^{-1}$ passes through a transparent medium. What is the speed of the light in this medium?

Solution:

$$c = \overset{\text{frequency}}{\nu} \cdot \overset{\text{wavelength}}{\lambda}$$

\downarrow in vacuum

$$\begin{aligned} v &= \nu \cdot \lambda \\ &= 6.50 \times 10^{14} \text{ s}^{-1} \cdot 6.30 \times 10^{-7} \text{ m} \\ &= 4.9 \times 10^8 \text{ m/s} \end{aligned}$$

- ⑥ - Determine the wavelength of light absorbed in an electron transition from $n=2$ to $n=4$ in a hydrogen atom.

Solution:

$$\begin{aligned} \Delta E &= R_H \cdot \left(\frac{1}{2^2} - \frac{1}{4^2} \right) \\ &= 2.179 \times 10^{-18} \text{ J} \cdot \left(\frac{1}{4} - \frac{1}{16} \right) \\ &= 4.086 \times 10^{-19} \text{ J} \end{aligned}$$

$$\Delta E = \frac{h \cdot c}{\lambda} \Rightarrow \lambda = \frac{h \cdot c}{\Delta E} = \frac{6.626 \times 10^{-34} \cdot 2.998 \times 10^8}{4.086 \times 10^{-19}} = 4.862 \times 10^{-7} \text{ m} = 486.2 \text{ nm}$$

- ⑦ Determine the value of n corresponding to the Balmer series line at 410 nm.

Solution:

$$\Delta E = \frac{h \cdot c}{\lambda} = \frac{6.626 \times 10^{-34} \cdot 2.998 \times 10^8}{4.10 \times 10^{-7}} = 2.179 \times 10^{-18} \left(\frac{1}{n^2} - \frac{1}{2^2} \right)$$

$$-0.222 = \left(\frac{1}{n^2} - \frac{1}{4} \right)$$

$$\begin{array}{l} \text{energy} \\ \text{emitted} \end{array} - 0.222 = \frac{1}{n^2} - 0.25 \quad 0.028 = \frac{1}{n^2} \quad \begin{array}{l} n^2 = 36 \\ n = 6 \end{array}$$

- ⑧ A bomb calorimetry experiment is performed with xylose, $C_5H_{10}O_5$, as the combustible substance. The data obtained are

mass of xylose burned : 1.183 g

heat capacity of calorimeter : 4.728 kJ/°C

initial calorimeter temperature : 23.25 °C

final " " : 27.19 °C

What is the heat of combustion of xylose, in kJ per mole?

Solution:

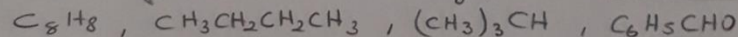
Heat given off by xylose = Heat absorbed by the calorimeter

$$\begin{aligned} Q &= c \cdot \Delta T \\ &= 4.728 \text{ kJ/}^\circ\text{C} \cdot (27.19 - 23.25)^\circ\text{C} \\ &= 18.44 \text{ kJ} \end{aligned}$$

$$\text{mole of xylose} = 1.183 \text{ g xylose} \cdot \frac{1 \text{ mol xylose}}{150 \text{ g xylose}} = 7.89 \times 10^{-3} \text{ mol xylose}$$

$$\text{Heat of combustion} = \frac{18.44 \text{ kJ}}{7.89 \times 10^{-3} \text{ mol}} = 2337 \text{ kJ/mol} = 2.337 \times 10^3 \text{ kJ/mol}$$

- ⑨ Sort the following compounds according to their increased boiling point.



$$\Delta H = -2.337 \times 10^3 \text{ kJ/mol}$$

Solution: C_8H_{18} : 114.2 g/mol

$CH_3CH_2CH_2CH_3$: 58.1 g/mol

$(CH_3)_3CH$: 58.1 g/mol

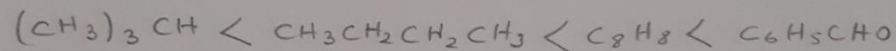
C_6H_5CHO : 106.1 g/mol

C_8H_{18} has a higher boiling point than $CH_3CH_2CH_2CH_3$ because its size is larger than the other molecule.

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Branching decreases the boiling point. As the length of carbon chain increases, the surface area of the compound will also increase. Therefore linear alkanes have stronger van der Waals forces than unbranched alkanes. This makes the boiling point greater.

C_6H_5CHO is a polar molar molecule and has hydrogen bondings between own molecules. Although C_8H_8 has a higher molecular mass, it is an apolar molecule. Hence its boiling point is smaller than that of C_6H_5CHO . As a result;



(10) Sort the following compounds according to their increase boiling point: C_4H_{10} , C_8H_{18} , $CH_3(CH_2)_7OH$, $(CH_3)_3CC(CH_3)_3$

Solution: $C_4H_{10} < (CH_3)_3CC(CH_3)_3 < C_8H_{18} < CH_3(CH_2)_7OH$

↓	↓	↓	↓
it has the least molecular mass	branched alkane	unbranched alkane	polar molecule

(11) An aqueous solution with density 1.04 g/mL is prepared by diluting $200 \text{ mL } H_2SO_4$ (d: 1.25 g/mL , 19.6% , by mass) in enough water to produce 1 L of solution. What is the molality of the sulfuric acid solution?

Answer : 47.12 m