

Mole Calculations Answers

1a. M_r of $CH_3OH = 12.0 + (3 \times 1.01) + 16.0 + 1.01 = 32.0 \text{ g mol}^{-1}$

1b. Moles $CH_3OH = \text{mass} / M_r = 5.0 / 32.0 = 0.16 \text{ mol}$
(Answer to 2 significant figures as mass given to 2 significant figures.)

2. M_r of $CO_2 = 12.0 + (16.0 \times 2) = 44.0 \text{ g mol}^{-1}$
Mass of $CO_2 = M_r \times \text{moles} = 44.0 \text{ g} \times 0.50 \text{ g mol}^{-1} = 22 \text{ g}$

3a. $M_r = \text{mass} / \text{moles} = 54 / 3 = 18 \text{ g mol}^{-1}$

3b. It could be water (H_2O)

4. M_r of $CuCO_3 = 108 \text{ g mol}^{-1}$
Moles of $CuCO_3 = \text{mass} / M_r = 9.0 / 124 = 0.073 \text{ mol}$
 M_r of $CuCO_3 = 63.5 + 12.0 + (3 \times 16.0) = 123.5 = 124$ (to 3 sf)

5a. Mass of $Br_2 = \text{density} \times \text{volume} = 3.1 \times 2.0 = 6.2 \text{ g}$

5b. M_r of $Br_2 = 160 \text{ g mol}^{-1}$
Moles of $Br_2 = \text{mass} / M_r = 6.2 / 160 = 0.039 \text{ mol}$

6. Mass of $Fe = \text{moles} \times M_r = 0.25 \times 55.8 = 14 \text{ g}$

7. Moles of cyclohexane = $\text{mass} / M_r = 3.0 / 84.1 = 0.036 \text{ mol}$
 M_r of cyclohexane (C_6H_{12}) = $(6 \times 12.0) + (12 \times 1.01) = 84.1$

8. Mass benzene = $\text{moles} \times M_r = 4.00 \times 78.1 = 312 \text{ g}$
 M_r of benzene (C_6H_6) = $(6 \times 12.0) + (6 \times 1.01) = 78.1$

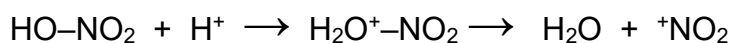
9a. Moles of tetrabutylammonium bromide ($\text{Bu}_4\text{N}^+ \text{Br}^-$) = mass / M_r
= $1.0 / 322 = 0.0031 \text{ mol}$
 M_r of $\text{Bu}_4\text{N}^+ \text{Br}^-$ ($\text{C}_{16}\text{H}_{36}\text{BrN}$) = $(16 \times 12.0) + (36 \times 1.01) + 79.9 + 14.0 = 322$

9b. 0.0031 moles of Br_2

9c. Mass Br_2 = moles $\times M_r = 0.0031 \times 160 = 0.496 = 0.50 \text{ g}$
Volume = mass / density = $0.50 / 3.10 = 0.16 \text{ cm}^{-3}$

10a. Electrophilic substitution.

Sulfuric acid protonates nitric acid to form, on loss of water, the nitronium ion (a strong electrophile):



10b. Moles added:

methyl benzoate ($\text{C}_8\text{H}_8\text{O}_2$)

$M_r = (8 \times 12.0) + (8 \times 1.01) + (2 \times 16.0) = 136$

Moles = mass / $M_r = (6.0 / 136) = 0.044 \text{ mol}$

nitric acid (HNO_3)

Mass = volume \times density = $4.0 \times 1.51 = 6.0 \text{ g}$

$M_r = 1.01 + 14.0 + (3 \times 16.0) = 63.0$

Moles = mass / $M_r = (6.0 / 63.0) = 0.095 \text{ mol}$

sulfuric acid (H_2SO_4)

Mass = volume \times density = $16.0 \times 1.83 = 29.3 \text{ g}$

$M_r = (2 \times 1.01) + 32.0 + (4 \times 16.0) = 98.0$

Moles = mass / $M_r = (29.3 / 98.0) = 0.299 \text{ mol}$

Methyl benzoate is the limiting reagent as there are only 0.044 mol of it

10c. 0.044 moles of product could be made

10d. Theoretical mass of product = $M_r \times$ moles = $181 \times 0.044 = 7.96 = 8.0 \text{ g}$

methyl 3-nitrobenzoate ($\text{C}_8\text{H}_7\text{NO}_4$)

$M_r = (8 \times 12.0) + (7 \times 1.01) + 14.0 + (4 \times 16.0) = 181$

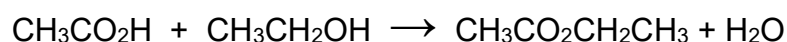
10e. Methyl 3-nitrobenzoate

10f. Methyl 2-nitrobenzoate and methyl 4-nitrobenzoate

11a. An esterification reaction

A catalyst is a substance that increases the rate of a chemical reaction without being consumed in the reaction

11b. Mass of ethyl ethanoate formed = volume x density = 6.40 x 0.90 = 5.76 g



The carboxylic acid is ethanoic acid ($\text{CH}_3\text{CO}_2\text{H}$)

$$M_r = (12.0 \times 2) + (4.0 \times 1.01) + (2 \times 16.0) = 60.0$$

$$\text{Moles} = \text{mass} / M_r = (6.0 / 60.0) = 0.10 \text{ mol}$$

The alcohol is ethanol ($\text{CH}_3\text{CH}_2\text{OH}$)

$$M_r = (12.0 \times 2) + (6.0 \times 1.01) + 16.0 = 46.1$$

$$\text{Moles} = \text{mass} / M_r = (6.0 / 46.1) = 0.13 \text{ mol}$$

Ethanoic acid is the limiting reagent as there are only 0.10 mol of it

$$\text{Theoretical mass of ester} = M_r \times \text{moles} = 88.1 \times 0.10 = 8.81 \text{ g}$$

$$M_r \text{ of ester } (\text{CH}_3\text{CO}_2\text{CH}_2\text{CH}_3) = (4 \times 12.0) + (8 \times 1.01) + (2 \times 16.0) = 88.1$$

$$\% \text{ yield} = \text{actual yield} / \text{theoretical yield} \times 100$$

$$\% \text{ yield} = 5.76 \text{ g} / 8.81 \text{ g} \times 100 = 65.4\% \text{ (to 1 dp, 3 sf)} = 65\% \text{ (rounding up)}$$

11c. Atom economy = M_r of desired product / combined M_r of all reactants x 100

$$88.1 / (60.0 + 46.1) \times 100 = 83.0\% \text{ (to 1 dp, 3 sf)} = 83\% \text{ (rounding up)}$$

(Note: 17% will be wasted)

11d. Conversion of RCO_2H into RCO_2R leads to a change in the wavenumber of the intense $\text{C}=\text{O}$ stretching vibration, from around 1710 cm^{-1} for RCO_2H to around 1740 cm^{-1} for RCO_2R . The peak intensities at 1710 cm^{-1} and 1740 cm^{-1} can be used to monitor the progress of the reaction.