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 CO_2 and 4.32 g H_2O. Determine the empirical formula for tartaric acid.

Solution:

$$\text{mol C} = 14.08\ g\ CO_2 \cdot \frac{1\ mol\ CO_2}{44\ g\ CO_2} \cdot \frac{1\ mol\ C}{1\ mol\ CO_2} = 0.32\ mol\ C$$

$$\text{mol H} = 4.32\ g\ H_2O \cdot \frac{1\ mol\ H_2O}{18\ g\ H_2O} \cdot \frac{2\ mol\ H}{1\ mol\ H_2O} = 0.48\ mol\ H$$

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

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

$$\text{mass of oxygen} = 12.01 - (\underbrace{3.84 + 0.48}_{4.32}) = 7.69\ g\ O$$

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

$$C_{\frac{0.32}{0.32}} H_{\frac{0.48}{0.32}} O_{\frac{0.48}{0.32}} \qquad \{C\ H_{1.5}\ O_{1.5}\} \times 2 \equiv C_2H_3O_3$$

(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:

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

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

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

$$C_{20}H_{23}N$$

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

$$4NH_3 + 5O_2 \longrightarrow 4NO + 6H_2O$$

a) what is the theoretical yield of NO in grams?

b) what are the limiting and excess reactants?

c) Howmuch of the excess reactant remains after the reaction?

d) If you ran the reaction and achieved an 84.0% yield, how much NO did you produce?

Solution:

a)

$$?\,g\,NO = 3.25\,g\,NH_3 \cdot \frac{1\,mol\,NH_3}{17.03\,g\,NH_3} \cdot \frac{4\,mol\,NO}{4\,mol\,NH_3} \cdot \frac{30.01\,g\,NO}{1\,mol\,NO} = 5.73\,g\,NO$$

$$?\,g\,NO = 3.50\,g\,O_2 \cdot \frac{1\,mol\,O_2}{32.0\,g\,O_2} \cdot \frac{4\,mol\,NO}{5\,mol\,O_2} \cdot \frac{30.01\,g\,NO}{1\,mol\,NO} = \underline{\underline{2.63\,g\,NO}}$$ (less!)

theoretical yield

b) limiting reactant ; O_2

excess reactant ; NH_3

c)

$$?\,g\,NH_3 = 2.63\,g\,NO \cdot \frac{1\,mol\,NO}{30.01\,g\,NO} \cdot \frac{4\,mol\,NH_3}{4\,mol\,NO} \cdot \frac{17.03\,g\,NH_3}{1\,mol\,NH_3} = 1.49\,g\,NH_3$$ used up

$3.25 - 1.49 = 1.76$ remain

d)

$$84.0 = \frac{x}{2.63} \times 100$$

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

4 - Consider the reaction below:

$$C_6H_6 + Br_2 \longrightarrow C_6H_5Br + HBr$$

a) what is the theoretical yield of C_6H_5Br if 42.1 g of C_6H_6 react with 73.0 g of Br_2?

b) If the actual yield of C_6H_5Br is 63.6 g, what is the the percent yield?

Solution :

a) $? \text{ g } C_6H_5Br = 42.1 \text{ g } C_6H_6 \cdot \frac{1 \text{ mol } C_6H_6}{78.11 \text{ g } C_6H_6} \cdot \frac{1 \text{ mol } C_6H_5Br}{1 \text{ mol } C_6H_6} \cdot \frac{157.0 \text{ g } C_6H_5Br}{1 \text{ mol } C_6H_5Br}$

$= 84.6 \text{ g } C_6H_5Br$

$? \text{ g } C_6H_5Br = 73.0 \text{ g } Br_2 \cdot \frac{1 \text{ mol } Br_2}{159.80 \text{ g } Br_2} \cdot \frac{1 \text{ mol } C_6H_5Br}{1 \text{ mol } Br_2} \cdot \frac{157.0 \text{ g } C_6H_5Br}{1 \text{ mol } C_6H_5Br}$

$= 71.7 \text{ g } C_6H_5Br$ (less!)

↳ theoretical yield

b) $\% = \frac{63.6}{71.7} \times 100 = 88.7 \%$

↳ percent yied.

5 _ A light with a wavelenght 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 :

$c = \nu \cdot \lambda$

ν → fequency

λ → wavelenght

c ↳ in vacuum

$V = \nu \cdot \lambda$

$= 6.50 \times 10^{14} \text{ s}^{-1} \cdot 6.30 \times 10^{-7} \text{ m}$

$= 4.9 \times 10^{8} \text{ m/s}$

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

Solution : $\Delta E = R_H \cdot \left(\frac{1}{2^2} - \frac{1}{4^2}\right)$

$= 2.179 \times 10^{-18} \text{ J} \cdot \left(\frac{1}{4} - \frac{1}{16}\right)$

$= 4.086 \times 10^{-19} \text{ J}$

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

$= 486.2 \text{ nm}$

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

Solution:

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

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

energy emitted

$$-0.222 = \frac{1}{n^2} - 0.25 \qquad 0.028 = \frac{1}{n^2} \qquad n^2 = 36 \quad n = 6$$

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 : 23.29 °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

$$Q = c \cdot \Delta T$$
$$= 4.728 \text{ kJ/°C} \cdot (27.19 - 23.25) \text{°C}$$
$$= 18.44 \text{ kJ}$$

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

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

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

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

C_8H_8, $CH_3CH_2CH_2CH_3$, $(CH_3)_3CH$, C_6H_5CHO

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 hdrogen 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;

$(CH_3)_3CH < CH_3CH_2CH_2CH_3 < C_8H_8 < C_6H_5CHO$

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

C_4H_{10} ↓ it has the least molecular mass

$(CH_3)_3CC(CH_3)_3$ ↓ branched alkane

C_8H_{18} ↓ unbranched alkane

$CH_3(CH_2)_7OH$ ↓ polar molecule

11_ An aqueous solution with density 1.04 g/mL is prepared by diluting 200 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