МОСКОВСКИЙ ГОСУДАРСТВЕННЫЙ УНИВЕРСИТЕТ
имени М.В. ЛОМОНОСОВА

ОЛИМПИАДНАЯ РАБОТА

Наименование олимпиады школьников: **«Ломоносов»**

Профиль олимпиады: **Химия**

ФИО участника олимпиады: **Речкалова Арина Ярославовна**

Класс: **11**

Технический балл: **99**

Дата проведения: **27 февраля 2022 года**

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Хорошутин А.В.

Вар 1

Числовик 2

№4. $C_nH_{2n+2}O \xrightarrow[H_2SO_4]{180^\circ C} C_nH_{2n}\uparrow + H_2O$

$C_xH_{2x+2}O \xrightarrow[H_2SO_4]{180^\circ C} C_xH_{2x}\uparrow + H_2O$

$T = 180^\circ C = 453\,K$

$p = 101325\,Па$

$V = 11{,}15 \cdot 10^{-3}\,м^3$

$m_{смеси} = 15{,}9\,г$

$pV = \nu RT \quad \nu = \frac{101{,}325 \cdot 11{,}5}{8{,}314 \cdot 453} = 0{,}3\,моль$

Пусть $\nu(C_nH_{2n+2}O) = a$ моль $\Rightarrow \nu_{(C_xH_{2x+2}O)} = 0{,}3 - a$ моль

$a(14n+2+16) + (0{,}3-a)(14x+2+16) = 15{,}9$

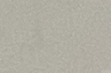
$14na + 18a + 4{,}2x + 5{,}4 - 14ax - 18a = 15{,}9$

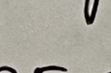
$14a(n-x) = 10{,}5 - 4{,}2x$ Допустим $n=4, x=2$

$28a = 10{,}5 - 8{,}4$

$a = 0{,}075$ моль $< 0{,}3$ – подходит

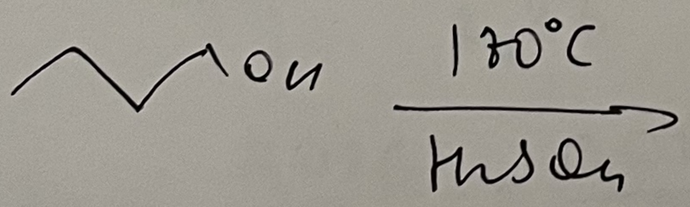
исходные спирты: $C_4H_{10}O$, C_2H_6O

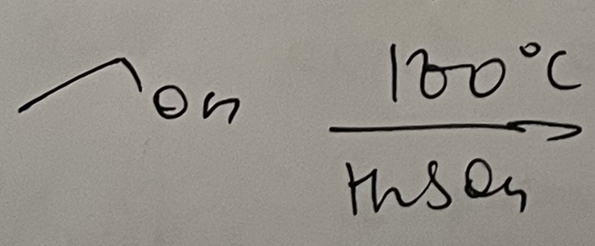


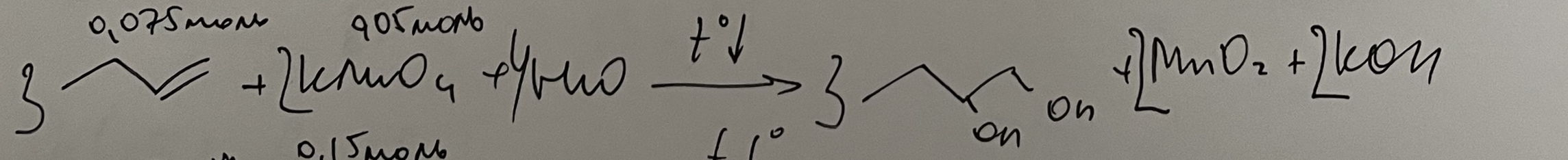


$\omega(C_4H_{10}O) = \frac{0{,}075 \cdot 74}{15{,}9} = 0{,}349 \cdot = 34{,}9\%$

$\omega(C_2H_6O) = \frac{0{,}225 \cdot 46}{15{,}9} = 0{,}651 = 65{,}1\%$



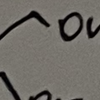
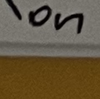




$C(KMnO_4) = 0{,}4\,M$

$\nu(KMnO_4) = 0{,}05 + 0{,}15 = 0{,}2$ моль

$\frac{0{,}2}{V} = \frac{0{,}4}{1} \quad V = 0{,}5\,л$

Ответ: исх. спирты  $\omega = 34{,}5\%$,  $\omega = 65{,}1\%$; $V(KMnO_4) = 0{,}5\,л$

Вар 1

Черновик ✍

$M = 46 = NO_2$

N_2O_4

$$K = \frac{[B]}{[A]^2} = \frac{k_{прям}}{k_{обр.}}$$

$\nu(B) =$

$\nu(A) =$

$V = 1\ л = \nu = C$

$$k_{обр} = \frac{k_{прям}}{1C} = \frac{5 \cdot 10^{-3}\ л/моль \cdot мин.}{143{,}13\ л/моль}$$

$$K = \frac{0{,}0246}{0{,}01729\,92} = 143{,}13\ \frac{л}{моль} = 3{,}5 \cdot 20^{-5}$$

№6 А.Б. + $MnSO_4$ → Bi ↓

$\bar{D}_{возд} = 0{,}275$

$M = 0{,}275 \cdot 32 = 28 \Rightarrow CO, C_2H_4, \cancel{\Delta N_2} \ldots$

B_2H_6

$HCOOH + H_2SO_4 \xrightarrow{t^\circ} CO\uparrow + H_2O$

$C_2H_5OH + H_2SO_4 \xrightarrow{t^\circ} C_2H_4\uparrow + H_2O$

$CO + H_2 \xrightarrow{kat}$ CH_3OH не реаг с $Cu(OH)_2$

$\rightarrow CH_2O$

$\rightarrow HCOOH$ - было

$CH_2O + 2C_2H_5OH \rightarrow H_2C(OC_2H_5)_2$

$CH_2O^{0,15} + 2Cu(OH)_2 \rightarrow HCOOH + Cu_2O\downarrow^{0,15} + H_2O$

21,6г

$\nu(Cu_2O) = \frac{21{,}6}{144} = 0{,}15$ моль

$\nu(CH_2O) = 0{,}15$ моль $\Rightarrow M = 0{,}15 \cdot 30 = 4{,}5$г

Вар 1

Чистовик 1

N 5.

1) $\underset{9,6\,г}{CuS} + \underset{120\,г,\,63\%}{8HNO_3} \longrightarrow CuSO_4 + 8NO_2\uparrow + 4H_2O$

2) $\underset{9,6\,г}{CuS} + \underset{142,7\,г,\,98\%}{4H_2SO_4} \longrightarrow CuSO_4 + 4SO_2\uparrow + 4H_2O$

$\nu(CuS) = \frac{9,6}{96} = 0,1$ моль $\quad \nu(HNO_3) = \frac{120 \cdot 0,63}{63} = 1,2$ моль $\quad \nu(H_2SO_4) = \frac{142,7 \cdot 0,98}{98} = 1,427$ моль

$\Rightarrow HNO_3$ и H_2SO_4 в избытке

$m_{1\,р\text{-}ра} = 9,6 + 120 - 8 \cdot 0,1 \cdot 46 = 129,6 - 36,8 = 92,8\,г$

$m_{2\,р\text{-}ра} = 9,6 + 142,7 - 4 \cdot 0,1 \cdot 64 = 126,7\,г$

$\Delta m = 126,7 - 92,8 = 33,9\,г$

$Na_2CO_3 \cdot 10H_2O + HNO_3 \longrightarrow 2NaNO_3 + CO_2\uparrow + 11H_2O$

$m(Na_2CO_3 \cdot 10H_2O) = x\,г$

$\nu(Na_2CO_3 \cdot 10H_2O) = \frac{x}{286}$ моль $\quad \nu(CO_2) = \frac{x}{286}$ моль

Масса р-ра увеличилась на $x - \frac{x}{286} \cdot 44 = \Delta m_1 = 33,9$

$\frac{242x}{286} = 33,9$

$x = \frac{33,9 \cdot 286}{242} = 40,06\,г$

$\nu(Na_2CO_3 \cdot 10H_2O) = \frac{40,06}{286} = 0,14$ моль. $\Rightarrow \nu_{прореаг}(HNO_3) = 0,28$ моль

$\nu_{ост}(HNO_3)$ после 1 реакц $= 1,2 - 0,8 = 0,4$ моль – избыток

Ответ: $\Delta m_{р\text{-}ра} = 33,9\,г$

Нужно добавить $40,06\,г$ $Na_2CO_3 \cdot 10H_2O$

Вар 1

Черновик

№5

CuS
9,6г
↓
120г 63% HNO_3
0,1 1,2

1) $CuS + 8HNO_3 \longrightarrow CuSO_4 + 8NO_2\uparrow + 4H_2O$

2) $CuS + 4H_2SO_4 \longrightarrow CuSO_4 + 4SO_2\uparrow + 4H_2O$

CuS
9,6г
↓
142,7г 98% H_2SO_4

0,2 0,4
$m_1 = 9,6 + 120 - 0,2 \cdot 46 = 129,6 - 36,8г = 92,8г$

$\nu(CuS) = \frac{9,6}{96} = 0,1$ моль $\quad \nu(HNO_3) = \frac{120 \cdot 0,63}{63} = 1,2$ моль изб.

$\nu(H_2SO_4) = \frac{142,7 \cdot 0,98}{98} = 1,427$ моль – изб $\Rightarrow$ ост 1,027 моль

$m_2 = 9,6 + 142,7 - \frac{0,4 \cdot 64}{25,6г} = 126,7г$

$126,7 - 92,8 = 33,9$

$Na_2CO_3 \cdot 10H_2O$

в 1 стакан нужно

0,4
3) $Na_2CO_3 + 2HNO_3 \longrightarrow 2NaNO_3 + CO_2\uparrow + H_2O$

4) $Na_2CO_3 + CuSO_4 + H_2O \longrightarrow (CuOH)_2CO_3\downarrow + Na_2SO_4 + CO_2\uparrow$

Вар 1

Чистовик 3.

№ 3. $2A \rightleftarrows B$ $V = 1л$ $T = 303k$ $\frac{\nu(B)}{\nu(A)} = \frac{1,86}{1}$ $M_{ср} = 75,9 г/моль$

~~$p = 101325 Па$~~

$p = 101325 Па$ $\nu = C$, т.к. $V = 1л$

$pV = \nu RT \Rightarrow \nu_{общ} = \frac{pV}{RT} = \frac{101,325 \cdot 1}{2,314 \cdot 303} = 0,04$ моль

$\nu(B) = 1,86 \cdot \nu(A)$

$M(B) = 2M(A)$, т.к. B-димер $\Rightarrow \nu_{общ} = \nu_A + 1,86\nu_A = 2,86\nu_A$

$\Rightarrow \nu_A = \frac{0,04}{2,86} = 0,014$ моль $\Rightarrow \nu_B = 0,0261$ моль

$M_{ср} = \varphi \cdot M_1 + (0,04 - \varphi) M_2 = 0,3507 \cdot M_1 + 0,6493 \cdot 2M_1 = 75,9$

$1,6493 M_1 = 75,9$

$M_1 = 46 \Rightarrow A = NO_2$

$B = N_2O_4$

$K = \frac{[B]}{[A]^2} = \frac{K_{прям}}{K_{обр}}$ $\nu = C$, т.к. $V = 1л$

~~$\nu(B) = \frac{1,86 \cdot 0,04}{2,86} = 0,026$ моль~~

~~$\nu(A) = \frac{1 \cdot 0,04}{2,86} = 0,014$ моль~~

$K = \frac{0,026}{0,014^2} = \frac{0,026}{0,000196} = 132,65 \frac{л}{моль}$

$K_{обр} = \frac{K_{прям}}{K} = \frac{5 \cdot 10^{-3}}{132,65} = 3,77 \cdot 10^{-5}$ ← крупное.

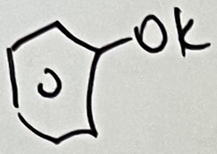
Ответ: $A = NO_2$

$B = N_2O_4$

$K_{разл} = 3,77 \cdot 10^{-5}$

Вар 1

Чистовик 4

№2.  $+ H_2O \rightleftarrows PhOH + KOH$

$PhO^- + H_2O \rightleftarrows PhOH + OH^-$

$K_r = \frac{[PhOH][OH^-]}{[PhO^-]} = \frac{k_w}{k_a} = \frac{10^{-14}}{10^{-10}} = 10^{-4}$

$K_r = \frac{x^2}{C_0 - x} = 10^{-4}$

$pOH = 14 - pH = 3$

$pOH = -\lg[OH^-]$

$[OH^-] = 10^{-3} = x$

$10^{-4} = \frac{10^{-6}}{C_0 - 10^{-3}}$

$10^{-4} C_0 - 10^{-7} = 10^{-6}$

$C_0 = \frac{10^{-6} + 10^{-7}}{10^{-4}} = 10^{-2} + 10^{-3} = 0{,}011\ M$

Ответ $C_0 = 0{,}011\ M$

№1 $42\bar{e}$; $32n$

$\bar{e} = p \Rightarrow p = 42$

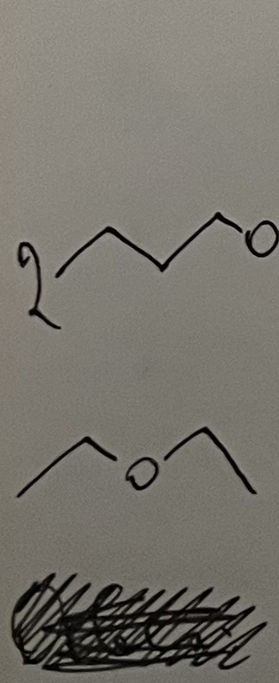
$\Rightarrow M = n + p = 74$ г/моль

$C_nH_{2n+2O} \Rightarrow 14n + 2 + 16 = 74$

$14n = 56$

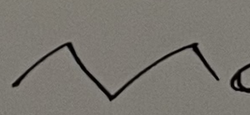
$n = 4$

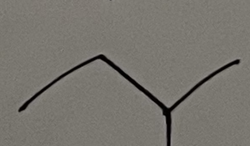
Изомеры $C_4H_{10}O$

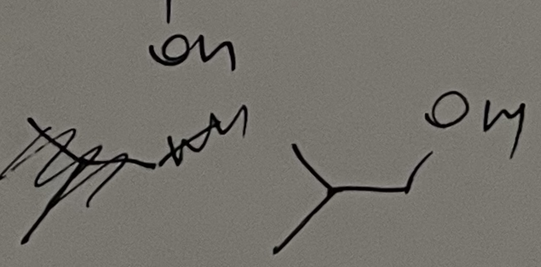


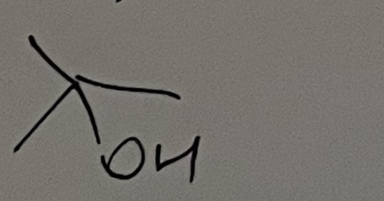
спирты

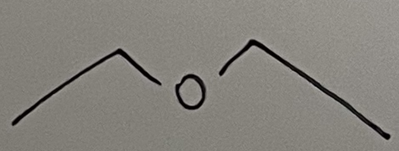
простые эфиры

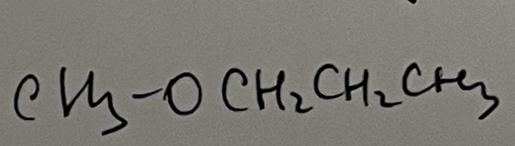


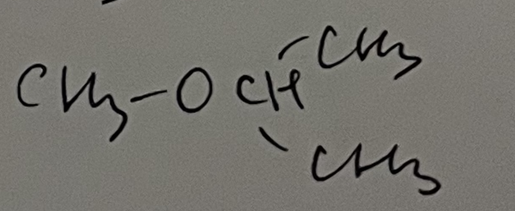












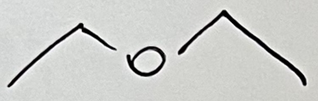
Вар 1 Черновик

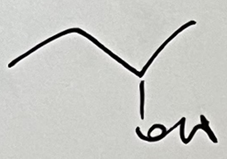
№1 $42\bar{e}$ $32n$ $\Rightarrow$ $42p \rightarrow M = 32+42 = 74$

$C_nH_{2n+2}O \Rightarrow 14n + 2 + 16 = 74$

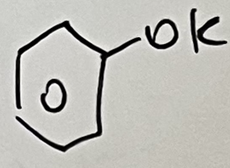
$14n = 56$

$n = 4$



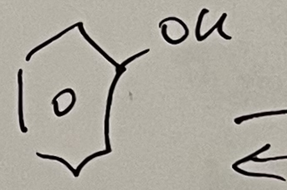


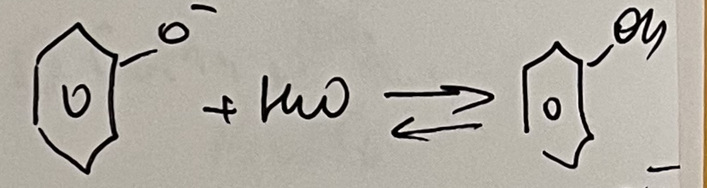
№2



$pH = 11$ $pH = -\lg[H^+]$ $pOH = 14 - 11 = 3 = -\lg[OH^-]$

$k_{дис} = 10^{-10}$





$k_g = \frac{[\text{ion}^-][K^+]}{[\text{ok}]} = \frac{(C_0 - [OH^-])C_0}{}$

№3. $2A \rightleftharpoons B$

$V = 1л = 10^{-3} м^3$

$T = 30°C = 303K$

$D_B = 1{,}86 D_A$

$\text{Кажн.} \frac{D_B}{D_A} = \frac{1{,}86}{1}$

$pV = DRT$

$D = D_A + D_B$

$p = 1 атм = 101325 Па$ $D = \frac{pV}{RT} = \frac{101325 \cdot 1 \cdot 10^{-3}}{8{,}314 \cdot 303}$

$M_{ср} = 75{,}9 г/моль$

$M_{ср} = \varphi \cdot M_1 + (1-\varphi) M_2 = 0{,}3507 \cdot M_1 + 0{,}6493 \cdot 2M_1 = 75{,}9$

$2M_1 = M_2$

$1{,}6493 M_1 = 75{,}9$

$M_1 = 46$

$D_{общ} = D_A + \underbrace{1{,}86 D_A}_{D_B} = 3{,}86 D_A$

$D_{общ} = 0{,}04$ моль

$D_A = 0{,}0141 \Rightarrow D_B = 0{,}0261$ моль

$\varphi_A = \frac{0{,}0141}{0{,}0402} = 0{,}3507$

Вар 1

Чистовик 5.

№6

A $\xrightarrow{H_2SO_4}$ B↑

Б $\xrightarrow{H_2SO_4}$ Г↑

$D_{(O_2)} = 0,875$

$M = D \cdot M(O_2) = 0,875 \cdot 32 = 28.$

$\Rightarrow CO, C_2H_4$

$HCOOH_{(ж)} \xrightarrow[t^\circ]{H_2SO_{4к}} CO\uparrow + H_2O$

$C_2H_5OH_{(ж)} \xrightarrow[t^\circ]{H_2SO_{4к}} C_2H_4\uparrow + H_2O$

$C_2H_4 + CO + H_2 \xrightarrow[t^\circ]{kat} CH_3CH_2C(=O)H$

$CH_3CH_2C(=O)H + [C_2H_5OH_{(изб)}] \xrightarrow{H^+} CH_3CH_2C(H)(OC_2H_5)OC_2H_5 + H_2O$

$CH_3CH_2C(=O)H + [Cu(OH)_2] \xrightarrow{t^\circ} CH_3CH_2C(=O)OH + Cu_2O\downarrow + H_2O$

21,6г

$\nu(Cu_2O) = \frac{21,6}{144} = 0,15$ моль

$\nu(CH_3CH_2C(=O)H) = 0,15$ моль $\quad m = 0,15 \cdot 58 = 8,7$ г

Ответ:

~~A~~ - HCOOH

~~B~~ Б - C_2H_5OH

В - CO

Г - C_2H_4

D - $CH_3CH_2C(=O)H$

E - $CH_3CH_2C(H)(OC_2H_5)OC_2H_5$

$m(CH_3CH_2C(=O)H) = 8,7$ г

Вар 1

Черновик

9

№4. C_nH_{2n+2} + [redacted] $\xrightarrow[H_2SO_4]{180^\circ}$ $C_nH_{2n}\uparrow + H_2O$

C_xH_{x+2} [redacted] $\xrightarrow[H_2SO_4]{200^\circ}$ $C_xH_{2x}\uparrow + H_2O$

$T = 180^\circ C = 453 K$

$p = 101325$ Па

$V = 11,15 \cdot 10^{-3}$ м³

$m_{смеси} = 15,9$ г

$pV = \nu RT$ $\quad \nu = \frac{pV}{RT} = \frac{101,325 \cdot 11,5 \cdot [redacted]}{8,314 \cdot 453} = 0,3$ моль

[redacted] Пусть $\nu_{C_nH_{2n}O} = \alpha$ моль $\Rightarrow \nu_2 = 0,3 - \alpha$

$\alpha \cdot M_1 + (0,3 - \alpha) M_2 = 15,9$

$\alpha(14n + 2 + 16) + (0,3 - \alpha)(14x + 2 + 16) = 15,9$

$14n\alpha + 18\alpha + 4,2x + 5,4 - 14\alpha x - 18\alpha = 15,9$

$14\alpha(n - x) + 4,2x = 10,5$ Допустим $n = 2$; $x = 3$

~~$14\alpha + 4,2 \cdot [redacted] = 10,5$~~

$14\alpha(n - x) = 10,5 - 4,2x$

$-14\alpha \quad -6,3$

$\alpha = 0,45$ моль — [redacted] $n = 4$, $x = 2$

$28\alpha = 2,1$

$\alpha = 0,075$ моль

$0,025 \cdot C_4H_{10}O + 0,225 \cdot C_2H_6O =$

$5,55 + 10,35 = 15,9$ г

$\omega_1 = \frac{5,55}{15,9} = \ldots$

$\omega_2 = \frac{10,35}{15,9} = \ldots$

$Mn^{+7} \longrightarrow Mn^{+4}$

C

[redacted]