CHEMISTRY: ART, SCIENCE, FUN

THEORETICAL EXAMINATION

ANSWER SHEETS

JULY 20, 2007

MOSCOW, RUSSIA

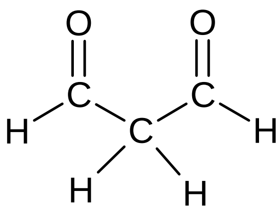
Official English version.

Problem 1	Name: ________________ Student code: __________	Quest.	1.1	1.2	2.1	3.1	3.2	3.3	3.4	Tot	Points
		Marks	3	3	2	4.5	2	4	6	24.5	7

1.1.1 *Structures:*

Propanedial
1st isomer
2nd isomer

1.1.2 *Circle the acidic hydrogen atom*



The acidity of propanedial is caused by

a) the stability of a carbanion due to conjugation with two carbonyl groups
b) weakness of C–H bond in a carbonyl group
c) hydrogen bonds between two propanedial molecules

The correct answer ________

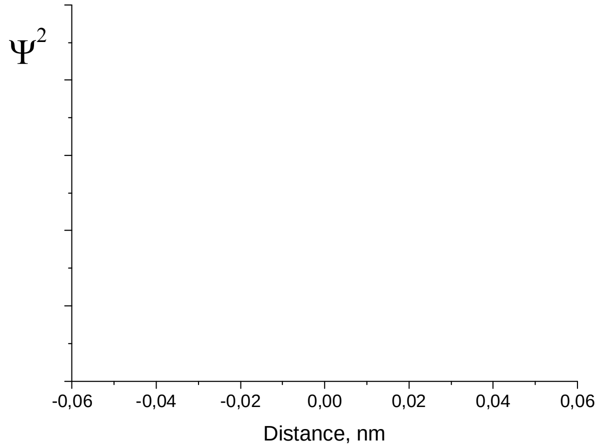
1.2.1 *The structures corresponding to minima on energy curve:*

Problem 1	Name: ________________ Student code: __________	Quest.	1.1	1.2	2.1	3.1	3.2	3.3	3.4	Tot	Points
		Marks	3	3	2	4.5	2	4	6	24.5	7

1.3.1 *The probability density*

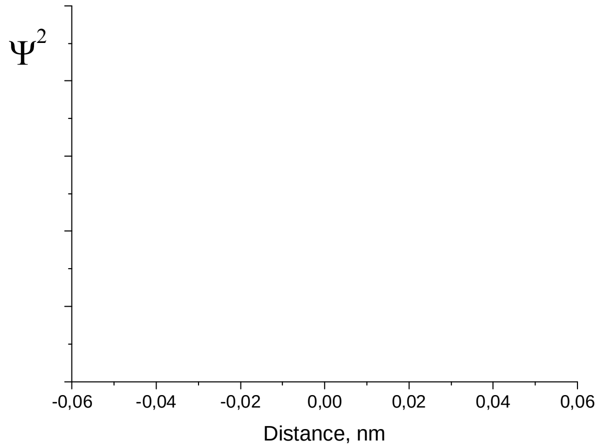
(a) $t = 0$

$\Psi^2(x,0) =$



(b) $t = \pi/(2\omega)$

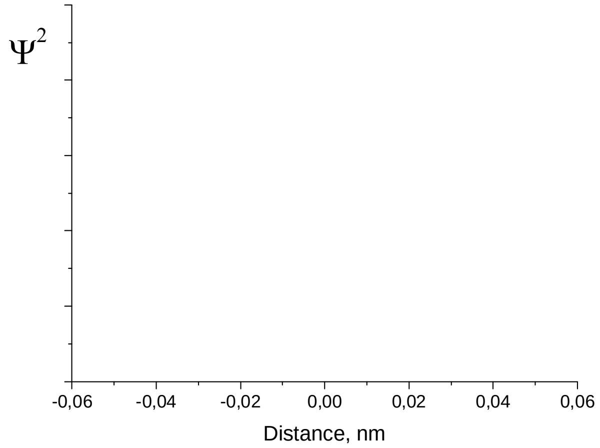
$\Psi^2\left(x, \dfrac{\pi}{2\omega}\right) =$



Problem 1	Name: ________________	Quest.	1.1	1.2	2.1	3.1	3.2	3.3	3.4	Tot	Points
	Student code: __________	Marks	3	3	2	4.5	2	4	6	24.5	7

(c) $t = \pi/\omega$

$$\Psi^2\left(x, \frac{\pi}{\omega}\right) =$$



1.3.2

The probability of finding the proton in the left well = ________

1.3.3 *The time of proton transfer*

Your work:

$t =$

The proton mean speed

Your work:

$v =$

1.3.4 *The uncertainty of proton position*

$\Delta x =$

Official English version.

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		Marks	3	3	2	4.5	2	4	6	24.5	7

The minimal uncertainty of proton velocity

Your work:

Δv =

a) Proton is a rather heavy particle, and its tunneling in malonaldehyde can be described in classical terms of position and velocity
b) Proton tunneling is a purely quantum effect; it cannot be described in classical terms
c) Uncertainty of proton velocity is so large that tunneling cannot be observed experimentally
d) Uncertainty of proton velocity is so small that tunneling cannot be observed experimentally

The correct answer is ________

Problem 2	Name: ________________ Student code: __________	Quest.	1.1	1.2	2.1	2.2	3.1	3.2	3.3	3.4	3.5	Tot	Points
		Marks	1	2	4	2	1	5	2	3	2	22	8

2.1.1 *Thermodynamic data for the reaction (1)*:
Your work:

$\Delta_r G^0$ (1) =

K =

2.1.2 *Equilibrium constant for the reaction (1) with cobalt nanoparticles:*
Your work:

(a) K (r = 10^{-8} m) =

(b) K (r = 10^{-9} m) =

Problem 2	Name: ____________ Student code: ________	Quest.	1.1	1.2	2.1	2.2	3.1	3.2	3.3	3.4	3.5	Tot	Points
		Marks	1	2	4	2	1	5	2	3	2	22	8

2.2.1 *Minimum water content in the mixture*:
Your work:

(a) $H_2O\%$(bulk Co) =

(b) $H_2O\%$(nanoparticles with $r = 1 \cdot 10^{-9}$ m) =

2.2.2 The correct answer is (mark the proper box):

(a) ☐ (b) ☐ (c) ☐

2.3.1 *Standard molar Gibbs function of CoO (external layer)*

$G^0(\text{CoO}, r_\text{b}) =$

2.3.2 *Standard molar Gibbs function of Co (internal layer):*

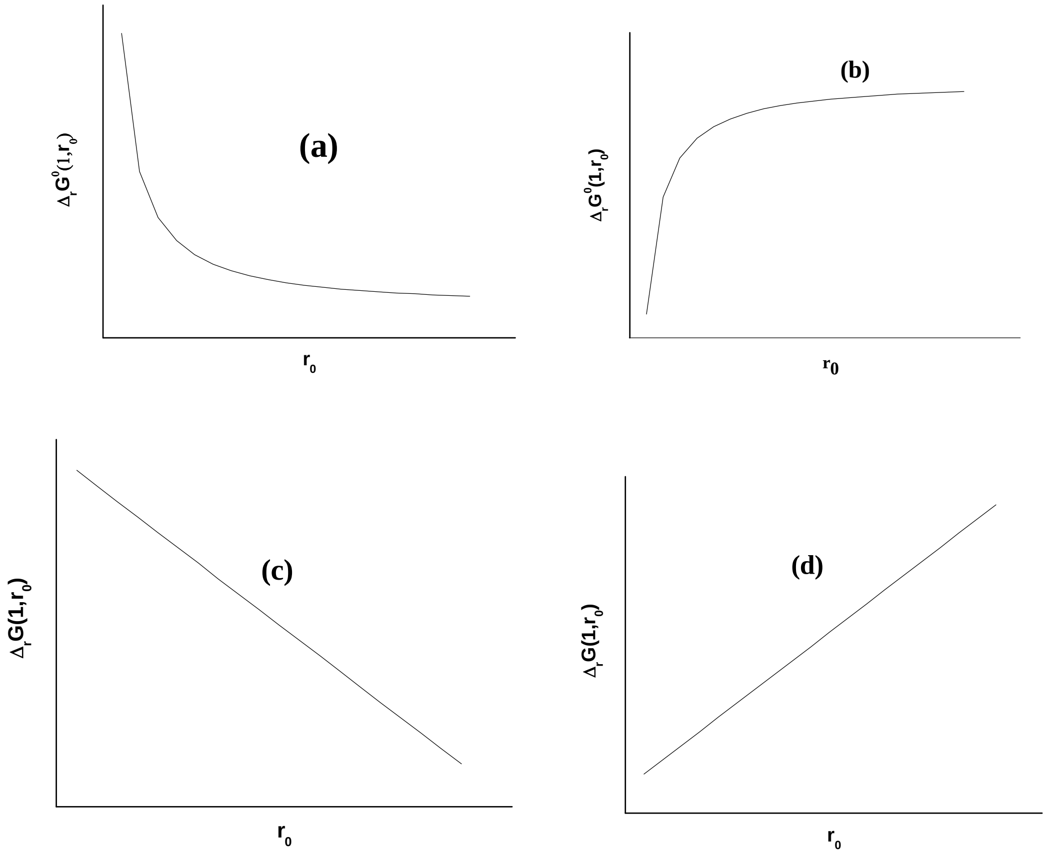
$G^0(\text{Co}, r_\text{a}, r_\text{b}) =$

2.3.3 *Standard Gibbs energy for the reaction (1) with the double-layered nanoparticles*

$\Delta_\text{r} G^0(1, r_\text{a}, r_\text{b}) =$

Problem 2	Name: _______________ Student code: _________	Quest.	1.1	1.2	2.1	2.2	3.1	3.2	3.3	3.4	3.5	Tot	Points
		Marks	1	2	4	2	1	5	2	3	2	22	8

2.3.4. Plot $\Delta_r G^0\,(1,r_0)$ vs. r_0



The correct plot is (mark the proper box):

(a) ☐ (b) ☐ (c) ☐ (d) ☐

2.3.5 The correct answer is (mark the proper box):

(a) ☐ (b) ☐ (c) ☐

Problem 3	Name: _______________ Student code: _________	Quest.	1.1	1.2	2.1	2.2	3.1	4.1	Tot	Points
		Marks	2	4.5	4	3	3	3	19.5	7

3.1.1 *The overall reaction equation*

The kinetic equation for X

$$\frac{d[\mathrm{X}]}{dt} =$$

3.1.2 *The rate equation*

Your work:

$$\frac{d[\mathrm{P}]}{dt} =$$

Reaction orders:

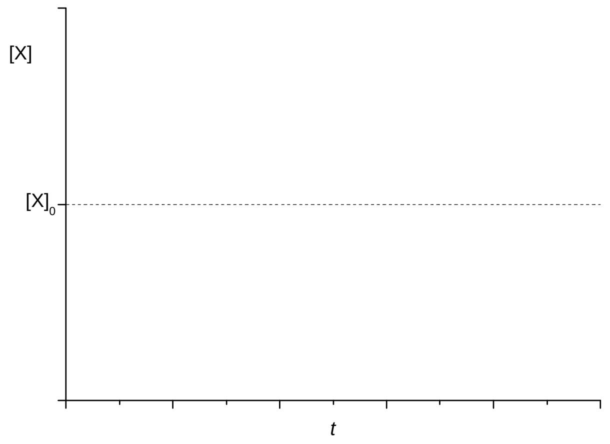
with respect to B (*i*): ______

with respect to D (*ii*): ______

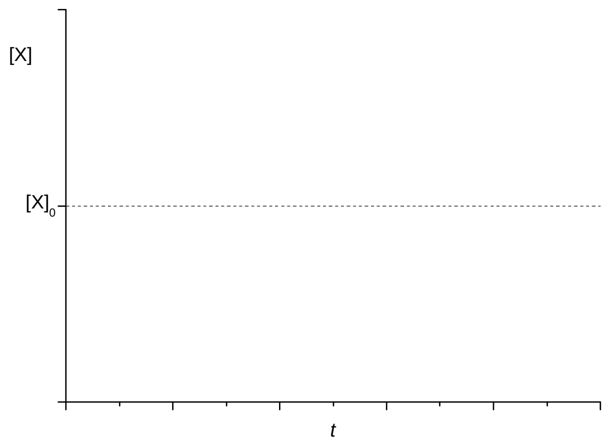
overall (*iii*): ______

Problem 3	Name: _______________ Student code: _________	Quest.	1.1	1.2	2.1	2.2	3.1	4.1	Tot	Points
		Marks	2	4.5	4	3	3	3	19.5	7

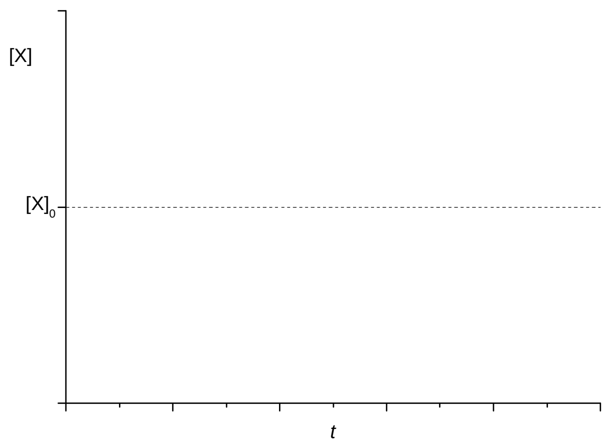
3.2.1 1) An open system, $[X]_0 > k_2/k_1$



2) An open system, $[X]_0 < k_2/k_1$



3.2.2 A closed system, $[B]_0 = [D]_0$, $[X]_0 > k_2/k_1$



Official English version.

Problem 3	Name: ________________ Student code: __________	Quest.	1.1	1.2	2.1	2.2	3.1	4.1	Tot	Points
		Marks	2	4.5	4	3	3	3	19.5	7

3.3.1

X –

Y –

P –

$$C_2H_6 + X + \ \ldots \ \rightarrow \ 2X$$

$$X + Y \ \rightarrow \ 2Y + \ \ldots$$

$$C_2H_6 + Y + \ \ldots \ \rightarrow \ 2P$$

3.4.1 The highest possible temperature:

Your work:

T =

Problem 4	Name: ________________ Student code: __________	Quest.	1	2.1	2.2	2.3	3	4.1	4.2	4.3	Tot	Points
		Marks	1	1.25	1.75	2.25	1	2	1	2.25	12.5	8

4.1. *Equation:*

4.2.1. *Calculation of the T value:*

Your work:

T = ________________ *mg/mL*

4.2.2. *Calculation of the T value:*

Your work:

T = ________________ *mg/mL*

4.2.3. *Calculation of the T value:*

Your work:

T = ________________ *mg/mL*

Problem 4	**Name:** ________________ **Student code:** __________	Quest.	1	2.1	2.2	2.3	3	4.1	4.2	4.3	Tot	Points
		Marks	1	1.25	1.75	2.25	1	2	1	2.25	12.5	8

4.3. *Equation(s):*

4.4.1 *Equation(s):*

4.4.2. *Equation:*

4.4.3. *The composition of the crystallohydrate is:*

Your work:

Formula of the salt $Fe_2(SO_4)_3 \cdot xH_2O$: x = _______________

Problem 5	**Name:** ________________ **Student code:** __________	Quest.	1.1	1.2	1.3	2.1	2.2	3.1	3.2	Tot	Points
		Marks	5	5	10	30	10	10	5	75	7.5

5.1.1 *Structure of product **D***

5.1.2 *Which class of organic compounds does **D** belong to? Check the appropriate box.*
***Note!** Only one checkmark is allowed. Several checkmarks will lead to 0 marks for this question.*

ketones	ethers	acetals	esters	alcohols	aldehydes	glycols
☐	☐	☐	☐	☐	☐	☐

5.1.3 *The expected yield of **D***

The yield is equal to 85% ☐; lower than 85% ☐; greater than 85% ☐

Your work:

yield = **%**

5.2.1 *The structures of **A**, **B**, and **C**.*

A	***B***	***C***

5.2.2 *Draw in the boxes intermediate compounds formed during the acidic hydrolysis of **C**, and basic hydrolysis of **B**.*

$$\textbf{C} \xrightarrow{H^+/H_2O} \boxed{} \xrightarrow{t} CH_3COOH + C_2H_5OH$$

$$\textbf{B} \xrightarrow{OH^-/H_2O} \boxed{} \xrightarrow{OH^-/H_2O} CH_3COO^- + C_2H_5OH$$

Problem 5	**Name:** _______________ **Student code:** _________	Quest.	1.1	1.2	1.3	2.1	2.2	3.1	3.2	Tot	Points
		Marks	5	5	10	30	10	10	5	75	7.5

5.3.1 *The structure of senecioic acid and the reaction scheme leading to SA sodium salt from acetone.*

5.3.2 *The structure of* ***E***.

Problem 6	Name: _______________ Student code: _________	Quest.	1.1	1.2	2.1	2.2	2.3	2.4	3.1	3.2	Tot	Points
		Marks	3	9	2	2	3	10	5	3	37	7

6.1.1 *The net ionic equation accounting for the ability of LGL to set in air*

6.1.2 *Write down the net ionic equations matching the processes enumerated in the Table. For each process check the "Yes" box if it leads to changes of pH. Otherwise check the "No" box.*

a) protonation of ortho-silicate ions leading to the formation of Si-OH groups
Reaction equation:

Yes ☐ No ☐

b) formation of hydrated $[SiO_4(H_2O)_2]^{4-}$ anions
Reaction equation:

Yes ☐ No ☐

c) polycondensation of ortho-silicate ions leading to the formation of Si-O-Si bonds
Reaction equation:

Yes ☐ No ☐

6.2 *For* $[Si_3O_9]^{n-}$ *ion found in aqueous solution of silicates:*

6.2.1 *Determine the charge (n).*

Your justification

n = _______

6.2.2 *Determine the number of oxygen atoms bridging adjacent tetrahedra.*

Your justification

Number of oxygen atoms = _______

6.2.3 *Depict the ion structure joining together several tetrahedra (1).*

6.2.4 *<u>The fragment</u> of the layered structure joining 16 tetrahedra* ***(1)***

Your justification
Structure

6.3.1 *pH of 0.1 M aqueous solution of copper sulfate*

Your justification

pH = ________

6.3.2 *Equation of a reaction between aqueous solutions of $CuSO_4$ and sodium metasilicate (LGL)*

Problem 7	Name: _______________ Student code: _________	Quest.	1.1	1.2	2.1	2.2	2.3	2.4	2.5	Tot	Points
		Marks	12	12	5	12	7	8.5	16	72.5	7.5

7.1.1 A number of reaction types is listed in the table below. All reactions involved in metabolism of HMG-CoA to IPP are in the list. Choose those types of reactions which are catalyzed by **E1** and **E3** (put numbers in appropriate places).

No	Reaction type
1.	Dehydration
2.	Decarboxylation
3.	Dephosphorylation
4.	4 electron reduction
5.	Release of the reduced form of coenzyme A (CoA-SH)
6.	Monophosphorylation
7.	Oxidation of hydroxyl group as the third stage of HMG-CoA β-oxidation cycle

E1 _______________

E3 _______________

7.1.2 *Draw the structure of **X** with stereochemical details and indicate absolute configuration (R or S) of the stereocenter.*

7.2.1 *Write down the overall reaction equation for reductive ozonolysis of DAP with dimethyl sulfide used as the reducing agent.*

7.2.2 *Determine molecular formula of **Y**.*

Your justification

Number of carbon atoms_______

Number of hydrogen atoms_____ Molecular formula:_________________

Problem 7	Name: ________________ Student code: __________	Quest.	1.1	1.2	2.1	2.2	2.3	2.4	2.5	Tot	Points
		Marks	12	12	5	12	7	8.5	16	72.5	7.5

7.2.3 *Calculate the number of IPP and DAP molecules needed to give* ***Y5****.*

Your justification:

Number of IPP molecules ____ Number of DAP molecules ____

7.2.4 *Draw the product of coupling reaction between one IPP molecule and one DAP molecule, subsequent reductive ozonolysis of which gives* ***Y1****,* ***Y2*** *and one more product, the latter containing phosphorus.*

7.2.5 *Draw the structures of* ***Y*** *and* ***Y4*** *with stereochemical details.*

Y4

Y

Problem 8	Name: ________________ Student code: __________	Quest.	1.1	1.2	2.1	2.2	2.3	3.1	3.2	3.3	3.4	Tot	Points
		Marks	8	9	5	11	14	16.5	12	10	13.5	99	8

8.1.1 *Expressions for the rates:*

v_{act} =	v_p =
v_{deact} =	v_t =

8.1.2 *Compare rates using operators <<, ≤, ≈, ≥, >>*

v_{deact} v_{act}	v_{deact} v_t
v_{deact} v_p	

8.2.1 *Mass of the obtained polymer.*

Your justification:

m =

8.2.2 *Degree of polymerization of the obtained polymer.*

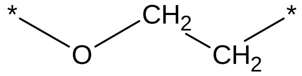
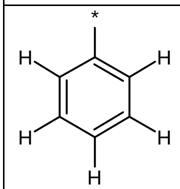
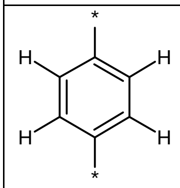
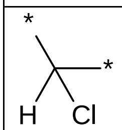
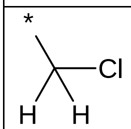
Your justification:

DP =

Problem 8	**Name:** _______________ **Student code:** _________	Quest.	1.1	1.2	2.1	2.2	2.3	3.1	3.2	3.3	3.4	Tot	Points
		Marks	8	9	5	11	14	16.5	12	10	13.5	99	8

8.2.3 *Structure of the obtained polymer.*

8.3.1 *Fill in the right column with symbols (a-g) of ^{1}H NMR signals corresponding to substructures in the left column.*

8.3.2 *Composition and molecular weights of copolymers P1 and P2.*

Your justification: n(C) = n(D) =	Your justification: M(P1) = M(P2) =

Problem 8	Name: _______________ Student code: _________	Quest.	1.1	1.2	2.1	2.2	2.3	3.1	3.2	3.3	3.4	Tot	Points
		Marks	8	9	5	11	14	16.5	12	10	13.5	99	8

8.3.3. *All possible reactions of activation*

P1:
P2:

8.3.4 *Structure of P1 and one of possible structures of P2*

P1:	P2:

Official English version.