

ENTRANCE EXAMINATION AT THE UNIVERSITIES OF TECHNOLOGY IN FINLAND (HELSINKI, TAMPERE, LAPPEENRANTA, OULU, ÅBO, TURKU, VAASA)

Model Solutions (Chemistry Exam 1 June 2005)

1. $m(\text{sample}) = 2.11 \text{ g}$, $m(\text{CaCl}_2) = x \text{ g}$

1. Dissolution reaction of salt: $\text{CaCl}_2(\text{s}) \rightarrow \text{Ca}^{2+}(\text{aq}) + 2 \text{Cl}^{-}(\text{aq})$
2. Precipitation reaction: $\text{Ca}^{2+}(\text{aq}) + \text{CO}_3^{2-}(\text{aq}) \rightarrow \text{CaCO}_3(\text{s})$
3. Heating reaction: $\text{CaCO}_3(\text{s}) \rightarrow \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$

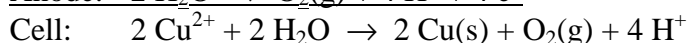
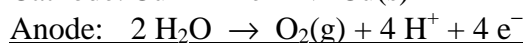
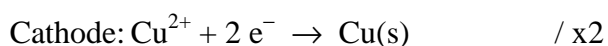
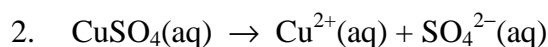
From the reaction equation: $n(\text{CaO}) = n(\text{CaCO}_3) = n(\text{Ca}^{2+}) = n(\text{CaCl}_2)$
 $m(\text{CaO}) = 0.480 \text{ g}$, $M(\text{CaO}) = 56.08 \text{ g/mol}$

$$\Rightarrow n(\text{CaO}) = \frac{m(\text{CaO})}{M(\text{CaO})} = \frac{0.480 \text{ g}}{56.08 \text{ g/mol}} = 0.008559 \text{ mol} = n(\text{CaCl}_2)$$

$$M(\text{CaCl}_2) = 110.98 \text{ g/mol}$$

$$m(\text{CaCl}_2) = n \cdot M = 0.008559 \text{ mol} \cdot 110.98 \text{ g/mol} = 0.9499 \text{ g}$$

$$\text{Mass fraction of CaCl}_2 \text{ in the sample (m-\%)} = \frac{0.9499}{2.11} \cdot 100\% = \underline{\underline{45.0\%}}$$



b) $m_{\text{Cu}} = 1.00 \text{ g}$, $M_{\text{Cu}} = 63.54 \text{ g/mol} \Rightarrow n_{\text{Cu}} = m/M = \frac{1.00 \text{ g}}{63.54 \text{ g/mol}} = 0.01574 \text{ mol}$

$$Q = Z n F$$

$$Z = 2 \rightarrow Q = 2 \cdot 0.01574 \text{ mol} \cdot 96490 \text{ A s/mol} = \underline{\underline{3038 \text{ A s}}}$$

c) $n(\text{O}_2) = n_{\text{Cu}} / 2 = 0.01574 \text{ mol} / 2 = 0.00787 \text{ mol}$

Or: $n(\text{O}_2) = Q / ZF$; $Z = 4 \rightarrow n(\text{O}_2) = \frac{3038 \text{ A s}}{4 \cdot 96490 \text{ A s mol}^{-1}} = 0.00787 \text{ mol}$

$$pV = nRT \rightarrow V(\text{O}_2) = \frac{n(\text{O}_2)RT}{p} = \frac{0.00787 \text{ mol} \cdot 8.314 \text{ J mol}^{-1} \text{K}^{-1} \cdot 293 \text{ K}}{101000 \text{ Pa}} = 1.90 \cdot 10^{-4} \text{ m}^3$$

$$= \underline{\underline{190 \text{ cm}^3}}$$

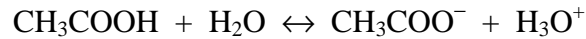
3. a) $m(\text{CH}_3\text{COOH}) = 0.600 \text{ g}$, $M(\text{CH}_3\text{COOH}) = 60.052 \text{ g/mol} \rightarrow n(\text{CH}_3\text{COOH}) = \frac{m}{M} = 0.00999 \text{ mol}$

$$V = 1 \text{ dm}^3 \rightarrow c(\text{CH}_3\text{COOH}) = 0.00999 \text{ mol/dm}^3$$

$$m(\text{CH}_3\text{COONa}) = 0.738 \text{ g}, M(\text{CH}_3\text{COONa}) = 82.034 \text{ g/mol} \rightarrow n(\text{CH}_3\text{COONa}) =$$

$$\frac{m}{M} = 0.00900 \text{ mol}$$

$$V = 1 \text{ dm}^3 \rightarrow c(\text{CH}_3\text{COONa}) = 0.00900 \text{ mol/dm}^3$$



At the beginning (mol/dm ³)	0.00999	0.00900	0
At equilibrium (mol/dm ³)	0.00999 - x	0.00900 + x	x

$$K_a = \frac{[\text{CH}_3\text{COO}^-][\text{H}_3\text{O}^+]}{[\text{CH}_3\text{COOH}]} = \frac{(0.00900 + x) \cdot x}{0.00999 - x} = 1.8 \cdot 10^{-5} \text{ mol/dm}^3$$

Approximation: $x \ll 0.00900 \rightarrow$

$$\frac{0.00900 \cdot x}{0.00999} = 1.8 \cdot 10^{-5} \text{ mol/dm}^3 \rightarrow$$

$$x = [\text{H}_3\text{O}^+] = [\text{H}^+] = \underline{\underline{2.00 \cdot 10^{-5} \text{ mol/dm}^3}} \text{ the approximation is ok!}$$

Or:

$$K_a = \frac{[\text{CH}_3\text{COO}^-][\text{H}_3\text{O}^+]}{[\text{CH}_3\text{COOH}]} \rightarrow [\text{H}_3\text{O}^+] = \frac{K_a [\text{CH}_3\text{COOH}]}{[\text{CH}_3\text{COO}^-]}$$

In the buffered solution:

$$[\text{H}_3\text{O}^+] \cong K_a \frac{[\text{happo}]}{[\text{emäs}]}$$

$$[\text{H}_3\text{O}^+] = 1.8 \cdot 10^{-5} \text{ mol/dm}^3 \quad \frac{0.00999 \text{ mol/dm}^3}{0.00900 \text{ mol/dm}^3} = \underline{\underline{2.00 \cdot 10^{-5} \text{ mol/dm}^3}}$$

$$\text{b) } [\text{OH}^-] = \frac{K_w}{[\text{H}_3\text{O}^+]^+} = \frac{1.00 \cdot 10^{-14} \text{ mol}^2/\text{dm}^6}{2.00 \cdot 10^{-5} \text{ mol/dm}^3} = \underline{\underline{5.00 \cdot 10^{-10} \text{ mol/dm}^3}}$$

$$\text{c) } \text{pH} = -\lg [\text{H}_3\text{O}^+]^+ = -\lg 2.00 \cdot 10^{-5} = \underline{\underline{4.70}}$$

4. a) The mole % given are the same as mole fractions x.
The average molar mass of dry air M_i :

$$\underline{\underline{M_i}} = x(\text{O}_2)M(\text{O}_2) + x(\text{N}_2)M(\text{N}_2) + x(\text{Ar})M(\text{Ar}) =$$

$$(0.21 \cdot 32.00 + 0.78 \cdot 28.02 + 0.01 \cdot 39.95) \text{ g/mol} = \underline{\underline{28.98 \text{ g/mol}}}$$

- b) Mass of air $m_i = 28.0140 \text{ g} - 27.9214 \text{ g} = 0.0926 \text{ g}$
 Mass of hydrocarbon gas $m_g = 28.0175 \text{ g} - 27.9214 \text{ g} = 0.0961 \text{ g}$

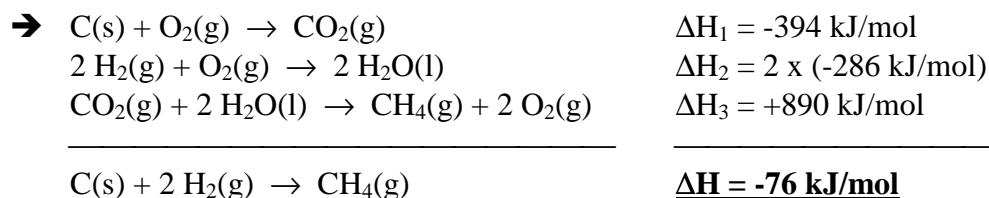
Same conditions, same volume $\rightarrow n_i = n_g$

$$n = \frac{m}{M} \rightarrow \frac{m_i}{M_i} = \frac{m_g}{M_g} \rightarrow M_g = \frac{m_g M_i}{m_i}$$

$$M_g = \frac{0.0961 \text{ g} \cdot 28.98 \text{ g/mol}}{0.0926 \text{ g}} = 30.07 \text{ g/mol}$$

- c) Hydrocarbon $C_xH_y \rightarrow$ C: 12.01 g/mol, H: 1.008 g/mol
 \rightarrow There can be 2 carbon atoms, in other words $x = 2$
 $\rightarrow 2 \cdot 12.01 \text{ g/mol} + y \cdot 1.008 \text{ g/mol} = 30.07 \text{ g/mol}$
 $\rightarrow y = 6.00$
 \rightarrow Hydrocarbon is **C_2H_6 ethane**

5. a) To obtain ΔH for the required reaction, the given equations 1, 2 and 3 must be combined to produce that reaction and add the corresponding ΔH values. Before summing the three reactions, reaction 2 and its ΔH value must be multiplied by 2 and reaction 3 must be reversed and the sign of ΔH must be changed accordingly (Hess's law).

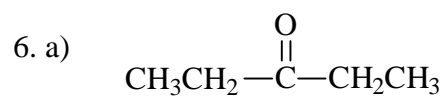


- b) $m(CH_4) = 100 \text{ g}$, $M(CH_4) = 16.042 \text{ g/mol}$

$$\rightarrow n(CH_4) = \frac{m}{M} = \frac{100 \text{ g}}{16.04 \text{ g/mol}} = 6.23 \text{ mol}$$

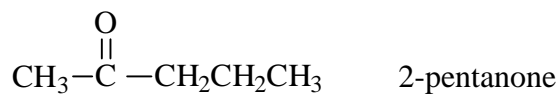
$$\Delta H = 6.23 \text{ mol} \cdot (-890 \text{ kJ/mol}) = -5544.7 \text{ kJ} = -5.54 \text{ MJ}$$

\rightarrow **The amount of heat released is 5.54 MJ**

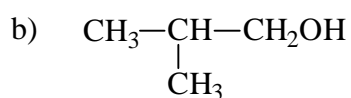
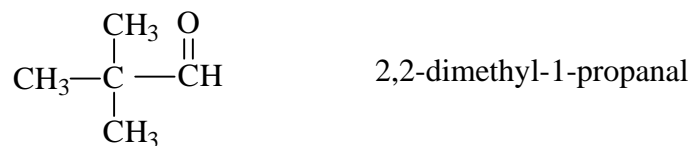
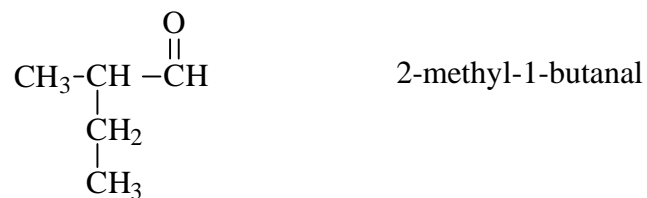
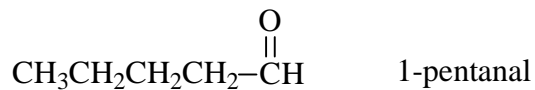


3-pentanone

Two ketone isomers:



Four aldehyde isomers:



2-methyl-1-propanol

Three ether isomers:

